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EARLY DUTCH RADIO ASTRONOMY (1940-1970)

THE PEOPLE AND THE POLITICS

proefschrift

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INTRODUCTION

Why should one write a history of *Dutch* radio astronomy? In a time when transnational history is the order of the day, this may seem a bit old-fashioned. However, in this particular case the choice for a national perspective can be justified. From an institutional point of view, the Dutch radio astronomers have been united in the National Foundation for Radio Astronomy ('Stichting Radiostraling van Zon en Melkweg' or SRZM) since 1948. SRZM was not merely a collection of radio astronomers who happened to live within the borders of the same country. It was on the contrary a coherent group of scientists with a specific research programme. Moreover, early Dutch radio astronomy developed in a very different way from radio astronomy in other countries. The main difference was that the initiative was taken by 'real' astronomers - i.e. optical astronomers – while in other countries it was mostly taken by engineers and physicists with a background in war industry, especially radar. This anomalous beginning had profound short-run and long-run impacts on the field. At the same time, it means that the history of Dutch radio astronomy does not 'fit' traditional histories of radio astronomy in Britain, Australia and the USA. This is also one of the reasons why in historiography on early radio astronomy, the Dutch story is often treated rather cursorily. In his book *Cosmic Noise*, for example, the American radio astronomer W. Sullivan ranks the Dutch radio astronomical group amongst the 'five major groups in the post-war decade' (Sullivan, 2009, p. 8). He also recognises that the story of early Dutch radio astronomy 'is anomalous in that it was not driven by radar veterans and in fact was directed by (optical) astronomers' (Sullivan, 2009, p. 8). In the rest of the book, however, he hardly pays any attention to the Netherlands. On the other hand – and in a way related to the anomalous beginning - Dutch radio astronomy in the earliest years focused on only a small range of topics, especially on 21 cm hydrogen line research, as will be explained. This can also be a reason why it does not occupy a prominent place in historiography.

Another striking feature of Dutch radio astronomy is that it remained a very small-scale, nationally oriented undertaking for quite a long time. At the same time, Dutch national science policy too was in the 1950s and 1960s still very new and in a certain way underdeveloped in comparison with science policy in most other European countries. National organisations for the stimulation of 'pure science', for example, were a typical interwar product. In the Netherlands, however, the Organisation for Pure Scientific Research ('Zuiver Wetenschappelijk Onderzoek' or ZWO) was only founded in 1950. Paradoxically, the embryonic stage of Dutch science policy *furthered* rather than hampered the quick and successful development of radio astronomy. On the other hand, however, it was an obstacle in the international cooperation with Belgium, which was set up in the late 1950s.

Our story starts in 1940. Although all historical delineation has a certain degree of arbitrariness and the pinpointing of a 'beginning' may seem ahistorical, there is good reason to choose 1940 as a starting point. For Dutch radio astronomy, this was a crucial year. On the other side of the Atlantic, an electronic engineer from Chicago, Grote Reber, had just been able to detect radio radiation from the Galaxy with a self-made telescope and he had studied how the intensity of radio emission changed with position in the sky and wavelength. He recognised that his findings could be important for astronomical research and therefore he wanted to publish them in astronomical literature. After some serious resistance from the astronomical community – after all, Reber was no professional astronomer - he got his findings published in the *Astrophysical Journal* of June 1940, in an article entitled, *Cosmic static.*

This happened at a time when the Second World War was raging and the international exchange of scientific information became more and more hampered. However, at the instigation of Bart Bok, a Dutch astronomer who had migrated to the USA, the American Astronomical Society appointed in September 1940 a *Committee for the Distribution of Astronomical Literature* that tried to secure the world-wide flow of astronomical literature. Thanks to the efforts of this committee, Reber's article reached the Leiden astronomer Jan Hendrik Oort on 24 December 1940. Oort's reading of this article would change the course of Dutch astronomy forever.

Oort immediately realised that radio radiation could be vital for astronomical research: as radio waves were not hindered by earthly clouds, radio radiation was particularly suitable for observation in the Dutch cloudy climate. Moreover, radio waves were an ideal means to answer a question Dutch astronomers had been trying to answer for decades, namely: What is the structure of the Milky Way? Under the impetus of the Groningen astronomer J.C. Kapteyn (1851-1922), unravelling the structure of the Milky Way had become one of the main objectives of Dutch astronomy since the beginning of the twentieth century. During the last part of Kapteyn's life, it became clear that the biggest part of the Milky Way was inaccessible to observations at optical wavelengths because of the extinction of the light by interstellar dust (Oort, 1981, p. 24). Astronomers had already put up with the fact that they could only have indirect knowledge about a large part of the Milky Way. This changed with the emergence of radio astronomy.

Reber's work – although of crucial importance for early Dutch radio astronomy – was largely unknown to early radio astronomers in other countries. Therefore, his status as one of the 'founding fathers' of radio astronomy is to a certain extent a myth.

Our book ends in 1970. In 1970 the radio telescope in Westerbork was inaugurated, Oort retired and his Utrecht colleague Marcel Minnaert died. In the history of Dutch radio astronomy, this year was a major turning point. Huge reorganisations took place both in the radio astronomical community and in Dutch science policy.

The existing literature on the history of (Dutch) radio astronomy consists of mainly internalist – rather triumphalist - accounts, focussing on the content of the research without paying much attention to political and strategic aspects. Rather than writing yet another such story, we chose to focus on three key events in the period 1940 – 1970, namely on the construction of the radio telescopes in Kootwijk (1948), in Dwingeloo (1956) and in Westerbork (1970). It was in the processes of planning, designing and constructing these instruments that the interests of the astronomers, industrial partners, politicians and lobby groups merged. Studying the role of Dutch radio astronomers as strategic lobbyists, networkers and organisers in a specific political and economic context, allows us to best answer the following questions. How can the rapid and remarkable success of Dutch radio astronomy be explained? How did the astronomers manage to raise the necessary funds for these expensive projects? What strategic alliances did they forge in order to safeguard their projects? How did they deal with the new and unfamiliar kind of instrumentation? To what extent did they collaborate or interact with other groups abroad? Why did the Dutch focus on *Galactic* radio astronomy, whereas in most other countries the focus was on *solar* radio astronomy?

Although it seems odd that a new and expensive field could develop in a war-stricken country like the Netherlands, Chapter I explains that the Dutch post-war context was remarkably favourable: it was precisely science and scientific applications the Dutch government considered to be a key factor in the rebuilding of the country.

The first radio telescope in Kootwijk was an adapted 'Würzburg Riese' a radar reflector the Germans had used during the war. As will become clear, it was thanks to the good relations with the Dutch Post, Telegraph and Telephone Service that the Dutch radio astronomers received this telescope. In spite of its modest scale, it produced some groundbreaking results. In May 1951, for example, the 21 cm hydrogen line was detected. Two months earlier, the same line was detected at Harvard. As will be shown, the different ways in which Harvard and the Netherlands dealt with this detection, epitomised the different background – physicists versus astronomers - of the researchers. At Harvard, the detection was an opportunity to explore the physics of the hydrogen atom while in the Netherlands, it was a crucial step in answering the question of the structure of the Milky Way.

Notwithstanding the important research that was done with this telescope, a better and more sensitive one had to be built to keep up with international developments. This would be the radio telescope in Dwingeloo, inaugurated in April 1956. Chapter II explains how the radio astronomers convinced ZWO and the Dutch government that this expensive telescope was worth the effort. Furthermore, it explains how they came to choose Dwingeloo as the most suitable location. Finding a suitable location for a radio telescope was not an easy job. First of all, the area had to be free from possible sources of interference and environmental conditions had to be optimal. And once they had finally found a suitable area near the village of Dwingeloo, they had to deal with resistance from local governments and lobby groups.

While digging into the history of early radio astronomy, we encountered a myth that needs to be debunked. In most accounts, radio astronomy is presented as a field characterised by openness, (international) cooperation, interdisciplinarity etc. rather than by severe competition. But this characterisation of early radio astronomy is at least one-sided. Indeed, competition between the different groups was enormous. When the Dutch planned to build the radio telescope in Dwingeloo, they were so anxious to be 'the first' that some of them even went as far as to say that if the Americans were preparing the construction of a similar telescope, the Dutch plans had to be abolished.

Another view that needs to be qualified concerns the position of the USA during the Cold War. A dominant feature of the historiography on science during the Cold War is the continuing emphasis on America's dominance and leadership. This is the picture John Krige paints in his famous 2006 book *American Hegemony and the Postwar Reconstruction of Science in Europe*. A few years later, in 2010, the journal *Isis* published a focus issue with the promising title *New perspectives on science and the Cold War*. In their introduction, Hunter Heyck and David Kaiser clearly state that the aim of this *Isis* focus is to give a much more varied picture of science in the Cold War. Unfortunately, America's hegemony is never questioned. Nevertheless, in some fields, for example in early radio astronomy, the USA was definitely *not* the leader. It was even seriously lagging behind the developments in Europe and Australia. Our account of early Dutch radio astronomy offers the possibility to moderate this picture of American dominance.

As soon as the first observations with the radio telescope in Dwingeloo were made, ideas came up to build an even larger and better instrument. This would become the radio telescope in Westerbork, inaugurated on 24 June 1970. While the construction of the Dwingeloo telescope was a truly Dutch affair – it was done by Dutch astronomers, engineers and construction companies and only Dutch money was used – for the new telescope, the Dutch started looking over the border. It was estimated that this instrument would be very expensive. By finding a partner, the cost of the project could be shared and that would make the project more acceptable for the Dutch government, so the astronomers thought. When the Dutch approached the Belgians in 1958, the idea of jointly constructing a large radio telescope was enthusiastically received by several Belgian astronomers. Nevertheless, the cooperation ultimately failed in 1966. In Chapter III, it will be explained why this was the case. Several reasons were to account for this: it had to do with the diverging astronomical traditions in both countries after the Second World War, with different science policies since the late 1950s, the different political cultures, and – more general – different 'mentalities'.

While the design of the Dwingeloo telescope was a rather straightforward operation, this was not the case with the Westerbork telescope. The first elaborate design was presented in 1961. Later, at least four other designs followed. The final telescope differed strongly from the initial design. Where in the beginning, the intention was to build a cross-shaped interferometer, the telescope would end up to be a linear array. Chapter IV explores the reasons why the Dutch changed the design several times. Sometimes these reasons were scientific, but often they were also practical, political or economic. A persistent problem was the continuous struggle to find competent engineers. Special attention is devoted to the developments abroad and to the hiring of foreigners for the project, as these factors truly 'shaped' the eventual design as well as the observational programme of the telescope.

As a location, the area of the former concentration camp Westerbork was chosen. It had consecutively served as a refugee camp for (German) Jews at the beginning of the Second World War, as a transit camp for Jews, Gypsies, homosexuals etc. during the war – when the Netherlands was occupied by Germany - and as an internment camp for members of the Dutch National Socialist Movement after the war. After the independence of Indonesia it became a residence for the Ambonese who had fought in the Royal Dutch-Indian Army against the Indonesian nationalists. In hindsight, building a telescope in such a place seems to be a strange way of dealing with the camp heritage. Nevertheless, after their dark past the inhabitants of the village of Westerbork were now very happy to see their name connected to something positive. But again, before construction could take off some problems had to be solved. For example, a military shooting range had to be closed and several remaining Ambonese families who were still living on the premises had to be moved. The relative ease with which Oort managed to get all this done is telling for his influence and the prestige of radio astronomy in general in the late 1960s.

With a construction cost of 25 million Dutch guilders, the telescope in Westerbork was one of the most expensive Dutch scientific projects at that time. At the same time financial problems had to be faced. Firstly, the Belgians paid their share only after years of delay, and secondly, from the mid-1960s onwards, Dutch government budgets were tightening. Especially the latter was a serious problem. It made application procedures more rigorous. As a dominant and stubborn person who was used to always getting his own way, a conflict arose between him and Bannier, the director of ZWO. Bannier blamed Oort for the authoritarian way he led SRZM and Oort in turn blamed Bannier for treating him as a 'school boy'. This conflict was illustrative for the radical changes that took place around 1970 and for Oort's inability to deal with them.

Sources

A lot of archival materials were available for this research. In the first place, there are the *Oort Archives* which are kept at the University Library in Leiden in its department of Western Manuscripts. It is thanks to the efforts of Oort's former student Dr. Jet Katgert, that the University Library now safely harbours this extensive collection of papers and letters. At the same time, Dr. Katgert provided a detailed and comprehensive catalogue - *The Letters and Papers of Jan Hendrik Oort* - which made digging into these archives a quite comfortable undertaking.

The archives of SRZM were another very valuable source, though its content is rather scattered. Most of it is kept at ASTRON, the Netherlands Institute for Radio Astronomy and successor of SRZM. Duplicates could be found at NWO (the successor of ZWO) in The Hague, and these were used in the first place. A little discomfort, however, was that these archives are not inventoried and not arranged. A small part of the archives of SRZM is also kept at Leiden Observatory.

The archives of Henk van de Hulst – who played a key role in the detection of the 21-cm hydrogen line - the *Van de Hulst Papers*, are kept at Leiden Observatory. These archives have been organised, but not inventoried (although we made a short inventory ourselves). They were especially useful to find out more about this famous 21-cm hydrogen line.

The archives of Oort's Utrecht colleague Marcel Minnaert – the other protagonist of early Dutch radio astronomy, although to a lesser extent than Oort, – are kept at the Noord-Hollands Archief in Haarlem. More than Oort, Minnaert was concerned to bring (radio) astronomy closer to the general public. His archives are especially revealing for the initiatives that were undertaken for the popularisation of astronomy.

In the *Dutch National Archives,* some interesting information could be found about the contacts between Oort and the Dutch post-war Prime Minister Schermerhorn.

Attempts were made to consult the archives of the Dutch company Philips, as this company, the *NatLab* in the first place was an important player in early Dutch radio astronomy. Unfortunately, these repeated attempts remained unsuccessful.

To study the cooperation with Belgium, the archives of the Belgian National Council for Science Policy ('Nationale Raad voor Wetenschapsbeleid' or NRWB) in Brussels were used. The archives of the Belgian Ministry of Education, which are kept in the State Archives in Brussels, were studied too. Unfortunately, these archives seemed to be very incomplete and no information on the radio telescope project has been preserved.

Besides the archival materials, the Annual reports of ZWO and the database with historical newspapers at the National Library of the Netherlands were consulted.

Last but not least, there were the various invaluable oral sources. In the first place, we were very grateful to be able to talk to the radio astronomer Hugo van Woerden - who was involved in Dutch radio astronomy from its very beginnings – and to Jean Casse, the Belgian engineer for the

Westerbork project. Furthermore, we spoke to several people who were themselves not involved in Dutch radio astronomy in this period, but who have known Oort and / or some of his colleagues quite well, for example former ASTRON radio astronomer Richard Strom, Leiden astronomer Frank Israel, emeritus professor of computer science and guest professor of astronomy at Leiden University Alexander Ollongren and former project manager at the Netherlands Institute for Space Research (SRON) Klaas Wildeman.

CHAPTER I: THE BEGINNING OF DUTCH RADIO ASTRONOMY: ASTRONOMERS TAKE THE LEAD

During the Second World War and its immediate aftermath, a new field of astronomy was born: radio astronomy. Radio telescopes - the instruments of this field - shared the technology of wartime radar installations. Therefore, in most countries engineers and physicists with a background in wartime radar research were the first to take the initiative for radio astronomical research. This was a logical consequence of the wartime work they had been doing. The early post-war radio astronomy group in the Netherlands was one of the most important radio astronomy groups in the world. However, it differed strongly from the other groups in that the initiative was led by 'real astronomers', which meant: people who had been trained in optical astronomy. It also needs to be mentioned that 'optical astronomy' was a concept that arose only *after* the introduction of radio astronomy. Before, all astronomy was 'optical' astronomy, so there was no need to add this adjective (Sullivan, 2009, p. 422). While the beginnings of Dutch radio astronomy have been researched and discussed (for example Strom and Van Woerden, 2006; Sullivan, 2009, pp. 395–406), the *consequences* of this different approach have rather been neglected. Nor has the take-off of Dutch radio astronomy been firmly placed in the context of Dutch science policy and Dutch efforts aiming at the post-war recovery of the nation. Therefore, the questions that will be answered in this chapter are: how did the Dutch astronomers manage to invade this unknown territory without the required skills and expertise and nevertheless turn their efforts into such a success story? This is all the more striking given the relatively high costs of radio astronomical research and the bleak conditions in a war-stricken country like the Netherlands. And more important: in which way did this peculiar take-off of Dutch radio astronomy influence the early field? It will become clear that the fact that the initiative for radio astronomy was taken by astronomers had profound long-lasting effects.

In order to answer these questions, the Dutch post-war context also needs to be considered. As will be shown, the astronomers greatly benefited from Dutch post-war politics in which science and scientific applications took a very prominent place. Moreover, the small scale of the undertaking and intelligent networking contributed to the fast take-off of radio astronomy.

First, however, the situation of Dutch astronomy during the interwar period will be discussed. It was exactly in that period that the protagonists of this story appeared on the scene and influential networks were established.

1.1 DUTCH ASTRONOMY IN THE INTERWAR PERIOD

During the interwar period, Dutch astronomers had firmly established their position in the international scientific community. The observatory at the University of Leiden – which would later also become the centre of Dutch radio astronomy - became an international centre of astronomy. Under the directorship of Willem de Sitter (1918–1934), the observatory was thoroughly reorganised, which led to an enormous increase in quantity and quality of output. Historian of science David Baneke summarises these changes as follows:

> In the decade after the First World War, Dutch astronomy changed from a small, guild-like community into a slightly bigger community that had all the characteristics of a modern academic discipline, with specialized graduate programs, a laboratory culture that was characterized by division of labour, a professional journal and a national professional organization. (Baneke, 2010, p. 191)

Two of De Sitter's staff members were instrumental in securing the reputation of the Leiden Observatory. The first was the Danish astronomer – chemical engineer by training - Ejnar Hertzsprung, best known for his development of what is now known as the Hertzsprung-Russell diagram, a classification system for stars relating their luminosity (or absolute magnitude) to their colour (or temperature). Hertzsprung would succeed De Sitter as director of the observatory. The second was Jan Hendrik Oort, who in turn would succeed Hertzsprung as director immediately after the Second World War. Around 1930, Oort had firmly established his reputation by empirically proving the theory of galactic rotation of the Swedish astronomer Bertil Lindblad. Lindblad - director of Stockholm Observatory from 1927 to 1965 - showed that the system of stars can be divided into several subsystems that rotate around a common axis. Each subsystem had its own rotation rate and consequent degree of flattening. In 1927, his theory was confirmed by Oort by a variety of observational data (Kron, 1954, p. 110).

Research into the structure of the Galaxy had always been one of Oort's main fields of interest. This was due to one of Oort's teachers, the Groningen astronomer J.C. Kapteyn (1851 - 1922). Kapteyn was one of the most influential Dutch astronomers ever. His work thoroughly influenced several generations. In 1877, he became the first professor of astronomy at Groningen University. He wanted to found an observatory at the university, but the Dutch government did not support his plans: the Netherlands had already two observatories – one in Leiden and one in Utrecht – and three observatories would simply cost the government too much. In 1896, Kapteyn founded an 'Astronomical Laboratory' in Groningen, a laboratory without a telescope. Nevertheless, by means of international collaboration, Kapteyn succeeded in becoming famous as 'astronomer without a telescope'. One of his great projects was his collaboration with the Scottish astronomer D. Gill, director of the observatory in Cape Town (South Africa). From the 1880s onwards, Kapteyn collaborated with Gill on the *Cape Photographic Durchmusterung*, a star catalogue of the southern hemisphere (DeVorkin, 2000a, p. 131).

In 2000, a book with the telling title *The legacy of J.C. Kapteyn* appeared, which discusses the different aspects of his research and personality that left an important mark on Dutch astronomy. Most important for this story, however, is that since the beginning of the twentieth century Kapteyn had spurred on Dutch astronomers to work on unravelling the structure of the Galaxy (Sullivan, 2000, p. 229). This would remain a dominant research programme in Dutch astronomy for several decades. During the last part of Kapteyn's life, however, it became clear that the largest part of the Milky Way was inaccessible for observations at optical wavelengths because of the extinction of the light by interstellar dust (Oort, 1981, p. 24).

Astronomers had already resigned themselves to the fact that they would only having indirect knowledge about a large part of the Milky Way. All this changed, however, with the emergence of radio astronomy.

1.2 RADIO ASTRONOMY: EARLY BEGINNINGS

Traditionally, the history of radio astronomy is traced back to the two twentieth-century American 'founding fathers' Karl Jansky and Grote Reber. However, radio waves were discovered much earlier. In the 1860s, James Clerk Maxwell, a Scottish physicist and mathematician, developed an extensive theory of electric and magnetic phenomena, built upon his conception of electromagnetic fields surrounding magnets, charged bodies, and current carrying wires. In his 1864 paper *A Dynamical Theory of the Electromagnetic Field*, he showed that disturbances in the electric and magnetic fields can spread in a wavelike manner with a velocity that is roughly equal to the speed of light. Furthermore, he concluded that, most likely, light itself was a type of electromagnetic radiation and he suggested that there were other wavelength ranges on either side of the optical spectrum (Hatt, 2007, pp. 29-30).

Inspired by the work of Maxwell, Heinrich Hertz succeeded in producing electromagnetic waves by using a special circuit, including a Ruhmkorff-coil-driven spark gap. In 1887, he managed to generate transverse waves with a wavelength of several metres, well within the frequency range of electromagnetic waves known as radio waves (roughly from 1 millimetre to 100 kilometres). At this time, astronomers were not able to register these wavelengths yet. But soon, it was suggested that 'radio astronomy' (although this word was not used yet) had to be feasible. As radio astronomy and communications have always been closely associated, it is not surprising that the next contribution to 'radio astronomy' came from one of the pioneers of communications, Thomas Edison. Edison collaborated with the American electrical engineer Arthur Edwin Kennelly in a proposal to detect radio waves from the Sun, by using a huge induction coil, wound around an iron ore mass in New Jersey (Smith, 1994, p. 71). Kennelly - who had predicted the existence of the ionosphere - wrote in 1890 to professor Edward Singleton Holden of Lick Observatory:

> Along with the electromagnetic disturbances we receive from the sun which of course we recognize as light and heat (...), it is not unreasonable to suppose that there will be disturbances of much longer wave length. If so we might translate them into sound.[1]

There is no record of the outcome of the experiment, but as the apparatus was very insensitive and could only detect very long radio waves, it is extremely unlikely to have succeeded. Indeed, the ionosphere reflects such long radio waves back into space and thus prevents them from reaching the Earth's surface (Smith, 1994, p. 71).

In the following decades, several attempts followed to detect solar radio waves, though all proved unsuccessful. It took until the 1930s before the first radio waves from space were detected. The discovery was due to Karl Jansky, a physicist from the University of Wisconsin. Jansky joined the staff of the Bell Telephone Laboratories in New Jersey, in 1928. At Bell, he was assigned to a project investigating possible sources of interference in shortwave radio communications (10 metres) across the Atlantic. Therefore, he built a directional antenna to locate the sources of radio noise. His equipment was set up in Holmdel, a rural part of New Jersey, in 1930. Soon, data collecting began. He expected to find only terrestrial sources of radio noise, like thunderstorms and the inner workings of the radio receivers themselves. But in addition to this noisy static produced by

[1] The entire letter is published in: Shane, C.D., Radio astronomy in 1890 : A proposed experiment, in : *Publications of the Astronomical Society of the Pacific*, 70 (1958), pp. 303-304.

terrestrial sources, he detected a persistent and faint hissing noise, somewhat like 'an angry cat' (Lang, 2006, p. 104).

It was during the autumn and winter of 1931-1932 that Jansky began to isolate this 'hiss type static'. At one point, it appeared to come from some unmodulated carrier,[2] but he soon became convinced that it had a natural origin. At first, he thought it came from the Sun, for the direction of its origin seemed to coincide quite closely with the position of the Sun. By February 1932, however, he noticed that the static was no longer aligned with the Sun, but preceded it by an hour. Although it was now clear that these radio waves did not come *directly* from the Sun, Jansky still thought that they were somehow controlled by the Sun (Sullivan, 2009, p. 36). He published these results in the *Proceedings of the Institute of Radio Engineers* (Jansky, 1932). During the following months he continued his research. He found out that the static was definitely not coming from the Sun, but that '(...) the source of this noise is located in some region that is stationary with respect to the stars' (Jansky, 1933a, p. 66). In other words: the noise came from *outside* the solar system. In another article in the *Proceedings of the Institute of Radio Engineers* (Jansky, 1933b), Jansky made this suggestion more specific: the waves probably originated in the centre of the Milky Way, in the direction of Sagittarius (Jansky, 1933b, p. 1398).[3]

On 27 April 1933, Jansky gave a talk before the URSI (Union Radio-Scientifique Internationale) in Washington, where he presented these results. A press release issued a week later by Bell Labs made Jansky an 'instant celebrity' (Sullivan, 2009, p. 39). Newspapers all over the world reported his discovery. On 5 May 1933, *The New York Times* wrote about it in a front page article, entitled *New radio waves traced to centre of the Milky Way*. Therefore, in hindsight, Jansky's talk is generally seen to have been a decisive moment in the history of radio astronomy. The Italian radio astronomer F. Mantovani even goes as far as to say that 'That date is officially considered the beginning of radio astronomy' (Mantovani, 2004, p. 1). However, it should not be forgotten that – contrary to the media coverage Bell's press release brought about – Jansky's talk *itself* garnered little reaction, neither from his colleagues, nor from astronomers. Jansky's fellow engineers or physicists saw his work rather as an 'interesting curiosity' (Sullivan, 2009, p. 44). Jansky himself tried to kindle the interest of his colleagues, but without success. The only other observations of any depth that were carried out as a kind of follow-up of Jansky's research were those of the physicists G.W. Potapenko and D.F. Folland at the California Institute of Technology in the mid-1930s. They tried to confirm Jansky's result and to explain the mechanisms of the emission. However, they had only very basic antennas available that yielded results that were too rough to publish. A large antenna was needed to do the job properly. This, however, would cost about 1000 dollars and the head of the Physics Department and President of Caltech, R.A. Milikan, could not be convinced this amount would be well spent. This was the end of radio astronomy at Caltech (Sullivan, 2009, p. 45).

Of course, it must not be forgotten that it was the middle of the Great Depression, which can explain why institutes were not so eager to spend lots of money on rather uncertain projects. Bell

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[2] This is a carrier wave (such as to be used for AM or FM) whose phase, amplitude or frequency has not yet been varied so as to contain meaningful information.

[3] It is noteworthy that Jansky made his observations during a sunspot minimum. Had he continued his observations during a period of high sunspot activity, he would undoubtedly have detected solar radiation (Kraus, 1981).

too, was not interested in a follow-up of Jansky's research. Jansky himself, on the other hand, wanted to investigate radio waves from the Galaxy more thoroughly. For this he needed to build a 30-m dish antenna. But Bell had found out what they wanted to know, namely that radio waves did not disturb transatlantic telephone traffic very much. And this was the only thing that mattered for the company. Therefore, they put Jansky on another project (Van Delft, 2008, p. 55).

Jansky also tried to reach the astronomical community with a publication in *Popular Astronomy* (Jansky, 1933c), a magazine for amateur astronomers, published between 1893 and 1951. But his conclusion that '(...) data have been presented which show the existence of electromagnetic waves in the earth's atmosphere which apparently come from a direction fixed in space' (Jansky, 1933c, p. 555) was too vague to arouse much enthusiasm among professional astronomers. Moreover, observatories were also reluctant to take on (expensive) new projects, because of the economic depression.

Jansky never returned to astronomical research, nor did he receive a scientific reward for his discovery (Lang, 2006, p. 104)

To summarise, besides the budgetary tightness, the main problem with Jansky's research was that on the one hand, the results seemed unimportant for communication research and, on the other hand, they were too vague for professional astronomers to know how they should deal with them, or as the American astronomer Sullivan said:

> In the context of contemporary research into radio communications and astronomy, Jansky's fundamental discovery was a misfit. Neither fish nor fowl, it was unable to be appreciated by either scientists or engineers, and therefore lay untouched as an isolated curiosity (Sullivan, 2009, p. 29).

Around 1935, however, there was a sign of interest in Jansky's work: a letter arrived from Grote Reber, an electronic engineer (and radio amateur) from Wheaton, a suburb of Chicago. He had read Jansky's work and was fascinated by it. He contacted Jansky, applying for a job that would allow him to collaborate with Jansky on this project, but was surprised and disappointed to learn that Bell Labs did not plan any further work in this area (Kellerman, 2004, p. 704).

In the first place, Reber wanted to find out how the intensity of radio emission changed with position in the sky and with wavelength. Therefore, in the summer of 1937, he built a steerable paraboloid of 30 feet in a vacant lot next to his mother's house. It took him some time to detect any radiation. Finally, in the spring of 1939, he detected Jansky's Galactic radio noise, which he called 'cosmic static'. He could also confirm Jansky's observation that the maximum radiation came from a direction near the centre of the Galaxy. By the end of the summer of 1939, he figured that he had collected enough data to merit publication. It was only 'natural' that he sent his paper to the journal that had also published Jansky's papers, namely the *Proceedings of the Institute of Radio Engineers*. The paper was published in February 1940 (Reber, 1940a). It presented many plots of signal level recorded as the Milky Way drifted through his beam. Reber's article differed from that of Jansky insofar as it contained only a brief description of the equipment and concentrated on an *astronomical* interpretation of the radiation (although the journal was not intended for an audience of astronomers) (Sullivan, 2009, p. 60).

This was indeed a noteworthy difference between Jansky and Reber: unlike Jansky, Reber made considerable efforts to get his findings known by the community of professional astronomers, as he was convinced his findings were very relevant to astronomical research. Therefore, it was crucial to get his results published in the astronomical literature. There, however, he had to face great difficulties. The astronomical community was at first very sceptical. Reber submitted the results of his research to the *Astrophysical Journal*. According to Jesse Greenstein, who was then a young astronomer at the Yerkes Observatory, 'it produced a flurry at Yerkes [where the ApJ editorial offices were] since Reber had no academic connection, and unclear credentials' (Kellerman, 2004, p. 705). Nevertheless, several astronomers – such as Chandrasekhar, Greenstein and Keenan - were intrigued and went to Wheaton to inspect Reber's equipment. Kennan reported that Reber's apparatus 'looked modern' and that his work 'looked genuine' (Kellerman, 1999, p. 372).

The resistance that Reber faced from the astronomical community needs further clarification. Astronomy is a discipline in which the contribution of amateurs has always been very much welcomed. Characteristic for the community of amateur astronomers is their good organisation: amateurs had and have their own magazines (which were also read by professional astronomers) – remember that in 1933, Jansky too published an article in *Popular Astronomy*, a magazine for amateur astronomers, they had their own organisations etc.[4] However, a closer look at the *kind* of contributions of amateurs reveals that these consist in the first place of *generating data*. That does not mean that they are always merely passive observers. McCray underscores that in Operation Moonwatch, for example, observers *actively* participated in the research programme. By volunteering in global efforts to spot the first satellites and informing and educating their neighbours about the new science of satellites amateur scientists of Moonwatch played 'an integral and visible role in the Space Age's opening days (McCray, 2008, p. 164).

However, the fact remains that throughout history the contributions of amateur astronomers to astronomy generally did not concern the *methodology* of doing astronomy. And this was exactly the problem with Reber, who was an amateur astronomer and foremost a 'loner'. That Reber met with such resistance might have been because he did not just add some data to the existing body of astronomical knowledge, but his detecting and measuring of radio waves implied another way of *doing* astronomy. And letting an amateur tackle astronomical methodology was apparently a bridge too far for the community of professional astronomers.

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[4] In the Netherlands, for example, amateur astronomers have since 1901 been active in the Dutch Association for Meteorology and Astronomy ('Nederlandse Vereniging voor Weer- en Sterrenkunde') (later: *Royal* Dutch Association for Meteorology and Astronomy). Since 1903, this organisation has been publishing the magazine *Hemel en Dampkring* ('Sky and Atmosphere') - now *Zenit* - to which professional astronomers also sometimes contribute. One of the most remarkable contributions of amateur astronomers is perhaps the famous 'Operation Moonwatch'. In this programme, initiated in 1956 by the American Smithsonian Astrophysical Observatory, amateur astronomers and ordinary citizens were mobilised to help professional scientists to spot the first artificial satellites. Often with homemade telescopes, these amateurs provided crucial information. In his book *Keep Watching the Skies,* historian of science Patrick McCray explores the relation between amateur and professional scientists in Operation Moonwatch (McCray, 2008). Today, amateur astronomers still play an important role in astronomy. John S. Lewis, professor emeritus of planetary science at the University of Arizona, explains that amateurs made and still continue to make valuable contributions in variable star observations, meteor observations, comet seeking etc. (Lewis, 2011). Moreover, this excellent organisation of amateur science can also be found in entirely different fields. In the middle of the 1960s, for example, several groups of amateur computer scientists arose. In 1966, the Amateur Computer Society (ACS) was founded by Stephen Gray, computer editor of the American journal *Electronics*. Soon, it was an international organisation with members from the USA, Canada, Switzerland, Italy and Japan. They issued a bimonthly newsletter in which they exchanged ideas on how to build your own computer, on technical information about electronic parts etc. (Veraart, 2008, p. 71).

1.3 WARTIME DISTRIBUTION OF ASTRONOMICAL LITERATURE: THE EFFORTS OF BART BOK

The fact that Reber's article was eventually accepted, however, was in the first place due to the efforts of Bart Bok, a Dutch astronomer who had migrated to the USA in 1929 to work at Harvard College Observatory. Bart Bok was the referee of Reber's article. He too decided to visit Reber's equipment and took the editor, Otto Struve, along. Bok said the journal should not reject something that might later turn out to be important, and convinced Struve to publish Reber's paper. It was indeed accepted, but only as a short note (Reber, 1940b).

The American physicist Marc L. Kutner concludes from this that Bart Bok 'was the first traditional optical astronomer to understand the importance of radio astronomy' (Kutner, 2003, p. 68). This may be a little exaggerated – some astronomers like Jesse Greenstein of Caltech were also truly interested in Reber's work –, however, the importance of the action Bok undertook to get Reber's work published in the *Astrophysical Journal* can hardly be overestimated. This publication, indeed, forced the first links between radio scientists and astronomers (Kellerman, 2005, p. 52).

And it was also due to Bart Bok that Oort was actually able to *read* Reber's article, which was by then not so self-evident. Indeed, Reber's article appeared during the Second World War. While before the outbreak of the war, there was a constant world-wide exchange of astronomical literature, after the German invasion of the Netherlands in May 1940, this exchange was severely disturbed. Bart Bok was bothered by this. Still very concerned about his former Dutch colleagues, he wrote to Oort:

> It was great to hear that all Dutch astronomers came safe and sound through the invasion of the beginning of May. (…) I write to you (…) to ask whether you would like to let me or Shapley[5] know whether we can simplify in one way or another your work or that of other Dutch astronomers. You know the possibilities and also the difficulties in America, but if there is anything with which we can be at your service, you know that the Dutch astronomers have a lot of friends in America. You write in your post card that it will continue to be difficult to receive American journals in Holland. (…) If sending is possible, we can probably arrange within America, that Leiden, Groningen, Amsterdam and Utrecht each receive a copy of the AP.J. [Astrophysical Journal], A.J. [Astronomical Journal] etc. on a regularly base.[6]

At the instigation of Bok, the American Astronomical Society appointed in September 1940 a *Committee for the Distribution of Astronomical Literature* (CDAL), chaired by Bart Bok. The task of

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[5] Astronomer Harlow Shapley was the director of Harvard College Observatory.

[6] 'Het was heerlijk te hooren dat alle Nederlandsche astronomen veilig en wel door de inval van begin mei zijn gekomen. Ik schrijf je (…) om je te vragen of je mij of Shapley zoudt willen laten weten of wij op de een of andere manier je werk kunnen vergemakkelijken of dat van andere Nederlandsche astronomen. Jij kent de mogelijkheden en ook de moeilijkheden in Amerika, maar indien er iets is waarmee wij van dienst kunnen zijn weet je dat de Nederlansche astronomen heel veel vrienden in Amerika hebben. Je schrijft in je briefkaart dat het moeilijk zal blijven om Amerikaansche tijdschriften naar Holland te krijgen. (…) Indien verzending mogelijk is kunnen wij het waarschijnlijk wel van uit Amerika regelen dat Leiden, Groningen, Amsterdam en Utrecht elk een copie van het AP. J., A.J. etc. regelmatig blijven ontvangen.' Bok to Oort, 31 July 1940, OA, 151b.

the CDAL was 'promoting as far as possible the continued world-wide flow of astronomical literature' (Bok and Kourganoff, 1955, p. 22). Astronomers from several countries assisted the work of the committee: Wilhelm Brunner in Switzerland, Bertil Lindblad in Sweden, Kathleen Williams in Great Britain, and G. Neujmin of the USSR. Much help was also received from Oort in Holland and A. Kopff in Germany. About a dozen copies of each astronomical publication from the USA, Great Britain and Canada were distributed in this fashion and in return, the CDAL received many publications from the cooperating countries to distribute in the USA, Great Britain and Canada.

The importance of the CDAL for the exchange of astronomical literature can hardly be overestimated. In the following months, there was an extensive correspondence between Bok and Oort that indicates that several journals and articles were successfully sent from one country to another. It was thanks to the efforts of the CDAL, that Oort received Reber's article in the *Astrophysical Journal* of June 1940. In the beginning of November 1940, Bok sent this issue to the Netherlands[7], Oort received it on 24 December.[8]

1.4 THE FIRST RADIO ASTRONOMY GROUPS: AN ORIGIN IN RADAR

Oort's reading of Reber's article was a decisive moment in the history of radio astronomy in the Netherlands.

Several accounts on the history of early radio astronomy have been written by astronomers themselves (e.g. Sullivan, 1984; Sullivan, 2000; Sullivan, 2009; Ryle, 1971; Lovell, 1968; Strom and Van Woerden, 2006, Hey, 1973 etc.). These histories are sometimes criticised by professional historians as being teleological, too linear, written as inevitable success stories, retelling one another until they get the status of 'fact' etc. It is exactly in these stories that the history of radio astronomy is sometimes traced back merely to the 'founding fathers' Karl Jansky and Grote Reber. Almost mockingly, historian of science Jon Agar, said in this respect:

> Cosmic radio waves were first identified in America before the war, by the two lone figures of radio astronomy mythology: Karl Jansky and Grote Reber, retrospectively elevated to everpresent 'founding fathers' in the linear histories of radio astronomy, although their work was largely unknown in Britain or Australia (...). (Agar, 1998, p. 27)

However, Agar's words need to be taken with a pinch of salt. Sometimes these historical accounts written by astronomers - certainly the more recent ones – strongly mitigate the influence of Jansky and Reber. Sullivan, for example, said it 'is surprising that Jansky and Reber, despite their prewar discoveries, little influenced the postwar decade of radio astronomy, especially outside the US' (Sullivan, 2009, p. 13).

Indeed, outside the Netherlands, there was little *direct* influence of Jansky and Reber on early post-war radio astronomy. Several pioneers hardly knew the work of either Jansky or Reber. In Australia, for example, it is unclear to what extent the pioneers of Australian radio astronomy, such as John Bolton, Bernard Mills, and J.L. Pawsey were familiar with their work. Mills, for

[7] Bok to Oort, 4 November 1940, OA, 151b.
[8] Oort to Bok, 14 January 1941, OA, 151b.

example, makes no reference to Jansky or Reber in his account of the origins of radio astronomy in Australia (Mills, 2006). Nevertheless, it remains a fact that the explosive development of radio astronomy in Australia after the Second World War was centred in the Radio Physics Laboratory of the CSIR, the *Council for Scientific and Industrial Research*[9], and E.G. Bowen, chief of this Laboratory, was well aware of Jansky's work in the 1930s. Bowen's first exposure to the concept of radio 'noise' – interference at radio wavelengths - from outer space came in 1935, when he joined the small team of Sir Robert Watson-Watt, assembled to build the first air-warning radars in Britain. Bowen and his colleagues called the cosmic noise their receivers were exposed to the 'Jansky noise' (Bowen, 1984, p. 87). And although most pioneers of British radio astronomy might not have known the work of Jansky or Reber, Stanley Hey (see below) was well aware of Reber's work, as even Agar admits (Agar, 1998, p. 27). And Hey in turn, strongly influenced the course of early post-war radio astronomy (Sullivan, 2009, p. 13). So the *indirect* influence of the pre-war 'heroes' might not be entirely negligible, although it is difficult to determine to what extent Reber's work influenced the *content* of early radio astronomy.

Of far greater importance for the post-war emergence of radio astronomy in most countries, however, were wartime developments in military radio and radar electronics.

Radar uses radio waves to detect the presence of objects and to find their position. This is done by a transmitter sending out a radio signal which scatters off anything it encounters and a small amount of energy is scattered back to a radio receiver. After amplification in the receiver, the signals are processed by a combination of electronic signal processing and computer software (Kingsley and Quegan, 1999, p. 1). Although the basic notion to bounce radio waves off metallic objects at large distances had been known since the first decade of the twentieth century, it was only in the 1930s that practical systems were developed for showing the positions, ranges, and speeds of ships and aircraft through clouds or darkness (Sullivan, 2009, p.79). Radar was not invented at a specific time in a specific place. The systems developed during the 1930s owed a great deal to simultaneous developments in other areas, such as television. The first truly operational radar system, however, was developed by the aforementioned Englishman Watson-Watt between 1935 and 1938. From the earliest days, radar was developed within the military sphere. Watson-Watt's work was commissioned and strongly supported by the British Air Ministry. With the growing German threat, Britain had realised that it would be powerless against an air attack from the German *Luftwaffe*. By the start of the war in 1939, twenty 'Chain Home' stations ('Chain Home' was the code name for the British radar system during the Second World War) covered the southern and eastern coasts of England. Britain not only had an early start in radar, it stayed at the forefront of innovation during the Second World War and it shared the developments in radar technology with four of the Commonwealth nations: Australia, Canada, New Zealand, and South Africa.

Of course, Britain was not the only place where radar was being developed. In the USA, the Army and Navy also developed radar from the 1930s onwards. The Germans also had a strong radar capability at the start of the war and were even ahead of the Allies in the use of higher frequencies. The Gesellschaft für electroakustische und mechanische Apparate (GEMA) had developed an early warning radar, called Freya, for the German navy in the late 1930s. This was a kind of mobile version of the Chain Home transmitter/receivers. Even more flexible Würzburg radar dishes were

[9] Now called the Division of Radiophysics of CSIRO (the Commonwealth Scientific and Industrial Research Organization)

introduced in 1940 (Agar, 2012, p. 272). The Würzburg dishes play a very important role in the history of radio astronomy. As will be explained, Würzburg precision reflectors were used extensively by a number of radio astronomy groups for a decade after the war. In the Netherlands, ground-breaking research has been done with one of these reflectors. The Würzburg dishes were one of the most well-constructed and reliable radar antennas during the war. Although the standard wartime operating wavelength was 54 cm, the Würzburg could operate at wavelengths as short as 10 cm. Sizes of 1.5 m, 3 m, and 7.5 m were built. It was especially the largest version – the *Riese* – that was useful for radio astronomical research (Sullivan, 2009, p. 78). However, after a very promising start, German radar research stagnated between 1941 and 1943, due to 1941 decisions to cut long-term advanced research on the presumption that the war would soon be over (Zaloga, 2009, p. 16). There were also relevant radar developments in France, Italy, the USSR, Japan, and – last but not least – in the Netherlands.

As the technology of radio telescopes is very similar to that of radar, it is not surprising that the first radio astronomy groups originated in wartime radar research. During the war these radar operators often encountered anomalous radio phenomena which pulled them in the direction of radio astronomy. The pursuit of radar work, indeed, led unexpectedly to radio-astronomical discoveries, namely the radio emission associated with solar flares, the observations of radar echoes from ionised meteor trails, and the discovery of a discrete radio source in the constellation of Cygnus (Hewish, 2002, p. 171).

Immediately after the war, several radio astronomy groups were formed, among which five stood out: three in England, one in Australia and one in the Netherlands (Sullivan, 2009, pp. 5-10). All these groups – except the Dutch group – had their origins in wartime radar research.

The first group was that of the British physicist S. Hey. During the war, Hey was a radar-operations researcher at the Army Operational Research Group (AORG) (a research group that was under control of the Ministry of Supply). In 1942, he came to the conclusion that the apparent jamming of British coastal radar installations was in fact due to interference by radio radiation from the Sun.[10] His interest was aroused and led him to investigate the nature of these solar emissions. In 1946, he published his first article on this topic in *Nature* (Hey, 1946). Until 1948, Hey led a small Army group that conducted scientific research in all aspects of radio astronomy. For example, they discovered the first discrete radio 'star', later known as Cygnus A (Sullivan, 2009, p. 7).

A second English radio astronomical group was the one led by B. Lovell at Jodrell Bank, near Manchester. Lovell - who had a PhD in physics from the University of Bristol - had been doing cosmic ray research at the Physics Department of the University of Manchester since 1937. During the war, he became involved in radar research. On 3 September 1939, he was in the control room of the Staxton Wold radar station when Prime Minister Chamberlain broadcast to the nation that Britain was at war with Germany. Lovell immediately expected to see large numbers of echoes, signalling the advance of German bombers. There were indeed numbers of echoes, but there were no German bombers. The operators explained to Lovell that these echoes derived from the 'ionosphere' (Lovell, 1984, p. 194). Lovell then realised that the echoes might be radar reflections from the ionisation caused by extremely energetic cosmic ray showers. In the meantime it occurred to him that with radar, he now had a powerful new technique to investigate the high

[10] Note that this was a period of enhanced solar activity, compared to the early 1930s, the days of Jansky's early observations.

energy region of the cosmic ray spectrum. In the spring of 1940, Lovell joined the Telecommunications Research Establishment (TRE), the main centre of radar development in Britain. In his spare time, he studied the ionospheric literature in the library of TRE. Together with P.M.S. Blackett – a former professor of physics in Manchester whom Lovell had worked with before the war – he published an article, entitled *Radio echoes and cosmic ray showers* in 1941 (Blackett and Lovell, 1941). After the war, Blackett returned to his post in Manchester. Lovell followed him as a lecturer in the Physics Department. With ex-army radar equipment, he restarted his research on cosmic rays. However, the interference caused by electric trams forced him to look for another observation site. He was directed to the botanical grounds of the University about 25 miles south of the city. This was a small area known as Jodrell Bank. There, he received a report of Hey about the latter's investigation of the attempts to detect the German V2 rockets when the V2 bombardment of London commenced in September 1944. The operators of the radars had seen frequent echoes and gave warnings of the approach of rockets which did not arrive. Indeed, at the times reported, no rockets had been launched by the Germans. Hey concluded that the transient echoes probably had an ionospheric origin and that some of them might be associated with the radar reflections from the ionised trails of meteors (Lovell, 1984, p. 197). And it was exactly Lovell's reading of this report that triggered the start of the study of meteors at Jodrell Bank.

A third English radio astronomy group was established by Martin Ryle at the Cavendish Laboratory, the Physics Department at Cambridge University. In the late 1930s, Ryle – a physicist from Oxford - had been doing ionospheric research at the Cavendish Laboratory. He was a member of a small research group of about five researchers, led by J.A. Ratcliffe. At the outbreak of the war, the Cavendish became a place of greatly reduced activity. Many of its staff vanished into various defence research establishments. So did Ratcliffe and Ryle. Like Lovell, both men joined TRE, where they made important contributions to airborne radar. At the end of the war, Ratcliffe went back to the Cavendish to rebuild his ionospheric research group. Ryle rejoined him, but his interest quickly shifted to other areas. Influenced by his work at TRE and intrigued by Hey's work on solar outbursts, he was soon investigating radio waves from the Sun and radio 'stars', 23 of which (including Cassiopeia A) his group had found by 1949. Ryle had a keen interest in the development of new observation techniques. He was the driving force in the improvement of astronomical interferometry [11] (in the late 1940s he built the famous Long Michelson interferometer, a radio telescope interferometer) and aperture synthesis [12], which greatly contributed to the upgrading of the quality of radio astronomical data (see also Sullivan, 2009, pp. 155-170).

The largest of all post-war radio groups – and also the most important for this story as will be shown in the following chapters - however, was the one in Sydney (Australia). This laboratory was created in August 1939 as a secret branch of CSIR ('CSIRO' since 1949). It was agreed that the Radiophysics Laboratory would do radar research and development in close cooperation with British laboratories and with the Australian military. The laboratory was housed in the National Standards Laboratory in the grounds of Sydney University. In 1940, the Radiophysics Laboratory was replaced by the 'Division of Radiophysics'. When the war came to an end, the staff numbered

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[11] In short, interferometry means that there is an array of telescopes, working together as if it were one telescope. This will be further explained in Chapter IV.
[12] A specific type of interferometry, see also Chapter IV.

about three hundred. As many as fourteen of them became notable in radio astronomy after the war (Sullivan, 2009, p. 120).

Unlike TRE, which continued military radar development in peacetime, the Radiophysics Laboratory was transformed into a research and development centre for the civilian technologies that Australia hoped would carry the nation into the modern age (Buderi, 1996, p. 281). E.G. Bowen became the head of the Division of Radiophysics of CSIR in 1946. Bowen had a long experience in radar. The Welshman Bowen was a physicist from the University of Wales. In 1933, he completed a PhD in atmospheric physics at King's College in London under the direction of Appleton. Two years later, he joined the British 'air-warning radars team' of Watson-Watt, where he was for the first time exposed to the 'Jansky noise'. When the war broke out, Bowen became a member of the famous 'Tizard Mission' that delivered radar secrets to the United States. He remained in the USA for three years, where he developed airborne radar systems at the MIT Radiation Laboratory. At the end of 1943, Bowen's work in the USA was virtually finished and it became clear that sooner or later the Allies would invade Europe. So he started looking for another job and was invited to join the CSIR Division of Radiophysics. In early 1944, he went there as 'deputy in chief'. In 1946, he became the director.

Soon, Bowen worked out several peacetime research proposals that were 'warmly received and quickly endorsed' by his CSIRO superiors (Sullivan, 2009, p. 121). He made plans for research programs in vacuum tube technology, radio propagation, radar navigation, electronic surveying, meteorology and last but not least: astronomy, although none of the staff members had ever taken a college course in astronomy (Buderi, 1996, p. 282).

Some of the programs – for instance vacuum physics – quickly died away. The two research programs that were most successful were – indeed – radio astronomy and rain and cloud physics (Sullivan, 2009, p. 123).

One of Bowen's most able researchers was the Australian-born J.L. Pawsey. He was a world expert in antenna development and did a PhD at Cambridge University in 1934 where he had studied radio wave propagation under Ratcliffe. Then, for five years he developed television equipment for the BBC station at Alexandra Palace. At the outbreak of the war in 1940, he joined the Division of Radiophysics.

Intrigued by reports of anomalies from radar stations, Pawsey and his colleagues tackled solar observations (Sullivan, 2009, p. 124). In September 1945, assisted by his colleagues Ruby Payne-Scott and Lindsay McCready, Pawsey began observations of the Sun at Collaroy (a suburb of Sydney), using a series of existing Air Force radar antennas. The experiment was designed for a standard radar wavelength of 1.5 metres. The observations made it clear that some regions of the Sun had temperatures as high as one million degrees Celsius. This was far higher than was thought possible at the time, as optical measurements of the solar surface had made it clear that temperatures there were around 6000 degrees Celsius. Only later did researchers develop a full theory explaining the temperature gradient from optical wavelengths to 1.5 metres as largely due to partially ionised atoms of solar radiation that cause the very thin outer layer of the Sun's atmosphere to heat to enormous temperatures visible only at longer wavelengths (Buderi, 1996, p. 283).

Pawsey had also read Hey's wartime work. He concluded from it that the intensity of the Sun's radio emissions seemed to vary with sunspot activity. Therefore, in early 1946, during a large sunspot eruption, Pawsey turned his attention to these sunspots. It became clear, however, that existing radar aerials could not pinpoint sunspots as the source of this type of radiation. Therefore, Pawsey designed an instrument that became known as the 'sea interferometer', which he placed on a cliff-top at Dover Heights, facing out to the sea. Like the British, especially Ryle, Pawsey had realised that accurately pinpointing the source of radio emissions depended on achieving a much greater angular resolution than was possible with a single aerial. An interferometer would be the solution. In this experiment the aerial would pick up two signals, one directly from the Sun and the other reflected from the surface of the sea. The combination of the two signals could then be combined to form an interference pattern, making it possible to determine the point of origin of the radiation (Buderi, 1996, p. 283). Indeed, after several weeks, Pawsey accurately located the source of this enhanced noise on the face of the Sun and showed unequivocally that it came from the vicinity of sunspots (Bowen, 1984, p. 89).

The importance of the observations with the interferometer can hardly be overestimated. As Buderi said: 'The experiment would put Australian radio astronomy on a par with the group in Cambridge, where Martin Ryle was deploying his radio interferometer to resolve the same question' (Buderi, 1996, p. 283). Between the two groups, there was a fair amount of rivalry. Bowen recalled an incident in this respect:

> I have a vivid recollection of describing these results, prior to their being published, at a lecture I gave at the Cavendish Laboratory in Cambridge on September 20th 1946. (…) About thirty or forty members of the post-war Cavendish team were there, including Martin Ryle. At the end of the lecture, Ryle rose quickly to his feet and assured the audience that on two counts I was dead wrong: the solar temperature could not possibly be a million degrees, and there was something very wrong about (…) [the] observation of circular polarization. It was some time before they were to change their minds! (Bowen, 1984, p. 89)

From that point on, Bowen suspected Ryle[13] of striving to undermine the reputation of the Australian group, and the tension between the two groups increased over time (Buderi, 1996, p. 284).

Nevertheless, both the British and the Australian group made important contributions to interferometry which became the fundamental technique used in many of the world's radio telescopes, as will be shown in Chapters III and IV.

Pawsey's sea interferometer was also used by several others of Bowen's researchers, for example by John Bolton and Gordon Stanley. John Bolton was a native Yorkshireman who had studied physics at Cambridge University, had served during the war as a Royal Navy radar officer, and joined Radiophysics after the war. Gordon Stanley was an electrical engineer from New Zealand who had joined the Lab during the war. Like Pawsey, both men performed also solar observations. Intrigued by an observation of Hey, who had accidentally discovered an oddity in the direction of the constellation of Cygnus – one of the strongest radio sources in the sky - Bolton and Stanley set out to measure Cygnus (Buderi, 1996, p. 285). They succeeded in determining the size of Cygnus

[13] As will be explained in the next chapter, Ryle had a very difficult character.

A to be smaller than 8 minutes of arc, which was considered to be a very important finding. Their results were published in *Nature* (Bolton and Stanley, 1948)

1.5 DUTCH RADIO ASTRONOMY: ASTRONOMERS TAKE THE LEAD

As in the Netherlands radio astronomy did not emanate from wartime radar research, one might wonder whether there had been any radar research in the Netherlands at the time.

However, in war-related research, the role of the Dutch should not be underestimated. For example, they played a vital role in radar development.[14] When vacuum tubes were developed, Philips Company in Eindhoven soon became the largest vacuum tube manufacturer in Europe. In 1914, Philips established the *Natuurkundig Laboratorium* (NatLab), its research laboratory. The decision of Philips to establish an industrial laboratory followed an international trend, initiated by German chemical concerns at the end of the nineteenth century and continued by American companies at the beginning of the twentieth century, to hire scientists. In the early twentieth century, American companies such as General Electric, DuPont, Bell and European companies such as Siemens and Philips had established industrial research laboratories to broaden scientific and technological knowledge. And this knowledge in turn should support and enhance the production process (Boersma and De Vries, 2003, p. 288).

In the early 1930s, much radar research was done by NatLab researchers such as K. Posthumus and C.H.J.A. Stall. The Dutch Navy sponsored this research. In 1939, plans were started by the company Nederlandse Seintoestellen Fabriek (NSF) (a joint venture of Philips, Marconi (UK) and Radio Holland, after the war entirely taken over by Philips), to build a chain of warning stations to protect the major ports. Some field testing was done, but after the German invasion in May 1940, the project came to a halt. It was secretly continued within the Philips NatLab until 1942. During the Second World War, Philips was placed under German supervision of two 'Verwalter' (administrators), Dr. O. Bormann and O.J. Merkel. This 'supervision', however, was little more than a formality, as Bormann and Merkel were already familiar business partners of Philips before the war. The Germans required large quantities of transmitter and receiver equipment for their army and forced Philips to supply this equipment. As Philips did not appear to deliver according to expectations, German control was enforced. Ludwig Nolte, a company manager of the Allgemeine Elektricitäts Gesellschaft (AEG) took over production supervision from Bormann and Merkel in February 1942. Under Nolte, the regime seems to have become much stricter and huge supplies were sent to the Germans. Consequently, on 6 December 1942, the British Royal Air Force bombed a number of Philips factories in Eindhoven to prevent further supplies being delivered to the German Army. A second air raid was carried out on 30 March 1943 (Boersma, 2002, pp. 68-69).

The attitude of Philips towards war-related research during the Second World War is unclear.[15] Boersma and De Vries conclude that in the first years of the war, research and production continued as far as possible. In the last period of the war, however, certain research programmes

[14] For an overview of radar in the Netherlands, see: Watson, 2009, pp. 337-441.
[15] As there are not many Philips archival records left from this period and Philips is very reluctant to give people access to their archives, much is open to speculation. Several attempts were made to consult the archives, but without success.

were interrupted. In particular Natlab's war-related research – such as research into radar technology – ceased (Boersma and De Vries, 2003, p. 299).

Another Dutch radar centre was the Laboratorium voor Fysieke Ontwikkeling (LFO, 'Laboratory for Physical Development') (Watson, 2009, pp. 339-341). This laboratory had its origin in the rumours about so-called 'death rays' in the 1920s. In 1924, the Dutch parliament set up a Committee for the Applications of Physics in weaponry under the direction of Professor G.J. Elias of Delft Polytechnic to examine these rumours. The committee quickly discounted the 'death rays'. However, it established the LFO, which was dedicated to supporting the Netherlands Armed Forces. In order not to arouse suspicions, the LFO was called the Meetgebouw ('Measurements Building'). It was opened in December 1927 and located on the plain of Waalsdorp in the dunes near The Hague. The building was shared with the Dutch Military Weather Service. J.L. van Soest, engineer, led the initial research efforts, which were aimed at developing sound devices for detecting aircraft and infrared detection apparatus. J.L.W.C. von Weiler, engineer, joined the LFO in 1934 and together with S.G. Gratama, he started research on a 1.25 m communication system to be used in artillery spotting. The Dutch Ministry of Defence realised that the system might be a method for detecting aircraft and supported the continuation of the research. In April 1938, an 'electrical listening device' was demonstrated to the inspector-general of the Army and detected an aircraft at a range of 18 km. The set was rejected, however, because it could not withstand the sand and water environment of Army combat conditions. The Navy was more receptive. They provided funding for the final development and M. Staal – an engineer of Delft Polytechnic – was added to the team. The work was carried out in great secrecy. Just before the outbreak of the war, several sets were completed, and one was put into operation on the Malieveld in The Hague. It worked well, spotting enemy aircraft at 120 km during the first days of fighting, but there were no associated anti-aircraft guns. As the country capitulated, essentially all assemblies and plans for the radar were destroyed. Von Weiler and Staal fled to England. Later, Gratama and van Leeuwen also escaped to England. All eventually worked on equipment for the Dutch Navy through the research Department of HM Signal School in Portsmouth (Watson, 2009, p. 341).

At the end of the 1930s, 37 people were employed at the LFO. In 1941, the Meetgebouw was incorporated in the PTT (the Dutch Post, Telegraph, and Telephone Service) and became the Physisch Laboratorium (Physical Laboratory).[16]

So the Netherlands were clearly experienced in radar research, although during the war their efforts were cut short. (An analogous situation occurred in Italy and France.)

Remarkably enough, nobody working in Dutch radar research thought of using radio waves to study the universe. We do not have a conclusive explanation for this, but it may have had something to do with traditional astronomers turning to it so early. As explained, in most other countries the first radio astronomical initiatives were taken by radar workers during the full war. In the Netherlands, on the other hand, as early as December 1940, Oort received Reber's 1940 article in the *Astrophysical Journal* from Bart Bok. Intrigued by this article, he also sent it to H. Rinia, an engineer at Philips NatLab. After reading it, Rinia wrote to Oort: 'Enclosed I send you the issue of the Astr. Journal back, with thanks. I read the article of Reber with great interest; and I

[16] Today, the Museum 'Waalsdorp' mirrors the history of Dutch defence from 1927 onwards: http://www.museumwaalsdorp.nl/

have seen that now there is at least a good theory about the origins of such radiation. It is nice, that in this way it is possible to “see” a spiral nebula during the day and when it is cloudy.’[17]

From Rinia’s answer, it becomes clear that Oort must have realised that Reber’s findings could be extremely important for astronomical research. The great advantage of radio waves was that they were neither hindered by interstellar dust, nor by earthly clouds. The latter made them—contrary to optical waves - very suitable for ‘observation’ in the cloudy Dutch climate, even during the day. Oort also realised that it was not the continuous radio radiation that would be most helpful for astronomy, but radiation at one specific frequency, emitted by a specific chemical element that is widespread among the interstellar matter, in other words a single spectral line. He wondered whether a spectral line could be found in the radio frequency range. And he found a suitable person to investigate this matter in the Utrecht astronomy student Hendrik (Henk) van de Hulst.

1.6 VAN DE HULST AND THE DISCOVERY OF THE 21-CM HYDROGEN LINE

‘(…) Waarop ben je gepromoveerd?’
‘Op waterstoflijnwerk.’
‘Wat is dat in hemelsnaam?’
‘Dat kun jij niet begrijpen. Daar moet je heel knap voor zijn.’
Harry Mulisch, *De ontdekking van de hemel*

Oort may have had a grand vision about the possibilities for radio-astronomy in the Netherlands, it would not be easy to launch such an ambitious project. Scientific research had been seriously hampered during the wartime years and so had scientific education. The German decision of November 1940 to fire all Jewish professors met with strong resistance. At the Technical University in Delft a strike broke out. As a consequence, the School was closed. A similar situation occurred at Leiden University: the dean of the faculty of law, R.P. Cleveringa gave a speech on 26 November 1940 to protest against the forced resignation of the Jewish professor E.M. Meijers of the Faculty of Law. As a consequence, Cleveringa was imprisoned and the university was closed too. Elsewhere, university life continued more or less as before. The universities of Utrecht and Amsterdam were very likely to register the former students of Leiden. Research stagnated too. There was a lack of money for research materials and energy. Scientific staff was sometimes taken hostage or had gone into hiding and international contacts were broken. Some laboratories, such as the Kamerlingh Onnes Laboratory in Leiden, were looted by the Germans. During the first two years of the war the damage was rather limited, but the situation worsened during the last two years. In 1943, the Germans required the students to sign a loyalty declaration. As many of them refused to do so, they had to go into hiding if they wanted to escape from forced employment in Germany (Van Berkel, 2000, p. 332).

At the end of 1942, Oort too went into hiding to avoid problems with the Germans. He moved to ‘De Potbrummel’, a small cottage in Hulshorst, a tiny village about hundred kilometres from

[17] ‘Hierbij zend ik U de aflevering van de Astr. Journal met dank terug. Ik heb het artikel van Reber met zeer veel interesse gelezen; en ik heb gezien dat er nu tenminste een behoorlijke theorie is over het ontstaan van dit soort straling. Het is wel aardig, dat het op deze wijze mogelijk is een spiraalnevel overdag en bij bewolkte lucht te kunnen “zien”.’ Rinia to Oort, 12 March 1941, OA, 94.

Leiden. He also resigned from his positions as associate professor and as deputy director of the Observatory. This resignation was official as of the beginning of February 1943, when the Department of Education, Science and Cultural Protection wrote to him that the Department 'HAD APPROVED: effective as of 1 February 1943 to give to Dr. J.H. Oort - following his request - honorable discharge as an associate professor at Leiden University and as a deputy director of the observatory.' [18] However, Oort stayed in touch with his colleagues. They exchanged letters regularly. It is not even clear how 'secret' his new address really was, as most of his colleagues and several people of the Dutch government (for example of the Department of Education) knew it.[19] Oort also visited the Observatory now and then by bike (which meant a 100 kilometres ride!) (Smith, 2008).

It was in the midst of this war turmoil that Oort met Henk van de Hulst. Van de Hulst was a student of the astrophysicist Marcel Minnaert, director of Sonnenborgh Observatory, the observatory of the University of Utrecht. In the spring of 1942, Minnaert introduced his talented student to Oort:

> Previously, you have raised the possibility that we would "exchange" students. At the moment, I have an excellent young man, Mr. H.C. v.d. Hulst, who obtained his bachelor's degree two years ago and who is a very versatile talent. He is a good experimenter and an even better theorist, moreover he knows the border area of physics pretty well. (...) I would be very pleased if he could work for 2 months at Leiden Observatory (...).[20]

It was settled that Van de Hulst would work in Leiden during October and November 1942.[21] However, things went differently. Because Van de Hulst was still a student, it was uncertain that he would get a permit to work at Leiden Observatory. Moreover, as the University's near future was uncertain because of the war, Oort even discouraged Minnaert from applying for the permit.[22]

It is unclear when Oort and Van de Hulst met each other in person for the first time. From 1 to 3 July 1942, the second Dutch Astronomers Conference ('Nederlandse Astronomenconferentie') was held in Doorn (Utrecht). Both Oort and Van de Hulst gave a talk there. Oort on *The fundamental system of proper motions* ('Het fundamentaalsysteem der eigenbeweging') and Van de Hulst on *Atmospheric oxygen bands* ('Atmosferische zuurstofbanden'). So they must certainly have met there.[23]

One should realise that organising a conference during the war was not so easy. First of all, travelling was difficult. Moreover, the war hardship becomes clear from the accompanying information to the participants that said: 'Bring along ration coupons for bread, butter or fat,

[18] 'HEEFT GOEDGEVONDEN: met ingang van 1 Februari 1943 aan Dr. J.H. Oort op zijn verzoek eervol ontslag te verleenen als buitengewoon hoogleeraar aan de Rijksuniversiteit te Leiden, en als adjunct-directeur van den sterrewacht.' Jan Van Dam to Oort, 28 January 1943, OA, 96.

[19] See several letters: OA, 96.

[20] 'Je hebt indertijd de mogelijkheid geopperd dat wij studenten zouden "uitlenen". Ik heb op dit ogenblik een voortreffelijke jonge man, de heer H.C. v.d. Hulst, die al 2 jaar candidaat is en een zeer veelzijdige aanleg heeft. Hij is een goed experimentator en nog beter theoreticus, daarenboven kent hij het physische grensgebied al heel aardig. (…)Ik zou het buitengewoon op prijs stellen indien hij 2 maanden aan de Leidse Sterrewacht zou kunnen werken (…).' Minnaert to Oort, 20 April 1942, OA, 162a.

[21] Minnaert to Oort, 20 April 1942, OA, 162a.

[22] Oort to Minnaert, 1 May 1942, OA, 162a.

[23] Programme of the Dutch Astronomers Conference in Doorn, 1-3 July 1942, OA, 95.

potatoes, porridge oats, sugar and meat. You have to bring a sleeping bag, or sheets and a pillow case, towel and soap.'[24]

In the meantime, the war had taken its toll on Minnaert too. From May 1942 until April 1944, Minnaert was taken hostage by the Germans in the camp at Sint-Michielsgestel. This was a special camp for the elite: amongst the prisoners were well-known Dutch writers, scientists and politicians. The regime was much less strict than in other camps: prisoners had enough to eat, there was good medical care and a lot of intellectual and creative activities were organised by the prisoners themselves. (De Keizer, 1979). To understand how Minnaert ended up in this camp, one needs to read his biography (an extensive biography on Minnaert has been written by Molenaar, 2003). The Belgian Minnaert was born in Brugge in 1893. He got a PhD in biology at Ghent University in 1914. In his student days, he became a radical 'Flamingant' and hence he was a strong supporter of the 'Dutchification' of the then French speaking Ghent University. During the First World War, a Dutchified Ghent University was opened at the insistence of the German governor-general Moritz von Bissing. This fitted in with the German 'Flamenpolitik', which meant that the German occupier supported the Flemish in their conflict with the French-speaking community. By doing this, the Germans hoped to get the sympathy of the Flemish, which would enable them to enforce their grip on the country (Elbers, 2010, p. 14). When the Germans had lost the war in 1918 and Minnaert realised he could get in big trouble because of his Flamingantism - this could be seen as collaboration with the Germans – he fled to the Netherlands with his mother at the end of October 1918. Minnaerts fear to be accused of collaboration proved to be justified: in July 1920, he was sentenced in absentia to fifteen years hard labour.

The Netherlands was not entirely new for Minnaert: in 1915, he had already taken some physics courses at Leiden University. At the end of 1919, Minnaert was appointed observer at the Heliophysical Institute of Utrecht University. Professor Willem Henri Julius was the director of the Physical Laboratory. In 1910, he had founded the Heliophysical Institute as an experimental research centre that was part of the Physical Laboratory. Julius was one of the pioneers of the research on the Sun, in which Minnaert would specialise too, as will be shown. Besides his work at the observatory, Minnaert also accepted a position at the Royal Dutch Meteorological Institute (KNMI). Under the supervision of Julius, Minnaert got a PhD in physics, entitled *Irregular Refraction of Light Rays* ('Onregelmatige Straalkromming'). In 1932, he became a Dutch citizen. Four years later, in 1937, Minnaert accepted the position of director of Sonnenborgh, the Observatory of Utrecht University.

Minnaert developed into an extremely versatile person: he was a talented scientist, a friendly and competent teacher, a poet, a piano player, and he spoke seven languages fluently. Moreover, he remained a man of strong political convictions. Just as these convictions brought him into serious trouble when he was in his twenties, they brought him again into trouble during the Second World War, albeit the situation was entirely different then. In the Netherlands, Minnaert became an internationalist and he developed communist sympathies. Especially the latter lay at the basis of his arrest by the Germans on 4 May 1942. When his wife – the physicist Miep Coelingh – asked the *Sicherheitsdienst* (Security Service) for the reason of his arrest – after all, Minnaert was not anti-German - she was told that it was because 'he had made a communist fist at the funeral of De Clercq' (Molenaar, 2003, p. 279). Indeed, ten years earlier, on 12 June 1932, the Flemish poet René De Clercq was buried in Utrecht. Like Minnaert, De Clercq was a Flamingant who had fled to the

[24] Programme of the Dutch Astronomers Conference in Doorn, 1-3 July 1942, OA, 95.

Netherlands after the First World War. At his funeral, an incident took place that would be remembered long after. As there had been a connection between Flamingantism and National Socialism, several National Socialists were present at the funeral. While they sang anthems, a lot of attendees gave the fascist greeting. As a reaction, Minnaert made a 'communist fist'. This aroused the anger of the fascists, who started to threaten Minnaert. Finally, Minnaert had to leave the funeral (Molenaar, 2003, pp. 239-240).

There is of course a certain amount of irony in the fact that after the First World War, Minnaert left Belgium because he feared to be accused of collaboration with the Germans, while in the Second World War, he was imprisoned by these same Germans.

While in Sint-Michielsgestel, Minnaert found a useful occupation in teaching his fellow prisoners some astronomy and other sciences. He was also allowed to send and to receive letters. Oort and Minnaert corresponded intensively during these years. Oort sent his letters from Hulshorst, which proves that this 'secret' residence was actually not secret at all. In September 1942, for example, Oort wrote to Minnaert:

> From the many messages from St Michiels Gestel (sic), I deduce that you are making yourself very useful by teaching your fellow hostages something of the beauty of research into nature and to tell them about the wonders of the inorganic world.[25]

To keep his unfortunate colleague up to date with astronomical developments, Oort also proposed to send him a photographic reproduction of the latest issues of the *Astrophysical Journal* which he had himself received through Bart Bok.[26]

The imprisonment of Minnaert seems to have been an incentive for Van de Hulst to informally shift his studies to Leiden (Sullivan, 2000, p. 238). Although we do not know exactly how long he stayed there, he must have been there for several months during 1943-1944. He regularly met with Oort during this period. Oort in turn, was very pleased with Van de Hulst's visit: 'At the moment, we have Van de Hulst visiting us for a few months here in Leiden. I am looking forward to discuss all kind of things with him.'[27]

And it was during this stay, in the spring of 1944, that Oort asked Van de Hulst to look for the spectral line in the radio frequency range. Van de Hulst later remembered Oort saying to him:

> We should have a colloquium on the paper by Reber; would you like to study it? And, by the way, radio astronomy can really become very important if there were at least one line in the radio spectrum. Then we can use the method of differential galactic rotation[28] as we do in optical astronomy (Van de Hulst, 1957, p. 3).

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[25] 'Ik merk uit vele berichten die vanuit St Michiels Gestel komen dat je je daar heel erg nuttig maakt met den medegijzelaars iets van het prachtige van het natuur-onderzoek bij te brengen, en hen over de wonderen der anorganische wereld te vertellen.' Oort to Minnaert, 24 September 1942, OA, 162a.

[26] Oort to Minnaert, 24 September 1942, OA, 162a.

[27] 'We hebben hier in Leiden nu van de Hulst voor eenige maanden op bezoek. Ik verheug me er op om allerlei met hem te kunnen bepraten.' Oort to Minnaert, 11 January 1944, OA, 162a.

[28] Differential galactic rotation means that the angular velocity of stars or gas moving around the center of the Galaxy is not a constant, but varies as a function of radial distiance to the nucleus. As a consequence, along any given line of sight through the Milky Way, different regions of hydrogen gas observed will be moving with different radial velocities with respect to us. Oort understood that detectable spectral lines in

At a clandestine meeting of the Dutch Astronomers Club ('Nederlandse Astronomen Club') on 15 April 1944 at Leiden Observatory, van de Hulst confirmed the existence of this spectral line in a talk, entitled *The Origin of Radio Waves from Space* ('Herkomst der Radiogolven uit het Wereldruim')[29] By scrutinising the literature on spectroscopy, he had discovered a spectral line of hydrogen at 21 cm, well within the radio spectrum. As Van de Hulst pointed out, hydrogen was the most abundant element in interstellar space in the Galaxy, so detection of the extremely weak line might very well be possible. The detection of the line could be used to unravel the structure of the Milky Way beyond the small part that was observable by means of optical waves.

The importance of Van de Hulst's discovery of the 21 cm line can hardly be overestimated. As radio astronomer Richard Strom stated: 'This discovery would set the agenda for generations of radio astronomers in Holland and elsewhere' (Strom, 2005, p. 94).

1.7 HOW TO BUILD A TELESCOPE?

The obvious next step was to build a radio telescope. But how could this be done?

As mentioned before, in other countries it was engineers and physicists with a background in the war industry who were pushing ahead with radio astronomy. These people had the necessary knowledgeof receiver techniques and they knew how to build a radio telescope. Oort and his colleagues, however, were university-based astronomers with little engineering knowledge. Therefore, they had to look for people who could provide them with the necessary technical know-how. To this end, Oort contacted people from Philips NatLab, from Delft Polytechnic and Reber himself.

That Oort contacted members of Philips NatLab should not come as a surprise: during the pre-war period, Philips NatLab was after all one of the two centres of development of radar technology in the Netherlands. Moreover, since the foundation of Philips NatLab (1914), there had been a connection with Leiden University. The first director of the NatLab was Gilles Holst, a physicist who had worked at the Kamerlingh Onnes low temperature physics laboratory at Leiden University. From 1930 until 1938, Holst was also professor of industrial physics at Leiden University. In 1946, Holst retired from the NatLab and was succeeded by the triumvirate H. B. G. Casimir, H. Rinia and E. J. W. Verwey. With Casimir - a former professor of physics at Leiden University - the Leiden connection was continued.

The first written record we have of contact between Oort and an employee of Philips about radio astronomy was the letter of Rinia to Oort of 12 March 1941. Rinia was an electrical engineer from Delft Polytechnic. In 1928, he joined the staff of Philips NatLab. Although we do not know much about Rinia's life or his contacts with Oort, it seems he had a great personal interest in astronomy (Teer, 1986, pp. 176-177).[30]

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the radio spectrum could be used, through Doppler shifts of these lines, to investigate the location and rotation of interstellar gas throughout the galactic system (Smith, 2008).

[29] Van de Hulst, H.C., "Lezing", April 1944, VdH, 38.

[30] Several people of NatLab were involved in amateur astronomy. In 1935, the 'Eindhovense Weer en Sterrenkundige Kring' (Eindhoven Meteorology and Astronomy Circle, EWSK) was founded and consisted mainly of Philips employees. By means of a generous donation of A.F. Philips, the EWSK was able to found

More important were Oort's contacts with another member of Philips NatLab: the physicist C.J. Bakker. At the aforementioned meeting of the Dutch Astronomers Club on 15 April 1944 where Van de Hulst confirmed the existence of the spectral line of hydrogen at 21 cm, Oort had invited Bakker to explain the technical possibilities for building a receiver for the radio telescope that would allow detection of the 21-cm hydrogen line. Both Bakker and Van de Hulst's talks were published as a joint article in the Dutch physics journal *Nederlands Tijdschrift voor Natuurkunde* (Bakker and Van de Hulst, 1945).

One may wonder why Bakker was so interested in radio astronomical research. As a matter of fact, this was in line with his activities at Philips NatLab. Between 1934 and 1941, he investigated electronic problems that occurred when developing radio tubes at Philips. In the company, he was also influenced by the physicist Balthasar van der Pol. Van der Pol had performed research in areas such as the propagation of radio waves, the theory of electrical circuits and vibrations. These experiences drew Bakker's interest to radio waves from the Sun and the Galaxy (De Boer, 1960, p. 284). As early as 1942, Bakker published an article in the journal *Nederlandsch Tijdschrift voor Natuurkunde* (Bakker et al., 1942) together with the astronomers M. Minnaert (Utrecht Observatory), A. Pannekoek (University of Amsterdam) and the geophycisist J. Veldkamp (Royal Dutch Meteorological Institute KNMI). This article contains a section on radio research of the ionosphere, written by Bakker. (During the war Bakker was also a member of the editorial board of this journal.)

A few days after the meeting of the Dutch Astronomers Club, Oort wrote to Bakker that he wanted to continue the cooperation with Philips:

> After having reconsidered the possibility that the Observatory with the help of Philips Factories could start an investigation into the interstellar radio radiation, it seems more and more attractive if at least such an investigation could happen entirely with your cooperation. Because it only makes sense to start this work if there is a reasonable possibility that we will be able to do it better than elsewhere (…)[31]

This letter also contains the first written record that Oort intended to build a radio telescope with a mirror of 10 to 20 metres diameter. He asked Bakker whether Philips could build the receiver for this telescope. But Bakker replied:

> Following your letter of 19 April, I have had a conversation about this with Prof. Holst, the director of our laboratory. In principle, he was very positive towards the idea that we

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an observatory in Eindhoven. This observatory was (and still is) a public observatory, aiming at bringing astronomy closer to the general public. Also prominent astronomers, such as Oort and Hertzsprung, regularly gave talks at this observatory. See also: http://www.dse.nl/~sterrenwacht/ (accessed on 6 February 2013).

[31] 'Na nog eens nader te hebben gedacht over de mogelijkheid dat de Sterrewacht met behulp van de Philips Fabrieken een onderzoek zou kunnen beginnen over de interstellaire radiostraling, lijkt me dit hoe langer hoe meer aantrekkelijk, indien althans zo'n onderzoek geheel in samenwerking met U zou kunnen geschieden. Want het heeft alleen zin dit werk te beginnen als er een redelijke kans op is dat we het beter zullen kunnen doen dan elders (…)' Oort to Bakker, 19 April 1944, OA, 158a.

> would provide you with a suitable receiver installation, but he considered it practically impossible to deliver it to you before the end of the war.[32]

Why it was impossible to build this receiver during the war, Bakker did not explain. Philips, however, was under German control in those days. And it is very likely, of course, that under these circumstances, the company could not deliver war-sensitive materials such as a receiver. So Oort would have to wait at least until the war was over to execute his plans.

An extensive correspondence between Bakker and Oort followed in which they discussed the size of the mirror in relation to the wavelengths Oort wanted to measure.[33] The resolving power of a radio telescope is proportional to the diameter of its dish and inversely proportional to the wavelength that is used. To increase the resolving power – provided that the wavelength stays the same - the diameter of the dish needs to increase too. Oort wanted to obtain an opening angle[34] of one degree, which meant that, for a wavelength of 50 cm, he would need a dish as large as about 30 m diameter, as Bakker had calculated. A problem, however, was the wavelength of 21 cm Oort was aiming for. At the time, Philips did not have much experience with receivers for wavelengths shorter than 1 m. But Bakker promised Oort to try to develop a receiver for a wavelength 'as short as possible'.[35] And Oort did not only ask Bakker for advice concerning the size of the dish in relation to wavelength, he also contacted several other persons. He corresponded with Reber[36] and with von Weiler (who had joined LFO in the 1930s to do radar research). To von Weiler, Oort explained that he wanted to build a receiver installation to detect radio radiation emitted by interstellar gas and with a wavelength between 50 cm and 1 m[37]. Reber's instrument had an opening angle of only 12 degrees, which was, according to Oort, insufficient 'to obtain valuable new data on the structure of the Galaxy and the distribution of the interstellar gas'.[38] He asked von Weiler for advice in these matters.

To conclude, it can be said that during the war, Oort laid a firm claim on 'radio astronomy'[39] in the Netherlands. Although there was still no 'radio telescope', no observations had yet been made and no funding was provided for this kind of research, between 1941 and 1945 Oort did extensive preliminary research and made clear he *intended* to perform radio research. As early as 1941, he

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[32] 'Naar aanleiding van Uw brief van 19 April l.l. heb ik thans een gesprek hierover gehad met Prof. Holst, den directeur van ons laboratorium. Deze voelde er in principe veel voor, dat wij U aan een geschikte versterkerinstallatie zouden helpen, maar hij achtte het practisch uitgesloten, dat wij deze vóór het einde van de oorlog zouden kunnen leveren.' Bakker to Oort, 3 May 1944, OA, 158a.
[33] Correspondence between Bakker and Oort, OA, 158a.
[34] The opening angle of the smallest resolvable angular unit is the 'beam' of the radio telescope.
[35] Oort to Bakker, 19 April 1944, OA, 158a.
[36] Oort to Reber, 30 August 1945, OA, 98c; Reber to Oort, 17 September 1945, OA, 251.
[37] At the time, Philips could not yet provide a receiver for shorter wavelengths.
[38] 'waardevolle nieuwe gegevens over de structuur van het sterrenstelsel en de verdeeling van het interstellaire gas verkrijgen', Oort to von Weiler, 26 March 1964, OA, 251.
[39] The word 'radio astronomy' did not yet exist in those days. It is unclear when the word was used for the first time, but Sullivan said the earliest written mention he could find was in a review article written by the Russian Vitaly Ginzburg in 1947 (Sullivan, 2009, p. 423). When the Dutch used the term for the first time is also unclear. In the early days, terms they used to refer to 'radio astronomy' were: 'research into radio waves from the interstellar gas'; 'research into radio waves from interstellar space'; 'research into interstellar radio waves' etc. (Sullivan, 2009, p. 422). What is said here may seem in contradiction with the words Oort spoke to Van de Hulst in 1944 to ask him to look for a spectral line in the radio spectrum, as Van de Hulst mentions in his 1957 article (see above). In this quote, both 'radio astronomy' and 'optical astronomy' are used. However, we think this is a rather 'liberal' post factum interpretation of Oort's words by Van de Hulst. It is highly unlikely that Oort actually used these terms in 1944.

contacted people (Rinia for example) from Philips - which had been a centre of radar research – and made it clear to them what he wanted. Here is a possible explanation why in the Netherlands, the initiative for radio astronomy was not taken by former radar researchers: from the very beginnings, Oort held the reins firmly and therefore his partners – who had nevertheless a clear interest in the topic - in a certain way never got the chance to take any initiative in this respect.

1.8 SEEKING FINANCIAL SUPPORT AFTER THE WAR

The Netherlands was liberated on 5 May 1945. Oort was appointed full professor and director of Leiden Observatory that same year and then considered it the right time to return to his plans for a radio telescope, which he then pursued with more vigour than ever.

He asked Grote Reber how much his telescope had cost:

> At the Leiden Observatory we have been much interested in the interstellar gas and its distribution through the Galaxy, and I am considering the possibility of erecting a large mirror and receiving set for ultra-short waves in this country. Naturally, the plans are vague, and it is still quite uncertain whether we shall be able to carry them out. However, in this stage, it would be of value for us to be able to make a general estimate of the cost of the instrument. If it is possible for you to give us a rough idea of the expenditure for your 31 feet mirror this would be of some help in the general planning. I should be greatly obliged if you could give us this information. Of course all other advice you could give would be warmly welcomed.[40]

Reber responded enthusiastically: 'Your interest in this work is greatly appreciated by me because for a very long time now, It (sic) seems that I have been the only enthusiast and it has been rather lonesome.' [41] He gave a detailed explanation about the cost of his telescope. The mirror had been made of galvanised iron 0.20 inches thick and the frame or carrier was of wood, fastened together by gusset plates and machine bolts. The cost of the structure was as follows:

Foundations	$ 73.15
Steel Stock	$ 181.73
Wood	$ 127.92
Hardware	$ 150.24
Paint carriage	$ 109.80
Paint mirror	$ 34.12
Total	**$ 676.96**

[40] Oort to Reber, 30 August 1945, OA, 98c.
[41] Reber to Oort, 17 September 1945, OA, 251.

Moreover, the cost of the labour of one man for four months had to be added. The necessary electrical apparatus to get the results he had published in his 1940 article in the *Astrophysical Journal* was about 500 dollars plus again several months of labour to get it working.

After his 1940 'success', Reber thought the correctness of his general system was proven and he decided to go ahead on a larger scale. So he bought in addition:

General Radio D.C. Amplifier	$ 225.00
Esterline Angus recorder	$ 292.81
Cabinet for housing these	$ 36.17
Total	**$ 553.98**

Furthermore, between 1942 and 1944, Reber spent more than $ 3000, mainly on new electrical equipment. A large amount of labour was again needed to make things work.

Reber also gave Oort some other advice. First of all, he pointed out that his own location was near the street and automobiles were passing at about 100 feet, which brought about a lot of interference. Therefore, Reber recommended that Oort choose a location at least a mile from all automobiles. Moreover, as Reber himself had experienced a lot of problems with the amplifiers, he urged Oort to try to obtain the services of first class radio engineers. And as will be shown in the next chapters, finding suitable engineers was a problem Dutch radio astronomy had to cope with for several decades.

At the same time, Oort asked the advice of the physicist J.M. Burgers of the Laboratory for Aero- and Hydrodynamics at Delft Polytechnic:

> Concerning still vague plans for the construction of a parabolic "mirror" for the registration of radio waves from the interstellar gas (…) I would like to talk to someone who understands the building of large steerable metal constructions. To be more specific, it concerns the construction of a "mirror" of about 20 metres diameter (…).[42]

But for Burgers too, building a 'radio telescope' (the word did not exist yet) was an entirely new undertaking. He answered:

> The problem you propose, seems very interesting to me – firstly the thought itself, the detection of radio waves from interstellar space; and secondly also from a mechanical point of view. Although I am not an expert in these matters, I would still like to discuss them with you. I also contacted Biezeno[43], and he is willing to help you further.[44]

[42] 'In verband met nog vage plannen voor den bouw van een parabolische "spiegel" voor het registreren van radiogolven uit het interstellaire gas (…) zou ik graag eens praten met iemand die verstand heeft van den bouw van groote beweeglijke metaalconstructies. Het zou nl. gaan om het bouwen van een "spiegel" van plus minus 20 meter middellijn(...).' Oort to Burgers, 30 August 1945, OA, 98a.

[43] Biezeno was a professor in applied mechanics at Delft Polytechnic.

[44] 'Het probleem dat je stelt, lijkt me erg interessant – ten eerste de gedachte zelf, het opvangen van radiogolven uit de interstellaire ruimte; en ten tweede ook in mechanisch opzicht. Al ben ik in deze dingen geen expert , toch zou ik het prettig vinden er met je over te mogen spreken. Ik heb me ook al tot Biezeno gewend, en die is bereid verdere hulp te geven.' Burgers to Oort, 6 September 1945, OA, 98a.

Burgers had regular contacts with staff members of the Dutch construction company Werkspoor, with whom he discussed Oort's plans. From these discussions, it became clear to Burgers that 'the mirror has to be carried by a network, made from welded steel pipes, similar to the type that is used in the construction of fuselages'.[45]

A few days later, Werkspoor sent Oort an 'Avant projet' ('preliminary draft') of the construction for a mirror of 25 m diameter.[46]

As the project promised to be very expensive – a rough estimate of a price-tag was Dfl 100 000 (Katgert-Merkelijn, 1997, p. XXII) – Oort realised that government support would be necessary. He wrote to Burgers: 'I am trying to contact Schermerhorn to find out whether it is possible to get financial support from the government for this plan. Without this support, it is hardly even possible to start.'[47]

Indeed, two days later, on 8 November 1945, Oort wrote a letter to Prime Minister Schermerhorn, in which he asked for a meeting:

> Is there a possibility to have a talk with you about two astronomical projects[48] which are rather large and cannot be realised without special government support? I would be very grateful if I could have the opportunity to visit you to discuss these.[49]

This manoeuvre was very typical for Oort. When he wanted to get something done, he always tried to avoid the official procedures and *directly* contacted the highest official, the prime minister in this case. In the next chapters, this will become increasingly clear.

Oort actually visited Schermerhorn on 16 November 1945.[50] We do not have much information about what was exactly said during this visit. We only know that afterwards, Oort sent Schermerhorn a memorandum about his plans, which he asked him to discuss with the Minister of Education, Arts and Sciences. In the accompanying letter, he also explained that he had contacted Schermerhorn directly, because a fund for 'special scientific research' was non-existent. Otherwise, he would have contacted this fund.[51]

Oort also tried to get government support for his project in another way: on 26 November 1945, Oort sent the plans for his 25-m telescope to the board of the KNAW (Royal Netherlands Academy of Arts and Sciences). One of the tasks of the Academy was to serve as an advisory body for the

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[45] 'de spiegel gedragen zal moeten worden door een netwerk, dat uit gelaste stalen buizen kan worden opgebouwd, enigermate van een type als wordt toegepast bij de constructie van vliegtuigrompen.' Burgers to Oort, 23 September 1945, OA, 251.

[46] Theunissen to Oort, 25 September 1945, OA, 251.

[47] 'Ik probeer nu contact te krijgen met Schermerhorn om te zien of er van regeeringszijde geld voor het plan te krijgen zou zijn. Zonder steun van die zijde zullen we het nauwelijks kunnen beginnen.' Oort to Burgers, 6 November 1945, OA, 98a.

[48] One of them was the radio telescope, the other one was probably the (second) Leiden expedition to Kenya. This astronomical expedition - which took place from August 1947 until October 1951 – was carried out to determine accurate declinations of stars, see: Katgert-Merkelijn, 1991.

[49] 'Zou het mogelijk zijn dat ik bij gelegenheid eens een onderhoud met je had om over twee astronomische projecten te spreken, die van eenigszins grooten omvang zijn en niet zonder bijzonderen steun van de Regeering aangepakt kunnen worden? Ik zou het bijzonder op prijs stellen dat je me daarvoor eens kon ontvangen.' Oort to Schermerhorn, 8 November 1945, OA, 98c.

[50] Secretary of Schermerhorn to Oort, 12 November 1945, NA, 2.03.01 (Algemene Zaken), inv 5713.

[51] Oort to Schermerhorn, 17 November 1945, NA, 2.03.01 (Algemene Zaken), inv 5713.

government in matters of science (Van Helvoort, 2005, p. 46). Therefore, Oort asked the board of the Academy to recommend the project to the government and to request financial support.[52] However, despite all Oort's efforts, the cost of the project was a problem. His estimate of Dfl 100 000 was about as large as the government's total budget for scientific instrumentation and consequently his request was turned down (Katgert-Merkelijn, 1997, p. XXII). Fortunately, there was an alternative.

1.9 THE FIRST RADIO TELESCOPE IN KOOTWIJK: A 'PRESENT' OF THE PTT

On the Dutch coastline, the Germans had left behind several Würzburg radar reflectors which they had used during the war. These were the so-called 'Würzburg-Riesen'. During the war, about 1500 of these 'Riesen' were built. They were part of the 'Atlantikwall', the German line of defence between France and Norway. Along the Dutch coast, there were about 40 of these radar installations (Beekman, 1999, p. 154). When the war came to an end, there was a considerable interest among radio engineers in German radar technology. This was not only the case in the Netherlands, but all over Europe and overseas (Strom and Van Woerden, 2006, p. 12). This meant that almost everywhere, these Würzburgs were recycled for scientific research after the war.

The post-war history of the Dutch Würzburgs is only partly documented. The Würzburg with the best known history is the one that was used by the Dutch Organisation for Applied Scientific Research (TNO, a joint organisation of industry, universities and the government). During the war it was part of the radar installation of the Dutch island of Rozenburg. In 1947, it was moved to the Waalsdorper Vlakte on the outskirts of The Hague for experimental use by the Physics Laboratory of the Dutch State Defence Organisation ('Rijksverdedigingsorganisatie', which later became a division of TNO) (Strom and Van Woerden, 2006, p. 12).

The Dutch radio astronomers and the PTT also used several of these Würzburgs, but the history of these antennas is not well documented. It is generally accepted that the initiative to acquire the PTT Würzburgs came from engineer A.H. de Voogt (Strom and Van Woerden, 2006, p. 13; Muller, 1980, pp. 65-66; De Voogt, 1952, p. 211[53]). As the head of the PTT Central Department for Radio, De Voogt was in charge of the transmitting and receiving stations for communication with the Dutch East Indies in particular. This long-distance communication was crucial in the early post-war years, because the relations with Indonesia were deteriorating seriously. (Indonesia would finally gain independence in December 1949.) After the war, De Voogt therefore launched a research programme to understand how the ionosphere influenced radio propagation and which effect solar activity had on it. This appears to have been his motivation for acquiring several Würzburgs in about 1947 and installing them at the PTT stations (Strom and Van Woerden, 2006, p. 13). Subsequently, one of these Würzburgs was made available to the Dutch astronomers for studies of Galactic radiation (Strom and Van Woerden, p. 5). However, the details of this arrangement are not known.

[52] Oort to the Board of the Royal Academy of Sciences, 20 November 1945, OA, 251.
[53] De Voogt mentions that these Würzburgs were acquired by the PTT, but he does not explicitly mention his own initiative in this respect.

The first question we can ask is how Oort came by the idea that such a Würzburg Riese could be used for radio astronomical research. The story goes that shortly after the war Oort and the physicist J.H. Bannier, (later the first director of the funding organisation ZWO) were walking along the coast of the North Sea and there they saw some of these Würzburgs the Germans had left behind. Oort would then have seen immediately that with some modifications these reflectors could easily made suitable for radio astronomical research (Beekman, 1999, p. 154). However, this story is rather unlikely. From a letter of Minnaert to Oort in the Oort Archives it appears that Rinia from Philips NatLab showed the astronomers the way to these Würzburgs: 'Rinia told me that the mirrors he refers to are at various locations in the dunes, especially in Terschelling. According to him, they have a diameter of 8-10 metres (...).'[54] Furthermore, it seems that the antennas (or at least some of them) had at that moment not yet been transported to the transmitting station of the PTT, but the PTT had already laid a claim on them. This becomes clear from the fact that Minnaert said they needed to contact some people from the PTT to obtain one of these Würzburgs: 'He [Rinia] does not know another possibility to obtain these [the Würzburgs] than through colleague von Weiler – so I fear the worst.[55] I wonder if we could try van Soest, whom I do know and who is the head of the military laboratories.'[56]

In any case, in the beginning of 1948, the PTT made one of these Würzburgs available for the Dutch astronomers. The reason why the PTT was so eager to help the astronomers was because they thought they would benefit from the radio astronomical research too. More specifically, the PTT took an interest in the solar research the astronomer Marcel Minnaert and his team had been doing for several years. Indeed, solar research could be very valuable for communication. As pointed out above, solar activity influenced the ionosphere[57], which in turn influenced the propagation of radio waves through the ionosphere.

The solar research of Minnaert not only drew the attention of the PTT, but also of the Royal Dutch Meteorological Institute (KNMI), where Minnaert had been working in the interwar period. The KNMI was interested in solar research for similar reasons: the Sun influenced the ionosphere and this in turn influenced the weather conditions. Already during the war, there were contacts between the Utrecht astronomers and the KNMI, especially with Minnaert's assistant Houtgast, who was the deputy director of Utrecht Observatory when Minnaert was imprisoned in Sint-Michielsgestel. In 1944 for example, Houtgast participated in a colloquium of the KNMI with a paper on *The scintillation of stars* ('Het scintilleren van sterren'), which was thought to be connected to the weather.[58]

As the Netherlands had a special interest in this kind of solar research, not only from a scientific perspective, but also because of its overseas territories, Houtgast had proposed the creation of a new institute for solar and ionospheric research with observing stations at home and in the

[54] 'Rinia vertelde mij, dat de door hem bedoelde spiegels van de Duitsers hier en daar in de duinen staan, inzonderheid op Terschelling. Volgens hem hebben ze een middellijn van wel 8-10 meter (...).' Minnaert to Oort, 29 February 1948, OA, 162b.
[55] It is unclear why this is so 'bad', but probably this was just because Minnaert did not have any connection with von Weiler.
[56] 'Hij kende geen andere weg om hieraan te komen dan collega von Weiler – ik vrees dus het ergste. Het is de vraag of we 't zouden kunnen beproeven met van Soest, die ik wel ken, en die immers aan het hoofd van die militaire laboratoria staat.' Minnaert to Oort, 29 February 1948, OA, 162b.
[57] Solar activity had reached a maximum in 1947.
[58] Houtgast, J., 'Het scintilleren van sterren', talk for the colloquium of the KNMI on 18 February 1944, MA, 838, Box 19, Folder 6.

colonies (Strom, 2005, p. 97). Although these plans were never realised, Houtgast and Minnaert effectively joined forces with the PTT and the KNMI in March 1946 to study the ionosphere and its connection with radio wave propagation and solar activity (Houtgast, 1946, p.93).

So the first radio telescope in Kootwijk was in fact a 'present' from the PTT. The dish was much smaller and less sensitive than the one Oort originally planned—only 7.5 m—, nor was the receiver built by Philips: it was an adapted surplus American radar receiver that professor C. J. Gorter of the Kamerlingh Onnes Laboratory at Leiden had provided. Thus for several years, the astronomers did their research with a much smaller and less sensitive telescope than they had originally planned.

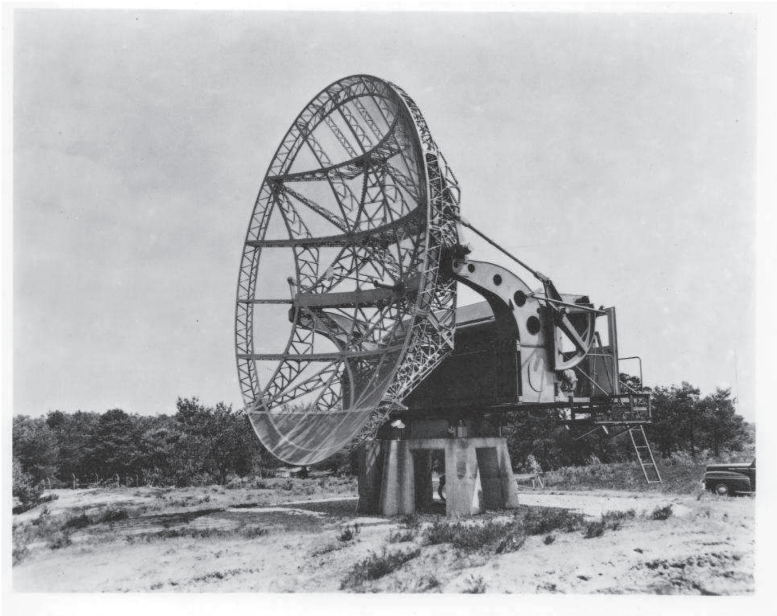

FIGURE 1. The first radio telescope in Kootwijk (Leiden Observatory Archives)

1.10 TOWARDS A 'KNOWLEDGE-BASED ECONOMY'

The Second World War had left the Netherlands with a devastated economy and, as we saw, science had been hit hard as well. After the war, it took a while before life was back to normal. Many basic products, like clothing, were hard to obtain. It is telling that in the late summer of 1945 Oort wrote to the city of Leiden to inquire whether it was possible to give shoes to the staff of the observatory:

> Among the staff of the Observatory are some people whose footwear is in such a condition that there is a good reason to fear that they will soon no longer be able to come to their jobs, because of a lack of footwear. (…) I would very much appreciate if you could let me know whether there is a possibility to provide footwear for the members of the staff for whom this is most urgent.[59]

It was also in this context that in 1945, Oort's request to the Dutch government for Dfl 100 000 for the building of a radio telescope with a mirror of 25 m was turned down.

Despite this setback, however, Oort did not give up. He kept hoping that in the short term it would be possible to build such a telescope. However, it remained to be seen whether such a project would be viable in the post-war context. Could science be a priority in a country that had been devastated by the war? To answer this question, it is necessary to put the Dutch post-war science policy in context.

Understandably, the main aim of the first post-war Dutch Prime Minister, Willem Schermerhorn, was the reconstruction of the country. And in this reconstruction *science* had to play a major role. Indeed, the main purpose of science was to serve the economy, as Schermerhorn made clear in his radio speech to the Dutch nation on 27 June 1945:

> Scientific research, improvement of existing products and the launch of new products, the reduction of the cost, partly by (…) extensive market analysis and needs analysis are (…) essential, if eventually the Netherlands want to maintain a prominent place in quality production.[60] (Schermerhorn and Queen Wilhelmina, 1945, p. 15)

In other words, the Netherlands had to evolve towards what since the 1960s has been known as a 'knowledge-based economy'. More specifically, Schermerhorn wanted to create a special organisation, a kind of brain trust of researchers linked to both industry and government, which was to conduct research into several new fields. This was supposed to stimulate industry and economic growth (Kersten, 1996, p. 10).

Eventually, this would lead to the foundation of the Dutch Organisation for Pure Scientific Research or ZWO ('Zuiver Wetenschappelijk Onderzoek'). It was formally founded in 1950, but provisionally already active in 1947.

A closer look at the foundation of ZWO reveals that from the very start academe, industry and the government were involved. On 13 September 1945, Schermerhorn had his first meeting about the topic with the Minister of Education, Arts and Sciences Professor G. van der Leeuw, the Minister

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[59] 'Onder het personeel der Sterrewacht zijn eenigen, wier schoeisel in zoodanigen staat verkeert, dat er gegronden reden is om te vreezen dat zij binnenkort door gebrek aan schoeisel niet meer naar hun werk zullen kunnen komen. (…) Ik zou het bijzonder op prijs stellen indien U mij wilde mededeelen of er een mogelijkheid bestaat schoeisel te verstrekken voor die leden van het personeel voor wie dit het meest urgent is.' Oort to the Central Distribution Office ('Centraal Distributiekantoor') of Leiden, 21 August 1945, OA, 98a.

[60] 'Het natuurwetenschappelijk onderzoek, de verbetering van bestaande en het op de markt brengen van nieuwe producten, verlaging van de kostprijs mede door (…) uitgebreide markt- en behoefteanalyse zijn (…) onmisbaar, wil Nederland op den duur een vooraanstaande plaats in de kwaliteitsproductie behouden.'

of Trade and Industry H. Vos, the president of TNO, Professor H. R. Kruyt and the Secretary General of Education, Arts and Sciences H. J. Reinink.

Schermerhorn decided to set aside 5 million Dfl annually for the expansion of the national research capacity and for improved education of scientific researchers. Not only the natural sciences, but also economics, the social sciences and the humanities were meant to benefit from this (Kersten, 1996, p. 10). The question was how all this could be organised. In order to set the wheels in motion, Schermerhorn and Van der Leeuw founded a special committee in April 1946. It was presided over by Reinink and therefore it was referred to as the 'Reinink committee'. There were 11 representatives of the government, industry and science on the committee (Reinink, 1950, p. 7).

The Reinink Committee drafted a bill during the first half of 1947 to formally establish the new organisation. This bill was largely based on a report of TNO president H. R. Kruyt, who took the organisational structure of the Belgian National Fund for Scientific Research (Nationaal Fonds voor Wetenschappelijk Onderzoek or NFWO) as an example (Reinink, 1950, p. 9). (NFWO had already been founded in 1928. Its organisational structure was roughly based in turn on that of the Rockefeller Foundation.) After the necessary recommendations and revisions, the bill was presented to the Dutch parliament on 26 April 1949. It was approved, after some amendments, by the Lower Chamber on 7 October 1949 and finally by the Upper Chamber on 4 January 1950. Between 1947 and 1950, the Reinink Committee operated as the provisional board of the 'Organisation for Pure Scientific Research in the course of formation'.

As Schermerhorn was a former professor of geodesy at Delft, it is tempting to draw the conclusion that his preoccupation with science was due to the fact that he was a scientist himself. But that seems to be only a minor part of the explanation. The view that science had to be a key factor in post-war politics was widespread at the time. In the USA for example, Vannevar Bush—the director of the Office of Scientific Research and Development—had just written his famous report for the president *Science: The Endless Frontier*. This report would ultimately serve as the basis for the creation of the American National Science Foundation (NSF) in 1950.

In this report, Bush argued for a national science policy and extensive support of science from public funds (Bush, 1945). He laid the emphasis on 'pure' or 'basic' research as this would ultimately lead to useful practical applications. According to Bush, scientific progress had proven to be extremely valuable during the Second World War. For example, medical applications—based on former basic research—had reduced the death rate in the Army. Many of the leaders in the development of radar had been doing basic research in physics (for example exploring the nucleus of the atom) before the war. Radar had played a vital role in defeating the Germans and driving back the Japanese (Bush, 1945). Understandably, Bush did not say a word about the secret Manhattan project, conducted to develop the first atomic bomb, because the report dated from 25 July, 2 weeks before the Americans dropped their atomic bombs on Hiroshima and Nagasaki, respectively on 6 and 9 August. Bush's reasoning was the following:

> Basic research leads to new knowledge. It provides scientific capital. It creates the fund from which the practical applications of knowledge must be drawn. New products and new processes do not appear full-grown. They are founded on new principles and new conceptions, which in turn are painstakingly developed by research in the purest realms of science. (Bush, 1945)

The 'Bush report' was well-known in Europe as well. Van Helvoort claims 'it became the starting point for government sponsorship of scientific research in many European countries, including Germany, the Netherlands and Belgium' (Van Helvoort, 2003, p. 3). However, to consider this report as a 'starting point' for government sponsorship of science may be a little exaggerated. In Belgium and in most other European countries, for example, government sponsorship of science had come into existence during the interwar period. Moreover, in these countries, after the Second World War, the emphasis had shifted from 'pure science that leads to applications' to 'applications' itself (see also Chapter III). And in the Netherlands, the content of the Bush report corresponded with a conception of the role of science that was already prevalent. At the meeting of 13 September 1945, Schermerhorn already explicitly stated that pure scientific research should be stimulated. Hence, instead of being the starting point of Dutch science policy, the Bush report must rather be seen an authoritative expression of the conception of the role of science that existed also in the Netherlands.

The report became known in the Netherlands, because Prime Minister Schermerhorn had sent his friend F. A. Vening Meinesz—head of the KNMI (Royal Dutch Meteorological Institute) and professor of geodesy at Utrecht and Delft—to the USA to find out how support for scientific research was organised over there. Before the Second World War, financial support of scientific research in the USA was largely in private hands and was not considered a federal responsibility. Therefore, the report of Vening Meinesz's visit, presented in December 1945, mainly contained an analysis of the structure of private funding organisations: the Carnegie Institution of Washington (founded in 1902) and the Rockefeller Foundation (founded in 1913). In addition, he also presented an analysis of the recent report of Vannevar Bush (Kersten, 1996, p. 11).

The aforementioned Reinink committee—the founding committee of ZWO—read the report of Vening Meinesz and in turn referred to the Bush report, when presenting its first report:

> In his Report to the president on a program for Postwar Scientific Research, entitled: 'Science the endless frontier,' V. Bush, director of the Office of Scientific Research and Development in the USA, writes: 'In the nineteenth century, Yankee mechanical ingenuity, building largely upon the basic discoveries of European scientists, could greatly advance the technical arts. Now the situation is different. A nation which depends upon others for its new basic scientific knowledge will be slow in its industrial progress and weak in its competitive position in world trade, regardless of its mechanical skill.' Indeed, America took on a leading position only after it had boosted its basic research (…) (Reinink, 1950, p. 8)

The benefits were proven by the example of Philips, according to the Reinink Committee: 'At Philips Companies in Eindhoven (…) in fields in which basic research has been done, it has been possible to get to the forefront with relatively few people, and to occupy a leading position in the world.' [61] (Reinink, 1950, p. 8)

Concerns about the relevance of science for the national economy were not entirely new after the Second World War. Although the Netherlands had remained neutral in the First World War, the country was plagued by shortages in the late 1910s. The idea then prevailed that science had to

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[61] 'In de Philips fabrieken te Eindhoven (…) in de gebieden waarin fundamenteel onderzoek verricht is, is het gelukt met weinig menschen vooraan te komen en een wereldpositie te veroveren.'

come to the rescue. In 1917, the Royal Netherlands Academy of Arts And Sciences (KNAW) asked the Dutch government:

> Is it not urgently needed, with all the power of science and experience the Netherlands has, to look for means and ways to get as much use out of the few available resources and means of production?[62] (Quoted in Lintsen et al., 2012, p. 20)

The Dutch government listened to this request. Its actions would lead to the establishment of the Organisation for Applied Research TNO in 1932 (Kersten, 1996, p. 6). However, TNO differed fundamentally from ZWO: it remained an independent institution (no government institution) and its focus was on applied research.[63]

1.10.1 BETWEEN PURE SCIENCE AND APPLICATIONS

As mentioned above, from the very start the ultimate goal of pure science in the post-war Netherlands was *applications*. But it was never made explicit how application-directed this pure science should be. Different parties involved in the founding of ZWO held different opinions about this question.

On 22 November 1947, for example, a conference took place on the organisation of basic research in the Netherlands. The provisional board of ZWO and several scientists were present. The conference was organised by the Association of Scientific Researchers or VWO ('Verbond voor Wetenschappelijke Onderzoekers'). VWO was an association of socially engaged scientists, founded immediately after the Second World War (Molenaar, 1994). The president of VWO was none other than Marcel Minnaert. In his introductory talk at the conference, Minnaert endorsed the plans for the foundation of ZWO: '(…) it is of crucial importance that the government prepares an organisation to stimulate pure scientific research. All scientific workers in the Netherlands appreciate this greatly'[64] (VWO, 1948, p. 1). Although VWO was clearly in favour of government support for pure science, the association strongly opposed science that was undertaken exclusively 'for its own sake.' As it stated in its mission statement: 'It is out of the question that the scientific researcher can or may always explore what he feels like (…)' [65] (VWO, 1947, p. 7). VWO recognised that completely free, unbridled research had yielded interesting results in the past, but to think that this kind of research was still possible at the current period of time, was in its eyes an 'anachronistic naivety' (VWO,1947, p. 7).

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[62] 'Is het niet dringend nodig, om met alle kracht van wetenschap en ervaring waarover Nederland beschikt, te doen zoeken naar middelen en wegen om uit de weinige beschikbare grondstoffen en productiemiddelen een zo groot mogelijk nu te trekken?'

[63] To read more on the history of TNO, see: Lintsen, 2012.

[64] '(…) is het van de grootste betekenis, dat de Regering een organisatie voorbereidt om het zuiver wetenschappelijk werk energiek te bevorderen. Alle wetenschappelijke werkers in Nederland stellen dit op hoge prijs.'

[65] 'Er is geen sprake van, dat de wetenschappelijke onderzoeker altijd kan of mag exploreeren waartoe de lust (…) hem drijft.'

This view of VWO was in sharp contrast with the view of the Minister of Education Van der Leeuw, who stressed that applied research was impossible without 'the entirely free pure research, which takes off and doesn't know where it is going to take us'[66] (Van der Leeuw, 1947, p. 120).

Although the main goal of the Dutch government to stimulate science was to help the rebuilding of the country, it seems that the early ZWO had no clear vision on the question as to what promises of applicability a pure science project had to hold in order to justify funding. In fact, a lack of well-articulated visions and plans was a characteristic of the general policy of ZWO, especially during the founding period (1947–1950). In these days, the government just followed the initiatives from the scientists themselves (Kersten, 1996, p. 19). Indeed, it was a conscious policy not to have a well-articulated vision. As it says in the annual report of 1950: 'In the founding period, ZWO has worked mainly "passively": people waited for initiatives to be taken by others, whereupon they examined which of these were to be selected for support'[67] (Annual report ZWO, 1950, p. 17). Moreover, ZWO was not inclined to change this attitude. Indeed, a more active approach that would focus on promoting unexplored fields was considered to involve the risk of a lack of capable, interested and experienced researchers. (Annual report ZWO, 1950, p. 18). This was of course a smart strategy: if one of the new initiatives would prove to be very successful, ZWO could easily claim the success.

This vagueness concerning possible applications of scientific projects was also an opportunity for scientists of course. As will be shown, funding could be obtained rather easily, especially if a project offered some vague promises of applications.

Of course, the astronomers were well aware of the fact the Dutch government had a special interest in possible applications of their research. Therefore, Oort was very happy to have Philips amongst his partners. When companies such as Philips showed an interest in his research, he could at least *pretend* it had potential spin-offs. Therefore, in the beginning of 1946 he wrote a letter to a member of Philips NatLab in which he said: 'It would certainly stimulate the execution of the plans if Philips Companies would show their active interest in this project (…)'[68] And when in 1948, Oort had written a memorandum for ZWO to acquire funding for radio astronomical research, Minnaert explicitly advised him to add a reference to the potential applications in telecommunication:

> In fact, it is a pity that it says nothing about the practical meaning of the research for the radio service: knowledge of the ionosphere and the disturbances in it; probably the possibility to predict these disturbances. I certainly believe that this consideration would be an argument to give us a grant. Maybe you should add a paragraph to the memorandum on a third page.[69]

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[66] 'het volkomen vrije fundamentele onderzoek, dat uitgaat, niet wetende waar het komen zal.'

[67] 'In de oprichtingsperiode is Z.W.O. hoofdzakelijk "passief" te werk gegaan: afgewacht werd welke initiatieven door anderen werden genomen, waarna werd onderzocht welke daarvan voor steun in aanmerking dienden te komen.'

[68] 'Het zou de uitvoering der plannen zeker bevorderen als de Philips Fabrieken (…) blijk zouden geven van hun actieve belangstelling in deze onderneming.' Oort to Balthasar Van der Pol, 28 January 1946, OA, 251.

[69] 'Eigenlijk is het jammer dat er niets staat over de praktische betekenis van het onderzoek voor de radio-dienst: kennis der ionosfeer en der daarin optredende storingen; wellicht de mogelijkheid, die storingen te voorspellen. Ik geloof zeker dat deze beschouwing een argument zou zijn om ons een toelage te bezorgen.

However, the question remains whether industry was *really* interested in this radio astronomical research. In the case of the PTT, this interest cannot be doubted. In the case of Philips, on the other hand, the situation was different. Although a few individuals of the NatLab of Philips had a personal fascination for the radio astronomical work, the company as a whole was rather indifferent.[70]

Moreover, the astronomers themselves soon realised that their radio astronomical research would yield no spin-offs at all. In their grant applications to acquire funding for the telescope with the 25-m dish – which was approved in 1951, as will be shown in the next chapter – they always stressed spin-offs in telecommunication. Nevertheless, already in 1949 Minnaert realised that a dish of 25 m was useful for *Galactic* research, but it was redundant for *solar* research, and it was only the latter that could yield these spin-offs. With regard to getting a grant, this was of course a rather upsetting conclusion. Minnaert wrote to Oort:

> We must have been mistaken at some point. (…) A mirror of 7.5 metres is as good for the observation of non-localised solar phenomena as a mirror of 25 metres. That means that an important point in our program becomes obsolete.[71]

Fortunately for them, however, Oort and Minnaert never mentioned this new 'insight' in their grant proposals: they kept on stressing that their project would have important spin-offs in telecommunication, although they knew it would not. So in a certain way, they fooled their funders.

In hindsight, Minnaert's prediction that the telescope with the dish of 25 metres was redundant for solar research was correct: almost no solar research was done with this telescope. Only in the 1970s was some solar research done with a 60-channel spectrograph (Strom and Van Woerden, 2007, p. 385).

Het zou denkbaar zijn, aan het memorandum een paragraaf toe te voegen op een 3e blad.' Minnaert to Oort, 29 March 1948, OA, 162b.

[70] It was difficult to gather more information on this topic. Our point of view, however, is sustained by the fact that in the Oort Archives the correspondence with Philips is limited to correspondence with individuals of Philips NatLab, who did not act as representatives of the company in these matters. Moreover, some personal accounts of people involved in early radio astronomy confirm our story. Alexander Ollongren - emeritus professor of computer science and guest professor of astronomy at Leiden University - remembers this very well. Ollongren has cooperated for a while with Ben G. Hooghoudt, an engineer of Delft who has been involved in Dutch radio astronomy from the very beginnings. Hooghoudt was an important advisor of Oort and the telescope with the mirror of 25 metres was constructed under his supervision (see also the next chapters). Ollongren - who performed some strength calculations for Hooghoudt - recalls that Hooghoudt regularly complained about the passive attitude of Philips. (Personal communication of Alexander Ollongren to the author, 12 May 2011). Klaas Wildeman – former project manager at the Netherlands Institute for Space Research SRON – says that this lack of interest from Philips is not surprising. Indeed, to expect the opposite would be very unrealistic. Philips – which was also involved in space research - was especially interested in products that could be manufactured on a large scale or that could yield knowledge that Philips could apply in other fields. It was clear from the very beginnings that radio astronomy offered neither. (Personal communication of Klaas Wildeman to the author, 11 October 2011).

[71] Minnaert to Oort, 12 September 1949, OA, 162b.

1.11 A SMALL NETWORK WITH A BIG IMPACT

From 1948 onwards, the astronomers received a subsidy from the provisional ZWO for its radio astronomical research with the small telescope in Kootwijk. For the year 1948, they received Dfl 13 650. With 62 applicants for that year and a total ZWO-budget of Dfl 804 144, this was a nice sum of money, but nothing exceptional. At the same time, taking into account that radio astronomy was still a new and uncertain field this sum was very easily obtained. As already mentioned before, because of the interest of companies such as Philips and the PTT in radio astronomy, predictions could be made about spin-offs. In an age in which the applications of 'pure science' were highly esteemed, this furthered the astronomers' case.

But there was more. The reason that funding was easily obtained was not only due to a clever rhetoric in the grant proposals. The astronomers greatly benefited from the fact that astronomy was still a very small-scale undertaking. In the Netherlands, there were only a dozen tenured positions for astronomers in the 1930s (Baneke, 2010, p. 184). During the first post-war years, this hardly changed. Similarly, ZWO was still in an embryonic stage and hence it was a very small organisation.

The fact that so few people were involved also meant that the impact of a personal network could be enormous. Indeed, Minnaert and - to a lesser extent - Oort had established a network of influential people from industry, politics, government and science. Although radio astronomy was mainly Oort's project, it was especially Minnaert's network that Oort used to further his own case. As we saw, Oort's network was mainly confined to some individuals of Philips NatLab. Minnaert, on the other hand, had joined forces with the PTT and the KNMI, but his network also involved some influential politicians. One of Minnaert's students who contributed to the research into the solar spectrum, for example, was J. H. Bannier. In 1936 Minnaert had published an article with Bannier in the *Zeitschrift für Astrophysik* (Minnaert and Bannier, 1936). After the war, Bannier worked at the department of Higher Education and Sciences for several years before he became the first director of ZWO. In this position, he was capable of seriously furthering the case of radio astronomy. As early as September 1949, he attended the meetings of the radio astronomers and discussed the possibilities for funding.[72]

Another acquaintance of Minnaert was none other than the Dutch post-war Prime Minister Willem Schermerhorn, whom he had met in Sint-Michielsgestel. There was a lot of intellectual activity in the camp. So-called 'circles' were organised. These were groups of politicians, industrialists and officials who discussed how the post-war Netherlands should be organised. As a matter of fact, the Dutch post-war Schermerhorn cabinet was prepared in these circles in Sint-Michielsgestel (Molenaar, 1994, p. 283).[73] Minnaert cooperated too: he was a member of the circle on educational policy and of the art circle'. We do not have any details about contacts between Minnaert and Schermerhorn in Sint-Michielsgestel. But as Minnaert was there from May 1942 until April 1944 and Schermerhorn from May 1942 until December 1943, they certainly must have met.

[72] Minutes of the board meeting of SRZM of 20 September 1949, SA.

[73] The role of the discussions of Sint-Michielsgestel on post-war politics has never been doubted: see for example the dissertation of Ruitenbeek (1955). In this dissertation, Ruitenbeek emphasises the role of the discussions in Sint-Michielsgestel in the founding of the Dutch Labour Party (PVDA) in 1946.

When we take a closer look at the funding procedure, we see that the people who had to judge the project were very often acquaintances of the astronomers. Moreover, some people were judge and party at the same time. The science committee of ZWO, which had to advise on astronomical projects, consisted of 11 members, 2 of whom were at the same time members of the board of SRZM (the national foundation for radio astronomy)[74] namely Minnaert and Rinia. As was to be expected, this science committee gave a positive advice to the board of ZWO. This board, which consisted of 17 members, in turn gave a positive advice to the Minister of Education, Arts and Sciences. This was also not so surprising, considering that the head of the KNMI (and personal friend of Prime Minister Schermerhorn) – F.A. Vening Meinesz - was at the same time a member of this board and a member of the board of SRZM. And Bannier—the director of ZWO and former student of Minnaert—was the secretary of the board. What is even more important is that Bannier combined his function at ZWO for about half a year with the function of deputy director at the Department of Higher Education and Sciences at the Ministry of Education. So he was working for the Minister of Education, Arts and Sciences J. Gielen, who had to give the final approval. (In most cases, the minister followed the advice of the board.)

1.12 THE RESEARCH PROGRAMME: GALACTIC VERSUS SOLAR RESEARCH

It is difficult to determine how, and even more to what extent the background of the first radio astronomers influenced their research questions. There are many other factors that may influence which questions are asked. Funding systems for example, can have non-negligible effects, as we will see in Chapter II. Nevertheless, to some extent we can still discern the effects of the researcher's background. In general, it is striking that the vast majority of radio astronomical research during or immediately after the war was radio astronomy of the *Sun*. As radar workers were often confronted with interference by radio radiation from the Sun in the metre-wave range, it was obvious that the first radio astronomical measurements were mostly solar measurements in this wave range. Nations such as Canada, Japan, France, and the Soviet Union initially focused almost exclusively on solar radio astronomy (Orchiston and Mathewson, 2009, pp. 28-29).

In Britain, Hey deduced in 1942 that the apparent jamming of British coastal radar installations was in fact interference by radio radiation from the Sun (see above). It is not surprising that his very first radio astronomical research concentrated on the nature of these solar emissions. At Cambridge too, the Cavendish Laboratory group initially concentrated on solar observations. Jodrell Bank on the other hand, specialised in the radar study of meteors and the ionosphere. Although this was not solar research, it was a continuation of the work Lovell and others had been doing during the war, as we saw. Moreover, it was still astronomical research 'close by'.

The Dutch group was one of the few groups to look *beyond* the ionosphere, in focusing on Galactic radio astronomical research. This focus was clearly shaped by pre-war astronomical research. In fact, it was a continuation of that research by means of a new technology. As mentioned above, until the 1960s Dutch astronomy was strongly influenced by the work of Kapteyn. He was especially concerned with the 'sidereal problem': the study of the locations and motions of the

[74] SRZM or 'Stichting Radiostraling van Zon en Melkweg' was formally established on 23 April 1949, but informally already active in the autumn of 1948 (see next chapter).

stars. This was one of the main astronomical questions of the time (also Kapteyn's contemporary, the German astronomer Hugo von Seeliger was working on it). By the end of his life, he had constructed the 'Kapteyn Universe', a model in which our Milky Way was relatively small and the Sun was located at or near the Galaxy's centre. This model proved to be completely wrong, but unravelling the structure of the Galaxy became the main goal of Dutch astronomy. The fact that this tradition, initiated by Kapteyn, was continued, is mainly due to Kapteyn's student – and later supervisor of Oort - Van Rhijn. In 1904 Kapteyn inaugurated a systematic sampling method that made it possible to obtain representative data in a fraction of the time that a complete star by star investigation of the Galaxy would involve. The whole sky, north and south, and also faint distant stars had to be included. This project was called the 'Plan of Selected Areas' (Lynds, 1963, p. 89). International cooperation was required for such a project. It was Van Rhijn's life work to coordinate this project and to involve observatories all over the world.

When radio astronomy originated, unravelling the structure of the Galaxy was still the main goal of Dutch astronomy, as Sullivan pointed out:

> Despite the wholly new technology compared to Kapteyn's day, there was no discontinuity in either research style or content – the radio astronomical problems too were tackled in a very Kapteynian manner. (Sullivan, 2000, p. 229)

Oort himself saw radio astronomy explicitly as the continuation of a program about 150 years old. It was a 'third phase' in the development of the quantitative investigations of the Galactic System, that had been started by the German-born British astronomer W. Herschel (1738 - 1822). A first development came from Kapteyn. Consistently pursuing the ideal of revealing the general structure of the entire stellar system, Kapteyn had initiated essentially all the methods that were used around 1950. A second great development began around 1914 by the American astronomer H. Shapley (1885 – 1972), when he started to study the distribution of globular clusters (dense spherical collections of stars). From the spatial distribution of these clusters, he inferred the true dimensions of the Galaxy and the position of its centre. About radio astronomy, Oort said the following:

> It seems that at present a third phase in the development of galactic research has begun by successful reception of radiation at radio frequencies. This research is still in its early infancy, comparable perhaps to the stage that Sir William Herschel had reached some hundred and fifty years ago by his star gauges in the visible radiation. What has been reached in the few years since active radio-astronomical research was started can hardly be expected to give more than the faintest glimpse of the changes of insight that the next years are likely to bring about. (Oort, 1952, p. 233)

1.13 ORGANISATIONAL ASPECTS: BIG SCIENCE – LITTLE SCIENCE

As is often pointed out in historiography, the Second World War thoroughly shaped post-war science. Historian of science Peter Galison made clear that in the USA, the consequences of the war for science were manifold: as far as research funding was concerned, the war configured the relations between the academic, governmental, and corporate worlds; university research became increasingly tied to military affairs; the relations between physicists, engineers, and technicians changed thoroughly (The three groups had to learn to work intensely together. So-called 'trading zones'[75] marked their contact sites.); there was a continuity between wartime weapons development work and post-war research, reaching back before the war to points of common peacetime research (which Galison calls 'continuity of technique, discontinuity of results'); and last but not least, the 'work organisation' thoroughly changed: pre-war, mainly individual research had changed into large-scale research with a complex organisation, specialisation and expensive equipment (Galison, 1997, pp. 239-311).

Outside the USA too the influence of the Second World War on science was non-negligible. The foundation of the national funding organisation ZWO in the Netherlands, which was to a large extent motivated by the post-war aim of the rebuilding of the country, has already been discussed. It has also been made clear that the research questions in early radio astronomy were shaped worldwide by wartime experiences. Now it is worthwhile to dwell on the organisation of early radio astronomy. In the USA, following their wartime experiences, physicists saw the organisation of their work as being completely different from its prewar shape. As Galison said: '(...) it is about the link between physicists' wartime experiences in radar and atomic bomb projects and the new picture they formed of how research would proceed – the picture of a collaborative, factory-scale effort that would displace the ideal of individual and small-group work.' (Galison, 1997, pp. 34-35) Indeed, academic research before the war was mainly individual research, pursued sometimes together with one or two colleagues (Fawcett, 1994, p. 34). We might call this working in small teams without a clear labour division 'Little Science'. During – and because of - the war, however, substantial changes had occurred in science: we had entered the era of 'Big Science'. Historian of science Steven Shapin associates the following characteristics with Big Science: a contract system binding academic research to the Federal Government, industrial sponsorship of science, the scale and expense of scientific instruments, the specialisation of scientific knowledge, the division of labour and so on (Shapin, 2008, pp. 166-167). Historian of science R.W. Smith, however, stresses that we should not focus exclusively on big technologies and on the number of researchers, but we have to take into account the differences in social organisation in the first place: the war had taught scientists to work together in groups, it had shown that progress was made by unified action (Smith et al., 1993, p. 21).

Radio astronomy is a prime example of a branch of science that was shaped through the war, as it owes its very existence to a large extent to the war. So the question is how and to what extent these new ways of organising science became visible in radio astronomy. One might expect that at least in countries where engineers and physicists with a background in war industry took the lead (not in the Netherlands), radio astronomy – like the war industry – was Big Science. This would be consistent with what Smith argues: radio astronomy was the first branch of astronomy to become 'Big', because the field was largely founded by engineers and physicists, who had been used to Big Science ways of working during the war and who, at least initially, employed apparatus the development of which owed much to the war (Smith, 1992, p. 185).

However, we doubt whether that is entirely true.

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[75] A 'trading zone' is an intermediate domain in which procedures would be coordinated locally even where broader meanings clashed (Galison, 1997, p. 46).

Let us take the example of Britain. Britain had an extensive war industry. As mentioned above, successful radio astronomy groups were established by the physicists Ryle and Lovell, who had been working at the Telecommunications Research Establishment (TRE). TRE's history dates back to the middle of the 1930s. It has its origin in radar research. The majority of the staff at TRE were research scientists, who had to make the adjustment to development and applications. The Big Science way of working at TRE was in sharp contrast with the way of working many staff members had previously experienced at the universities. TRE grew significantly during the war. In 1942, the staffing level was about 2000 people. By 1945, the increased electronics production had brought this number to about 3500. At that time, it was the largest research establishment in Britain. Research was performed around an extensive range of topics: radar, radio navigation, radio jamming, the development of cathode ray tubes, flight simulators and so on.

As far as radio astronomy was concerned, however, it is noteworthy that TRE staff members Ryle and Lovell did *not* establish their radio groups within the context of TRE. On the contrary, they went back to their universities: Ryle to Cambridge and Lovell to Manchester (Jodrell Bank). The way they organised their radio astronomical research at the universities was by no means comparable to the Big Science way of working at TRE. By the middle of 1946, Lovell had been joined by two of his wartime colleagues. Although the group at Jodrell Bank grew fairly quickly in size (8 researchers by the end of 1946, 21 by the end of 1951 (Edge and Mulkay, 1976, p. 16)) and research output, this undertaking can hardly be called Big Science during the first decade. There was very little technical advance: they just used the wartime apparatus for astronomy, without developing the technology further. Moreover, Lovell's university salary ran at half his TRE wages (Buderi, 1996, p. 278).

Like Lovell, Martin Ryle also returned to his old university. Before the war, Ryle had been doing ionospheric research at the Cavendish Laboratory. In 1945, he rejoined the Cavendish Laboratory and started investigating radio waves from the Sun with a small research group. The Cambridge group grew more slowly than the one at Jodrell Bank. (It counted 4 people in 1946, 9 in 1951 (Edge and Mulkay, 1976, p. 24).)

So contrary to what one might expect, the first British radio groups were small groups working with modest resources and using adapted war equipment. Hence, their organisation resembled Little Science – or at best 'Middle' Science - rather than Big Science. The American author Robert Buderi described them aptly: 'Most of the radio astronomers were young men working in small teams and doing all the dirty repair jobs themselves.' (Buderi, 1996, p. 288)

Unlike their foreign colleagues, Dutch radio astronomers had never left their universities to work in the war industry. Therefore, it is not surprising that the organisation of early post-war radio astronomical research in the Netherlands hardly differed from the organisation of their astronomical research in the previous period. First of all, the whole undertaking remained very small: in 1951, only six people were involved in radio astronomy. There was no outspoken labour division and the first radio telescope in Kootwijk was made out of adapted war equipment.

Hence, we come to the rather surprising conclusion that the organisation of early radio astronomy *nowhere* resembled the organisation of the research that took place in the war laboratories: not in the Netherlands – which was obvious, as research there was undertaken by university scientists

– but also not elsewhere, were the first radio astronomers were engineers and physicists with a background in war industry.

1.14 RADIO ASTRONOMERS VERSUS OPTICAL ASTRONOMERS

Last but not least, the fact that in the Netherlands radio astronomers and optical astronomers were the very same persons caused radio astronomy immediately to be recognised as a full-fledged branch of astronomy. In other countries, the first radio astronomers were not trained in astronomy and hence they lacked the interpretative skills optical astronomers had. Indeed, the first radio workers were astronomical novices who were frequently blundering in their astronomy. Therefore, they were not taken too seriously by the astronomical community. The Canadian astronomer Williamson recognised this already in 1948:

> (…) the radio engineer, well-versed in this [technical] side of the problem and perhaps possessed of the equipment for taking observations, may well find himself at loss to know best how to use it to obtain astrophysical data. (Williamson, 1948, pp. 13-14)

It was mostly this lack of astronomical insight that was responsible for the indifferent or even hostile attitude of the great majority of astronomers towards the new field. An example of this hostile attitude, is the opinion of (optical) astronomer D. Popper of Lovell's new chair of astronomy at the University of Manchester (1951), expressed in a book review of Lovell and Clegg's *Radio Astronomy* of 1952:

> The senior author is Professor of Radio Astronomy (!)(…) An astronomer will naturally be particularly alert to catch errors committed by these interlopers into his domain. (Popper, 1952, p. 210)

Not until around the early 1950s did the gap between the optical astronomers and the radio astronomers narrow. Crucial in this respect was the optical identification of radio sources. The first people to propose optical identifications of radio sources were Bolton, Stanley and Slee in Australia in 1949 (Sciama, 1975, p. 54). In an article in *Nature*, they identified the radio source Taurus A with the Crab nebula, Virgo A with the galaxy NGC 4486 and Centaurus A with the galaxy NGC 5128 (Bolton, Stanley and Slee, 1949). Optical identifications were very important from an astronomical point of view – they could provide information on temperature, density, chemical composition etc. – but more important for our research is that they lent 'a sense of reality and reliability to the very existence of radio sources' (Sullivan, 2009, p. 349).

In the Netherlands, this problem was non-existent of course. As radio astronomers and optical astronomers were the very same persons there, there was no 'gap' between the two communities that needed to be bridged. There was no need to wait for optical identifications before radio astronomy was taken seriously. In other countries, the gap between the two communities sometimes seriously slowed down the take-off of radio astronomy. This was especially the case in the United States, as we will see in Chapter III.

1.15 CONCLUSION

During the interwar period, the Netherlands – and especially Leiden Observatory – became an international centre of astronomy. The rising star in Leiden was the astronomer Jan Hendrik Oort, who had been a student of the Groningen astronomer Kapteyn. Under the influence of Kapteyn, research into the structure of the Galaxy had become one of Oort's life-long interests. However, it had become clear that the largest part of the Milky Way was inaccessible to observations at optical wavelengths because of the extinction of the light by interstellar dust. Astronomers had already resigned themselves to the fact that they would only have indirect knowledge about a large part of the Milky Way. All this changed, however, with the emergence of radio astronomy.

The history of radio astronomy can be traced back to the first half of the nineteenth century, but we have to wait until the 1930s when the first radio waves from space were detected by Karl Jansky. Ten years later, in the early 1940s, Grote Reber made his analogous detection known to the community of professional astronomers through the publication of an article in the *Astrophysical Journal.* Although Reber is considered to be one of the 'founding fathers' of radio astronomy, in most countries it was not Reber's article that initiated radio astronomy. The Dutch group was anomalous in this period. There, Oort's reading of Reber's article was a decisive moment in the history of radio astronomy. In the other countries, however, far more important than Reber's work were wartime developments in military radio and radar electronics. As we saw, immediately after the war, several radio astronomy groups were formed, among which five stand out: three in England, one in Australia and one in the Netherlands. All these groups – except the Dutch group – had their origins in wartime radar research. Indeed, technologies of radar installations and radio telescopes were closely linked. During the war, the radar workers – mostly engineers and physicists – were often confronted with interference, in the first place coming from radio radiation from the Sun. Some of them wanted to explore this radio interference further and hence, the first 'radio astronomers' were engineers and physicists with a background in wartime radar research. In the Netherlands, this was not the case. Although the Netherlands were vital in radar development – with important centres such as Philips and LFO – not a single radar researcher took the initiative to investigate radio waves further. We think this is probably due to the fact that Oort already laid a firm claim on radio astronomy in the first years of the Second World War. As early as 1941, he contacted people from Philips with whom he wanted to cooperate in *his* project. So from the very beginnings, Oort held the reins firmly and therefore his partners – who had nevertheless a clear interest in the topic - in a certain way never got the chance to take any initiative in this respect.

The reason why Oort needed industrial partners such as Philips was that as an optical astronomer without a technical background, he did not have a clue about how he should build a radio telescope. In the end, however, these contacts would offer much more than merely technical know-how. Indeed, in the context of post-war politics - in which science came to be seen as the key-factor in the rebuilding of the country – it was a great advantage for scientists to have industrial companies as their partners. The Dutch government heavily supported pure science, as it was believed that this pure science would yield the necessary applications to stimulate the economy. And if scientists could show that the industry had an interest in their research, this was in a way a 'proof' that the project would yield applications. So the initial disadvantage Dutch optical astronomers had - their lack of engineering know-how – turned out to be an advantage, in the context of post-war science policy. Therefore, Oort did not let an opportunity pass to emphasise that Philips had a great interest in his plans, as he thought this would stimulate their execution. However, although a few members of Philips NatLab had a personal fascination for radio-astronomical work, the company as a whole was rather indifferent.

Besides these relations with NatLab, the Dutch astronomers also had good relations with the Dutch Post, Telegraph and Telephone Service (PTT). These contacts with the PTT had earlier been established by Marcel Minnaert. For years, there had been a cooperation between Utrecht Observatory, the Royal Dutch Meteorological Institute (KNMI) and the PTT, as these three institutions were involved in solar research. In March 1946 Minnaert and Houtgast (his assistant) had effectively joined forces with the PTT and the KNMI to study the ionosphere and its connection with radio wave propagation and solar activity. Just like the contacts with Philips 'proved' that possible industrial applications of the radio astronomical research were to be expected, the relations with the PTT 'proved' that the project would yield possible spin-offs in telecommunication. However, unlike Philips, the PTT was truly interested in radio astronomical research. Thanks to the PTT, the radio astronomers had their first radio telescope in Kootwijk.

The rhetoric of the possible spin-offs facilitated funding of radio astronomical research. ZWO-funding had been received since 1948, when a sum of Dfl 13 650 was provided. This was intended for research to investigate the necessity of building a large and expensive radio telescope with a dish of 25 m. Funding for this large telescope was approved in 1951 (see next chapter). In their grant applications, the astronomers always stressed spin-offs in telecommunication. Nevertheless, already in 1949 Minnaert had realised that a dish of 25 m was only useful for *Galactic* research, but it was not needed for *solar* research, and it was only the latter that could yield these spin-offs. With regard to getting a grant, this was of course a rather upsetting conclusion. Fortunately for them, however, Oort and Minnaert never mentioned this new 'insight' in their grant proposals: they kept on stressing their project would have important spin-offs in telecommunication, although they knew it would not. So in a certain way, they fooled their funders.

Funding was not only easily obtained because of the smart rhetoric of possible spin-offs, but also because astronomy was still a very small-scale undertaking in the early post-war period. Even so, ZWO was still in an embryonic stage and hence it was a very small organisation. The fact that so few people were involved meant that the impact of a personal network could be enormous. Although Oort finally came to dominate radio astronomy, it was in the first place Minnaert's network that could be used to further the case of radio astronomy. Oort's network was in the first place confined to people from Philips NatLab, while Minnaert had established fruitful relations with influential politicians (for example the prime minister), with the PTT, with the KNMI and with Bannier, the later director of ZWO. When we take a closer look at the funding procedure, we see that the people who had to judge the project were very often acquaintances of the astronomers. Moreover, some people were judge and party at the same time.

The fact that in the Netherlands the initiative for radio astronomy was taken by optical astronomers also had an influence on the research questions. Worldwide, the vast majority of radio astronomical research during or immediately after the war was radio astronomy of the *Sun*. That was because during the war radar workers had often been confronted with interference by radio radiation from the Sun in the metre-wave range. So it was obvious that the first radio astronomical measurements were mostly solar measurements in this wave range. The Netherlands in turn, focused on Galactic radio astronomical research. This focus was clearly shaped by pre-war astronomical research. It was just a continuation of that research by means of a new technology.

Thus, Dutch astronomers did not have a background in war industry, and hence their research questions were not shaped by it. Just like their research programme was a continuation of pre-war astronomical research, the organisation of their research was also a continuation of pre-war research. That meant: small-scale research that made use of wartime surplus material. Although this might not be surprising, what *is* surprising, is that the organisation of early radio astronomy *nowhere* resembled the organisation of the research that took place in the war laboratories: not in the Netherlands, but also not elsewhere were the first radio astronomers were engineers and physicists with a background in war industry. Everywhere, radio astronomers were working in small teams with wartime surplus material.

Last but not least, the fact that in the Netherlands radio astronomy was initiated by optical astronomers, meant that there was no ‘gap’ that needed to be bridged between the communities of optical and radio astronomers. Indeed, radio astronomers and optical astronomers were the same persons. In other countries, on the other hand, as radio astronomers were astronomical novices that frequently made astronomical blunders, they were not taken too seriously by the community of optical astronomers. There it was necessary to wait for the first optical identifications around 1950 before radio astronomy began to be taken seriously.

CHAPTER II: THE LONG WAY TO DWINGELOO

From the very first days of Dutch radio astronomy, the idea arose to build a large radio telescope with a dish of 25 m. In this chapter, we explain how this idea became reality after several years. Questions we will address are: how did the Dutch radio astronomers finally convince ZWO that funding this expensive telescope was worth the effort? How did they come to choose Dwingeloo as the most suitable location? Did they try to 'sell' their telescope project to a broader public and if so, how did they do that?

Furthermore, we put the Dutch community of radio astronomers in an international perspective. Was cooperation or competition - or maybe both – the dominant feature of the relations between the different radio astronomical groups?

Not only did the community of early radio astronomers cross national boundaries, it also crossed disciplinary boundaries. Not only (radio) astronomers, but also radio technicians and especially engineers made vital contributions to the field. Hence, the question we must address is: what was the perception – both at the time and in historiography – of the role of the engineer?

Last but not least, we place early Dutch radio astronomy in a Cold War perspective. The general picture of the USA as the world leader in matters of science during the early Cold War is still maintained. As we will see, Dutch radio astronomy offers us the possibility to moderate this picture.

The very first thing that needed to be done before any other substantial action could be undertaken, however, was uniting all the Dutch radio astronomers in one foundation to enable an efficient coordination of the research. So let us first take a look at the creation of the National Foundation for Radio Astronomy.

2.1 A NATIONAL FOUNDATION FOR RADIO ASTRONOMY

As early as 1945, the idea to create a national institute for radio astronomy was launched. That this idea did not come from an astronomer, but from Bakker from Philips NatLab, has remained unnoticed until now:

> A few days ago, I [Bakker] got a report of Dr. Houtgast, in which the foundation of an 'Institute for Sun and Ionosphere' is proposed. It is also worth considering the foundation of a national institute for radio research in the ionosphere and the 'cosmic noise'.[1]

However, it took until shortly after the observations with the Kootwijk telescope had started before the astronomers really felt the need for an efficient organisation and coordination of their research. Then, Oort and Minnaert judged it the right moment to create the National Foundation for Radio Astronomy ('Stichting Radiostraling van Zon en Melkweg' or SRZM)[2]. It was formally established on 23 April 1949, but had been informally active since the autumn of 1948. In article

[1] Bakker to Oort, 5 October 1945, University Library Leiden, OA, 251.
[2] Sometimes, the English acronym 'NFRA' is used instead of 'SRZM', but SRZM is much more common.

2 of the founding charter we read that the aim of the foundation was 'the promotion and the execution of research into short-wave radiation from outer space. Its activities are exclusively in the scientific domain.'[3]

Oort and Minnaert carefully selected the board of SRZM: academe, industry and public utilities were represented. During the first years it consisted of Oort (chairman), Van de Hulst (lecturer at Leiden Observatory since 1948), Minnaert (director of the Utrecht Observatory), Houtgast (Utrecht Observatory, assistant of Minnaert), Stumpers (engineer at Philips NatLab), Rinia (member of the board of Philips NatLab), Veldkamp (KNMI), De Voogt (PTT) and Vening Meinesz (KNMI). New members of the board were officially appointed by the science section of the KNAW (Royal Netherlands Academy of Arts and Sciences) on the advice of the board of SRZM.[4] From this, however, it should not be concluded that the KNAW had a huge influence on early Dutch radio astronomy. As the KNAW always followed the advice of the board of SRZM, the appointment of the new members was in reality merely a formality. Besides, the KNAW had no further influence on the policy of SRZM (Van Berkel, 2011, p. 331). This negligible role of the KNAW in radio astronomy was nothing exceptional. The changing relationship between science and the government after the Second World War and the founding of ZWO had seriously threatened the role of the KNAW in matters of science (Van Berkel, 2011, p. 175).

2.2 OORT'S STRATEGY OF MAXIMAL EFFICIENCY

It may seem odd that Oort did not invite people from the other astronomical Dutch institutes to join SRZM. However, as he was a headstrong person who always wanted to arrange things as quickly as possible with as few parties as possible, this is not so surprising. Even Pieter van Rhijn, the director of the Kapteyn Laboratory (the astronomical laboratory of the University of Groningen) and former supervisor of Oort was not informed in any way of Oort's plans. Obviously, he reacted rather upset when he heard that SRZM had asked for a grant of Dfl 200 000 from ZWO for the construction of 'a very large instrument for the research of radio waves from Sun and Milky Way'[5]. Van Rhijn thought it was only natural that the other Dutch institutes would participate:

> Would it not be possible that the new instrument be managed not by a single institute, but by a board consisting of representatives of all Dutch astronomical and meteorological institutes and that all Dutch astronomers could work with the instrument?[6]

One might expect that Oort was bothered by Van Rhijn's implicit criticism on the fact that he had ignored the other institutes and that a subsequent letter with a clear invitation from Oort to join SRZM would follow. However, a rather odd and vague answer followed:

[3] 'het bevorderen en doen uitvoeren van onderzoekingen van de korte-golfstraling die van buiten de aarde komt. Haar werkzaamheden liggen uitsluitend op wetenschappelijk terrein.' Founding charter of SRZM, 23 April 1949, OA, 263.
[4] Founding charter of SRZM, Article 3, 23 April 1949, OA, 263.
[5] Van Rhijn to Oort, 2 December 1949, OA, 149f.
[6] 'Zou het niet mogelijk zijn, dat het nieuwe instrument wordt beheerd niet door 1 instituut, maar door een bestuur bestaande uit vertegenwoordigers van alle Nederlandse astronomische en meteorologische instituten en dat alle Nederlandse astronomen met het instrument zouden kunnen werken?' Van Rhijn to Oort, 2 December 1949, OA, 149f.

> I am a bit surprised that I have never told you about the Radio Foundation. Apparently, we see each other too infrequently even to discuss the most important things. (…) Personally, I would be very glad if other astronomical institutes than Utrecht and Leiden would actively participate. (…) As you will see, for the moment only the observatories of Utrecht and Leiden are represented on the board, because these, as we thought, were the only directly interested parties.[7]

Understandably, Van Rhijn was not entirely happy with this answer. As he knew it would take several years before the instrument was ready, he assured Oort he would come back to the issue on a later date and that he would then probably ask him to include a representative of the Kapteyn Laboratory on the board of SRZM.[8]

Indeed, about three years later, the correspondence on this matter was resumed. Van Rhijn was close to retirement and as he felt insecure about the future of the Kapteyn Laboratory, he thought it was useful to explore new directions for his institute. Radio astronomy could be an option. Therefore he asked Oort whether from then on, he could be present at the meetings of the board of SRZM.[9] But Oort refused. He answered that 'the board believes that it is undesirable to expand even further'.[10] Van Rhijn in turn, did not stop there. In an angry letter, he wrote that he thought it was 'incorrect that the director of the Kapteyn Laboratory was excluded from the decisions concerning the development of radio research'.[11] Too much centralisation would be detrimental for Dutch astronomy, according to Van Rhijn:

> If the practice of astronomy is strongly developed at one institute, compared to the others, the danger is that when prosperity is declining in the Netherlands, the smaller institutes are abolished. (…) As yet, for Groningen I do not see another possibility for astronomical work independent from foreign institutes than radio research. One has the great advantage here that the climate is no obstacle.[12]

Finally, Oort agreed to propose Van Rhijn as a member of the board of SRZM. The other members approved this proposal and Van Rhijn's membership was officially approved by the KNAW in the

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[7] 'Het verwondert me een beetje, dat ik je nooit over de Radio-Stichting verteld heb. Wij zien elkaar veel te weinig blijkbaar om zelfs de belangrijkste dingen te overleggen. (…) Persoonlijk zou ik het erg toejuichen indien ook andere astronomische instituten behalve Utrecht en Leiden hier actief aan wilden deelnemen. (…) Zoals je zien zult, hebben op het ogenblik in het bestuur alleen de Sterrewachten te Utrecht en Leiden zitting omdat deze, naar wij dachten, de enige direct geïnteresseerden waren.' Oort to Van Rhijn,' December 1949, OA, 149f.

[8] Van Rhijn to Oort, 30 December 1949, OA, 149f.

[9] Van Rhijn to Oort, 24 November 1952, OA, 149f.

[10] 'is het bestuur bepaald van mening dat het ongewenst is het nog omvangrijker te maken dan het reeds is.' Oort to Van Rhijn, 29 November 1952, OA, 149f.

[11] 'onjuist (…) dat de directeur van het Kapteyn Laboratorium van de beslissingen omtrent de ontwikkeling van het radio-onderzoek is uitgesloten.' Van Rhijn to Oort, 15 December 1952, OA, 149f.

[12] 'Indien men de beoefening van de sterrenkunde aan 1 instituut zeer sterk tot ontplooiing brengt vergeleken bij de andere, dan dreigt het gevaar, dat men bij verminderde welvaart in Nederland de kleinere instituten opheft. (…)Voorlopig zie ik voor Groningen geen andere mogelijkheid voor sterrenkundig werk onafhankelijk van buitenlandse instituten dan radio-onderzoek. Men heeft hierbij het grote voordeel, dat het klimaat geen belemmering vormt.' Van Rhijn to Oort, 15 December 1952, OA, 149f.

beginning of 1953.[13]

Oort's behaviour may not be the epitome of collegiality, but from the point of view of efficiency, it was certainly understandable. Oort was not per se opposed to the appointment of 'outsiders' in the board of SRZM. In 1951, for example, he agreed to appoint the Belgian astronomer P. Swings, as he thought the latter could make valuable contributions to the project. Indeed, radio astronomy had also recently started in Belgium and with some Belgian astronomers, especially Swings, the Dutch had good relations (see also Chapter III). It was unclear, on the other hand, how the Kapteyn Laboratory, Van Rhijn in particular, could further Dutch radio astronomy. Therefore, the Dutch (radio) astronomer Hugo van Woerden, a retired professor of the University of Groningen and former member of the board of SRZM can understand Oort's reaction:

> Van Rhijn was ill for several years during and after the Second World War (…). He had had tuberculosis and remained weak until the end of his life in 1960. My fellow students in Leiden (…) and I were already discussing in 1952/1953 who would be his successor after his retirement. Van Rhijn was rarely at the meetings of the NAC [Nederlandse Astronomen Club]. I think Oort respected Van Rhijn's scientific contributions, but at the same time, he thought he did not undertake many new things. Without doubt, Oort was convinced that Van Rhijn could not make a substantial contribution to the work of SRZM, because he had no staff available that could throw itself into radio astronomy, and because he had too little energy for managerial work.[14]

2.3 STARTING RESEARCH IN KOOTWIJK: THE HIRING OF HOO

One of the first things the newly founded SRZM needed to do was hire a radio engineer. The board of SRZM discussed the issue with professor Gorter of the Kamerlingh Onnes Laboratory. They decided that Hoo, a student-assistant at the Kamerlingh Onnes Laboratory would be a suitable person. At the Laboratory, he had already adapted a surplus American radar receiver to make it suitable for doing astronomical research in the 21-cm hydrogen line.[15]

Hoo was hired in late 1948, but soon there were doubts about his competence. Already in the spring of 1949, it was said that a second experienced radio engineer should be appointed for about six months, to work together with Hoo. The Englishman Martin Ryle was contacted to this end. At that moment, Ryle led a radio astronomy group at the Cavendish Laboratory of Cambridge University. In 1946, he had constructed a radio interferometer with some colleagues, so he had

[13] Oort to Van Rhijn, 26 January 1953, OA, 149f.
[14] 'Van Rhijn is jarenlang ziek geweest tijdens of na de Tweede Wereldoorlog (…). Hij had tuberculose gehad en bleef zwak tot het eind van zijn leven in 1960. Mijn medestudenten in Leiden (…) en ik bepraatten in 1952/53 al wie hem na zijn emeritaat zou opvolgen. Van Rhijn verscheen zelden bij bijeenkomsten van de NAC. Ik denk dat Oort respect had voor Van Rhijns wetenschappelijk werk, maar wel vond dat hij weinig nieuws ondernam. Ongetwijfeld had Oort de overtuiging dat Van Rhijn geen wezenlijke bijdrage aan het werk van SRZM kon leveren, omdat hij geen personeel had dat zich op de radiosterrenkunde zou kunnen werpen, en ook te weinig energie had voor bestuurlijk werk.' Personal communication of Van Woerden to author, 7 December 2012.
[15] Minutes of the board meeting of SRZM of 26 October 1948, SA.

ample experience with the instrumentation.[16] However, Ryle refused as he 'had no time'. (It was probably a little unrealistic of the Dutch to think that Ryle himself, by then already a rising star in British radio astronomy, would come over to the Netherlands to do this job.) He also had no assistants available.[17]

Half a year later, still no second radio engineer had been found. The doubts about Hoo increased. At that time, he was still a student with a provisional appointment. The question was whether he was good enough to get a permanent position afterwards. According to De Voogt of the PTT, who regularly controlled Hoo's work, Hoo 'lacked the flair for the experiment'.[18] Although there was a consensus that Hoo was enthusiastic and diligent, it was agreed upon that he needed to be supervised. So it was decided that he should write a work report for Oort every month, and that an instrument maker of De Voogt would assist Hoo.[19]

Finally, at the beginning of 1950, a second radio engineer to help Hoo was found: G. de Bruin.[20]

Hoo and De Bruin had only started to work together for a few months, when a disaster struck: on 10 March 1950 a fire broke out in the observation cabin of the radio telescope at Kootwijk. For SRZM, the consequences of this fire were 'disastrous, because of the loss of work and valuable instruments'.[21] Virtually all the equipment was burned and a lot of private belongings of Hoo and De Bruin too. Of course, things needed to be repaired as soon as possible. The construction of a new receiver was the most important. The idea was that Hoo and De Bruin would carry out this task at Philips NatLab, supervised by Stumpers. The new receiver would differ from the old one in some aspects, the most important of which was the possibility of high frequency amplification in the new receiver.[22] The management of Philips NatLab, however, did not want Hoo and De Bruin in their laboratory, but it was agreed that Philips itself would construct the receiver for SRZM.[23]

As the competence of Hoo was doubtful from the beginnings, SRZM had announced a vacancy for the position of leading engineer at SRZM in early 1950. But as mentioned above: finding good engineers was hard. In September 1950, only three candidates had applied: Hoo himself, Bruin (not to be confused with *De* Bruin!) and Muller.[24] It was immediately agreed that Hoo was not suited for the job. Muller and Bruin, on the other hand, were both very strong candidates. Bruin was an engineer at the Zeeman Laboratory, a laboratory for high-energy physics at the University of Amsterdam. There, he was the assistant of the well-known Bakker, former physicist at Philips NatLab (see Chapter I). Muller was engineer, and assistant at the electronics department of Delft Polytechnic.[25] Eventually, the choice fell on Muller, who was hired in late 1950.[26] With the hiring of Muller, Dutch radio astronomy embarked on an era of success.

In historiography on early radio astronomy, there is some disagreement on the role of the fire in

[16] Ryle's contributions to radio astronomy, especially to interferometry and aperture synthesis, will be discussed in detail in Chapter IV.
[17] Minutes of the board meeting of SRZM of 23 May 1949, SA.
[18] Minutes of the board meeting of SRZM of 1 November 1949, SA.
[19] Minutes of the board meeting of SRZM of 1 November 1949, SA.
[20] Minutes of the board meeting of SRZM of 17 January 1950, SA.
[21] Minutes of the board meeting of SRZM of 21 March 1950, SA.
[22] Minutes of the board meeting of SRZM of 21 March 1950, SA.
[23] Minutes of the board meeting of SRZM of 23 May 1950, SA.
[24] Minutes of the board meeting of SRZM of 12 September 1950, SA.
[25] Minutes of the board meeting of SRZM of 12 September 1950, SA.
[26] Minutes of the board meeting of SRZM of 23 October 1950, SA.

Kootwijk. First we need to say that the real cause of the fire has never been ascertained. Hoo's own account goes that when the door to the hut had been closed, a piece of wire had fallen of a workbench, causing a short circuit in one or more lead batteries below (Sullivan, 2009, p. 406). Concerning the consequences of the fire, on the other hand, most authors claim that it caused serious delays in the Dutch observations. Sullivan, on the other hand, holds an anomalous view in this. He says that the fire in fact hastened the eventual detection of the 21-cm hydrogen line (see below), because it hastened the replacement of Hoo (Sullivan, 2009, p. 414). But this is not correct. First of all, Hoo was never *replaced* by someone else. He held a temporary position as radio engineer at SRZM as part of his studies. Of course, if he would have proven to be very competent, he could later have been appointed in a permanent position as leading radio engineer of SRZM. However, it became clear very soon that Hoo's work was rather disappointing. Therefore, already at the board meeting of 17 January 1950 – almost two months before the fire - it was decided to announce a vacancy for the position of a leading radio engineer as soon as the budget to pay the engineer was approved by ZWO.[27] Besides, it took almost a year before a competent engineer – Muller – was found, so it can hardly be said that his appointment hastened the job. For several months – until Hoo's position ended – they collaborated. Moreover, Van Woerden (who had been involved in Dutch radio astronomy from the very beginning) and Strom, former astronomer at ASTRON (Netherlands Institute for Radio Astronomy), have pointed out that because of the fire, many months of development were lost (Strom and Van Woerden 2006, p. 5). It is of course impossible in hindsight to give a definite answer to the question 'who would have been the first if the fire had not happened'. And for the historian, it is perhaps not even the most interesting question to ask. However, we think it is absolutely true that the fire seriously delayed the early observations as a great deal of development was lost and consequently observations came to a halt for several months. On the other hand, there is good reason to assume that the role of the fire in this story is negligible: as will be explained in the following section, the Dutch lacked a key element for the detection of the line.

2.4 MULLER AND THE QUEST FOR THE 21-CM HYDROGEN LINE

In December 1950, the new 21-cm receiver was ready at Philips and was transported to Kootwijk, so the quest for the 21-cm hydrogen line could be resumed. Although there was general agreement that Muller was a very competent engineer, he did not succeed in detecting the line. The problem was that something crucial was missing and he had to wait until a solution came from … Harvard.

In the same period, in the USA there was a quest for the 21-cm hydrogen line too. At Harvard, at the end of the 1940s, physics student H.I. Ewen wanted to find a suitable topic for his PhD research in physics. After his advisor E.M. Purcell had discovered a paper by the Russian astronomer I.S. Shklovsky – which said that the hydrogen line should be relatively easy to detect (Shklovsky, 1948) – Ewen decided to build a radiometer to detect this interstellar hydrogen (Stephan, 1999, p.8).

As mentioned above, most of the early radio research was not done by 'real' astronomers, but by physicists and engineers with a background in wartime radar research. This was also the case at Harvard. Both Ewen and Purcell had a background in the war research. In 1944, Purcell had interrupted his work at Harvard to head the Fundamental Developments Group at the MIT

[27] Minutes of the board meeting of SRZM of 17 January 1950, SA.

Radiation Laboratory. There, he directed investigators in projects related to radar research and development. Ewen for his part had been an airborne-radar officer whose duty was to fly anti-submarine patrols in and around the English Channel. He had learned how to assemble and repair complex equipment with whatever facilities were at hand.

Early in 1951 it so happened that Henk van de Hulst – at that time a lecturer at Leiden University – was spending a few months at Harvard College Observatory, where he had been appointed a visiting professor, to give a course in radio astronomy. It is unclear whose initiative it was to get Van de Hulst to Harvard, but it was probably Bart Bok's. After Bok's efforts to get Reber's 1940 paper published in the *Astrophysical Journal*, he continued to follow the developments in this field closely. He set up a research programme in radio astronomy in 1952 and from 1953 onwards, he taught radio astronomy at Harvard, as he wrote to Oort: 'This Fall I am teaching the Radio Astronomy course that was initiated by Henk van de Hulst two and half years ago.'[28]

It is noteworthy that as early as 1950-1951 – despite the 'gap' between optical astronomers and radio astronomers – a course in radio astronomy was given to Harvard astronomy students. Moreover, the course was then called 'radio astronomy'. Probably, this was one of the earliest uses of the term.[29]

Shortly after Van de Hulst's arrival, he had learned of the 21 cm effort of Ewen and Purcell. Subsequently, collaboration between Ewen and Purcell and Van de Hulst began. Van de Hulst used his astronomical knowledge to help Ewen and Purcell with their endeavours. He said that the line might be considerably wider than the one measured in the laboratory. This was because the hydrogen in different parts of the Galaxy might be moving at a considerable range of velocities relative to the Earth. So the emission might be Doppler-broadened (i.e. covering a wider frequency range) over a band many kilohertz wide. Ewen adapted his equipment accordingly. On the other hand, Van de Hulst studied Ewen and Purcell's receiver techniques (Stephan, 1999, pp. 12-14). Ewen and Purcell's radiometer was based on the switching principle of Dicke. The so-called 'Dicke switch' was invented by the American physicist Robert Henry Dicke, when he was working in the radar industry in the Second World War. The Dicke switch repeatedly (and very rapidly) alternates the input of the receiver between an antenna and a constant-temperature load resistor. This is not so much to eliminate noise, as to eliminate the effects of receiver gain fluctuations[30] during a measurement. In a letter of 8 March 1951, Van de Hulst wrote to the Dutch group about this frequency-switching scheme, which was the key novel element for the engineer Muller (Sullivan, 2000, p. 250).

From then on, things proceeded quickly. In Harvard, Ewen managed to detect the hydrogen line on 25 March 1951. In the Netherlands, the first hints of the line came on 11 May, followed by the confirmation several nights later. Oort communicated the news enthusiastically to Van de Hulst in Harvard:

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[28] Bok to Oort, 6 October 1953, OA, 151c.

[29] 1950-1951 Harvard University, Astronomy 241b, radio astronomy. Final. June, 1951, VdH, 37. In 1950, Minnaert also used the word 'radio-astronomy' in his 'Report on Dutch research on radio-astronomy in 1948-1950' for the 9th General Assembly of the URSI in Zürich in 1950, VdH, 37.

[30] The 'gain' is the ability of an amplifier to increase the power or amplitude of a signal from the input to the output.

> Dear Henk, I have just received a call from Muller at Kootwijk, saying that he has observed the 22-cm line[31] tonight in the vicinity of Sagittarius! He estimated the strength of the same order as Ewen said. [32]

At the end of June 1951, further confirmation came from Australia. It is noteworthy that F. Kerr, a staff member of the Radiophysics Laboratory in Sydney (where microwave radar equipment was developed during the war), was spending a year at Harvard studying astronomy in 1950-1951. He was there at the moment of the line detection, and Purcell suggested that he cable the result to Australia. There, no attempt to look for the line was being undertaken at the time. However, upon receipt of Kerr's cable by Pawsey, a programme was immediately started. The necessary equipment was assembled. The professor of physics and engineering W.N. Christiansen and his assistant J.V. Hindman detected the line after only six weeks (Kerr, 1984, p. 138).

It appears that Purcell and Ewen were really looking for at least one confirmation of the detection before publishing their result. Once the confirmation by the Dutch was there, it was decided to try to have the two papers published in the same issue of Nature. Purcell wrote to the editors of Nature:

> Our first results were communicated privately to Professor van de Hulst and Professor Oort of the Leiden Observatory. We have just learned that our findings have been subsequently confirmed by observation there. The purpose of this letter is, therefore, to suggest that it might be appropriate if both communications (…) were to appear in the same issue of NATURE. Our results were also communicated to the Radio Physics Division of the Commonwealth Scientific and Industrial Research Organization in Australia. (…) It is possible, therefore, that you will receive still a third communication on this subject, from the Australian laboratory.[33]

The first papers from the Harvard and the Leiden groups were published in Nature in 1951, with a short cable from the Australian group as an addendum.

The differences between the Leiden and the Harvard group are strikingly obvious in the papers in Nature. The article by Ewen and Purcell was written as an experiment in interstellar microwave spectroscopy, whereas the article by Muller and Oort was a study of the structure of the Galaxy (Sullivan, 2000, p. 254). As Ewen and Purcell wanted to explore the physics of the hydrogen atom, they concentrated on the opacity and the physical state of the hydrogen gas. For example, they summarised:

> We have made rough theoretical estimates of the efficacy of various processes through which energy is exchanged between the hydrogen hyperfine levels and the other thermal reservoirs in the interstellar matter-plus-radiation complex. (Ewen and Purcell, 1953, p. 356)

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[31] The Dutch often referred to the line as the 22 cm line, even though its wavelength was known to be 21.1 cm

[32] Oort to Van de Hulst, 17 May 1951, VdH, 37.

[33] Purcell to the Editors of Nature, 14 June, 1951, VdH, 37.

The emphasis of Muller and Oort was on the line widths and the Doppler shifts (shifts in frequency) and what they revealed about the location of the gas. This in turn could tell them something about the structure of the Galaxy (Muller and Oort, 1951).

The differences between the Leiden and the Harvard papers illustrate that the questions researchers asked – even when studying the same topic (the 21-cm hydrogen line) – were strongly influenced by their background and previous activities.

It is worthwhile to mention that from the questions for the final exam in radio astronomy in June 1951, it becomes clear that Van de Hulst must have told his Harvard students about the Dutch plans to build a radio telescope with a dish of 25 m, as the main part of the exam was about this radio telescope. Students were asked to give their ideas on the instrumentation and possible research programmes:

> Plans have been made to construct a parabolic antenna of 25 meter diameter with a surface of wire screen reflecting waves of 10 cm and longer. The antenna will be able to move in two coordinates. Before appropriation of the funds a well-considered program of expected research problems has to be submitted. You are invited to submit such a program. Discuss solar and galactic and possibly other problems; freely use any data that are now available from observation with smaller equipment. Give sample estimates of beam width and antenna gain, where needed. Indicate clearly the type of result expected from each suggested problem and its impact on problems of classical astronomy or other fields of science. Finally try to state what programs deserve priority and how long it will take to complete them.[34]

This relative openness concerning the Dutch plans, however, did not prevent a huge amount of (international) competition, as we will see.

2.5 FUNDING, BUILDING AND INAUGURATING THE RADIO TELESCOPE

The detection of the 21-cm hydrogen line was not only important from an astronomical point of view; it was also instrumental in obtaining a ZWO grant for the construction of a large radio telescope.

Remember that the first time the astronomers asked for funding for this telescope was in 1945 (see Chapter I). In that year they asked the government a grant of Dfl 100 000. This amount, however, was as large as the government's total budget for scientific instrumentation and consequently the request was turned down.

The first time a plan was presented to ZWO was in 1949. Werkspoor had made an estimate of the price tag: the construction would cost around Dfl 200 000, which was about 16% of the ZWO-budget for 1950 (see above). Financial support was *not* possible in that year and the astronomers received only Dfl 5850 for 'research on short wavelengths originating from interstellar space, as

[34] 1950-1951 Harvard University, Astronomy 241b, radio astronomy. Final. June, 1951, VdH, 37.

well as those that are emitted by the sun'.[35] One of the reasons for this refusal was, indeed, the poor progress of the Kootwijk observations. This was illustrated by the words of Bannier, the director of ZWO, who was present at a meeting of the Dutch astronomers in September 1949. At that meeting, Bannier expressed his doubts on whether the technical and astronomical experiences with the small dish were already such that it would be justified to build a large dish.[36] After all, in the autumn of 1949 the astronomers had not yet succeeded in detecting anything significant at all.

In addition to this, however, Bannier mentioned that it was impossible for the provisional organisation to decide on such a huge amount of money. The astronomers had to wait until ZWO was officially installed. This argument sounds a bit odd, as it was obviously no problem for the provisional board to give a larger budget to the Foundation for Fundamental Research on Matter ('Fundamenteel Onderzoek der Materie' or FOM), the Dutch national foundation for nuclear physics, founded in May 1946. In 1947, ZWO distributed its total budget of Dfl 571 550 over twelve projects. FOM received Dfl 257.500 (Reinink, 1950, p. 59) which means that it consumed almost half (!) of the annual budget. For at least a decade, FOM continued to consume yearly on average fifty per cent of the annual budget of ZWO. To compare: SRZM received about ten per cent of the annual budget of ZWO, which meant it was in a respectable second place in matters of funding.[37] Obviously, the Dutch government gave higher priority to nuclear physics in the early Cold War context, although in the Netherlands, it was exclusively used for peaceful purposes.

In August 1951—about three months after the detection of the 21-cm line of 11 May — a definitive plan was presented to ZWO. The estimated cost was much higher than the previous estimate of 1949: the construction would cost Dfl 436 000 (Kersten, 1996, p. 98). However, the project was approved and it was decided to finance the building of the telescope in three stages from 1951 until 1953.

When we take a closer look at the funding process, this sudden success is not so surprising. Several people once again were judge and party at the same time. A ZWO ad hoc advisory committee of five people was appointed by the board to judge the plan. Among its members were the physicists G. Holst – former physics professor of Leiden University and director of Philips NatLab - and Vening Meinesz, head of the KNMI. Not surprisingly, they advised positively on the project.[38] In their argumentation, they stressed the great scientific value of the project. While the Dutch cloudy climate was unsuitable for optical astronomical observations, the Dutch could play a vital role in radio astronomy. With this new instrument, the Dutch would—in their own country—be able to have a significant influence on this new field of astronomy. The research would also have positive effects on related disciplines such as telecommunication and development of knowledge about the ionosphere. The project was of extraordinary importance for the education of scientific researchers and technicians. They would learn how to work very precisely and because of the interdisciplinarity, they would become familiar with problems of other disciplines. In other countries, there were no plans to build such a 25-m dish and so Dutch radio astronomy would stay

[35] 'voor onderzoek van de kortegolfstraling, die uit de interstellaire ruimte komt alsmede van die, welke door de zon wordt uitgestraald', Annual report ZWO, 1950, p. 41.
[36] Minutes of the board meeting of SRZM of 20 September 1949, SA.
[37] Annual reports ZWO, 1950-1960.
[38] Minutes of the board meeting of SRZM of 30 October 1951, SA.

at the international top (Kersten, 1996, pp. 98–99).[39] So from this line of argument it becomes clear that a rhetoric of practical applications and technical spin-offs was still highly relevant.

In the beginning of the 1950s, the network of people that put radio astronomy on the agenda was still very small: only a handful of astronomers, some people from industry and from the government were involved and ZWO was also still a very small organisation. Paradoxically, it was exactly this smallness that contributed to the early success of Dutch radio astronomy. Because of the small number of people involved, overlapping memberships were the rule rather than the exception so that people were often judge and party at the same time. In such a small network, 'friendship' between the protagonists could be a crucial factor. That an apparently trivial factor such as friendship can play an important role in the establishment of a new scientific field has been demonstrated already several times (see for example Michaelson, 1993). Historian Klaas Van Berkel also recognises that friendships and dominant personalities can play decisive roles, but only in fields which are still very small, such as Dutch radio astronomy:

> In a relatively small field, dominant personalities can distinguish themselves more easily than in more extensive, multi-hued fields. Oort's achievements – his scientific work as well as his diplomatic talents – were exceptionally important for Dutch astronomy, and would not have been possible within a large field such as physics (…). (Van Berkel, 2004, p. 350)

Van Berkel is indeed right in stressing that the smaller the field, the more influence dominant personalities can have. On the other hand, Oort was anything but a 'diplomatic' person. It has already been illustrated how dominant and even uncollegial he could actually be. But because he was embedded in a small network of people who knew him personally and were well acquainted with his scientific achievements, this hardly mattered: in the Netherlands, Oort almost always got what he wanted. However, when it came to collaboration with other countries – and hence with people that were outside his network – the situation was completely different. The collaboration that was established with Belgium in the late 1950s for the building of the radio telescope in Westerbork (see Chapter III) ultimately failed. It becomes clear that in Belgium Oort absolutely did not get the credit that he received in the Netherlands.

As mentioned before, Werkspoor estimated the cost of the telescope to be Dfl 436 000. Hence, this was also the amount ZWO made available. Over time, however, the total cost increased. In the beginning of 1953, Werkspoor handed in a new estimate of no less than Dfl 586 720.[40] In an accompanying letter, the company explained:

> Much to our regret, the amount of this offer is considerably higher than that of the estimate we gave you on 4 May 1951 [which was Dfl 436 000]. This increase of the estimate is almost exclusively due to important changes in the construction which seemed to be necessary in order to meet the requirements of the servo mechanism. [41]

But the astronomers were not pleased. According to them, it was clear that 'several entries calculated unnecessarily generously by Werkspoor could be lowered by better calculation and

[39] Unfortunately, we were unable to find the original text of the committee.
[40] Werkspoor to Houtgast, 15 January 1953, SA, NWO.
[41] Werkspoor to Houtgast, 16 January 1953, SA, NWO.

simplification of the construction'.[42] Werkspoor agreed to make a revision. In consultation with the astronomers, several entries were adapted. For example, it was agreed upon that the foundation could be of a lesser quality.[43]

In October 1953, Werkspoor's price estimate had gone down from Dfl 586 720 to Dfl 530 000. But at the same time, a new problem arose: the estimated delivery time had gone up from ten months to one year and a half.[44] New negotiations between the astronomers and Werkspoor took place, which led again to a lowering of the cost to Dfl 490 810 in the beginning of 1954. It was said, however, that this would go up again with Dfl 15 000 the next year, because of the pay rise.[45]

Dfl 490 810 was of course still higher than the original estimate of Dfl 436 000, the grant ZWO had reserved for the project. Fortunately for the astronomers, the increased cost was no problem for ZWO. The decision had been taken and ZWO realised that there was no going back. Hence, on 4 March 1954, SRZM received the permission of ZWO to give the tender to Werkspoor.[46]

The delivery contract of Werkspoor followed on 18 March 1954.[47]

Construction started, but very soon, new delays arose. As Werkspoor's drawing office was understaffed, a delay of four months had arisen in the machinery. Moreover, the delivery of several components – for example the large gear wheel - was delayed too. The astronomers started to panic, as they knew there were plans in some other countries too to construct large radio telescopes and they absolutely wanted to be 'the first'.[48]

And things only got worse. On 19 July 1955, SRZM received a letter of Werkspoor in which an additional delay of four months was announced. On top of this, the delay was announced much too late in the astronomers' eyes. The latter agreed to react 'immediately and in strong words'.[49]

Fortunately, all's well that ends well. The telescope was ready at the date when the inauguration was planned. Initially, it was said that the inauguration date would be 18 April 1956 and that the telescope would be opened by 'the Minister' (probably the Minister of Education, Arts and Sciences) by means of a 'push a button'. [50] However, Her Majesty Queen Juliana informed the astronomers she wanted to open the telescope *herself* on 17 April 1956,[51] and so it happened. Or at least, so it seem to happen so. An amusing anecdote is that, at the time of the inauguration, the automatic steering system of the telescope was still unfinished and the button pushed by Juliana was not connected. What actually happened when the Queen pushed the button, was that a bell rang in the control room, after which an SRZM employee manually

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[42] 'verschillende door Werkspoor onnodig royaal berekende posten door betere calculatie en door vereenvoudiging van constructie verlaagd kunnen worden', Minutes of the board meeting of SRZM of 3 February 1953, SA.
[43] Minutes of the board meeting of SRZM of 3 February 1953, SA.
[44] Minutes of the board meeting of SRZM of 27 October 1953, SA.
[45] Minutes of the board meeting of SRZM of 2 February 1954, SA.
[46] Minutes of the board meeting of SRZM of 16 March 1954, SA.
[47] Contract of Werkspoor, 18 March 1954, SA, NWO.
[48] Minutes of the board meeting of SRZM of 14 September 1954, SA.
[49] 'onmiddellijk en in krachtige termen', Minutes of the board meeting of SRZM of 19 July 1955, SA.
[50] Minutes of the board meeting of SRZM of 17 January 1956, SA.
[51] Minutes of the board meeting of SRZM of 14 February 1956, SA.

steered the telescope. For a moment, it was even steered in the wrong direction, but this mistake was quickly corrected (Gerding et al., 2009).

FIGURE 2. The radio telescope in Dwingeloo (Leiden Observatory Archives)

For a few months, the radio telescope in Dwingeloo would be the biggest radio telescope in the world. One would expect that this fact received a lot of media attention. However, compared to the number of articles that appeared in August-September 1953 when the plans for the radio telescope became public and protest arose (see also below), the media coverage of the inauguration was small. A quick search in the Dutch National Library's database of historical newspapers[52] revealed that only four newspapers reported this inauguration. This brings us to the question how the astronomers dealt with the press and with 'the general public'. But first let us take a look at how a suitable location for the telescope was chosen.

[52] http://kranten.kb.nl/ (accessed on 22 January 2013). This database contains over 1400 newspapers, 1152 of which cover the period 1940-1945.

2.6 IN SEARCH OF A LOCATION FOR THE LARGE RADIO TELESCOPE

Plotseling werd een deel van de Spiegel zichtbaar boven de bomen: een reusachtig staketsel van vijfentwintig meter doorsnee, een transparante parabool van grauw staal, in de landelijke omgeving zo detonerend als een vloek in een preek.
Harry Mulisch, *De ontdekking van de hemel*

The telescope was built in Dwingeloo, but the question remains of course which elements determined the choice of this location. As we will see, it was only after several years of carefully weighing the pros and cons of several locations and after a lot of negotiations that this location was finally considered the best.

As cooperation with the Belgians was considered for a while and the Belgian astronomer P. Swings was appointed to the board of SRZM in 1951, the initial plan was to build the 25-m telescope on the Belgian-Dutch border near the nature reserve of the Benedictine Abbey 'Achelse Kluis'.[53] In the context of Belgian-Dutch cultural cooperation (see also Chapter III) SRZM contacted the Dutch government to ask the Belgian government to keep this area free from possible sources of interference (such as cars, motorcycles etc.). There were also rumours that in the near future, a military airport would be located to the south of the city of Neerpelt (Belgium). Swings contacted the Belgian military authorities about this matter, but as military secrets were involved here, the authorities were reluctant to give information.[54] It was decided that if military activity in the area would be too much of a problem, a completely different location in Veenhuizen in the province of Drenthe (in the north of the Netherlands) would be considered.[55] This meant of course that the idea of constructing the telescope on the Belgian-Dutch border was given up.

Over time, it became more and more obvious that the location of Achelse Kluis was unsuitable. Although not many details were given, further contacts between Swings and the Belgian military authorities revealed at least that a lot of military activity was planned in the area around Achelse Kluis.[56] The Dutch Military Aviation Authority also discouraged this location[57].

So in the fall of 1952 it was decided that Veenhuizen was definitely the best location, as it would remain free of interference for a long time.[58] But the enthusiasm quickly waned, when the astronomers heard of existing plans for the construction of a main road between Assen (Drenthe) en Oosterwolde (Friesland), a road that would cross Veenhuizen. The astronomers contacted the provinces of Drenthe and Friesland, but neither was inclined to change the plans. Moreover, the southern part of the area seemed to be owned by private mining companies.[59] It was at this moment that the 'Kraloër veld'[60] near the village of Dwingeloo (Drenthe) – where the telescope would ultimately be built - was taken into consideration as a possible location for the first time. This was a nature conservation area. The state owned the area, but it was managed by the Forestry

[53] Minutes of the board meeting of SRZM of 27 November 1951, SA.
[54] Minutes of the board meeting of SRZM of 12 February 1952, SA.
[55] Minutes of the board meeting of SRZM of 18 March 1952, SA.
[56] Minutes of the board meeting of SRZM of 27 May 1952, SA.
[57] Minutes of the board meeting of SRZM of 24 April 1952, SA.
[58] Minutes of the board meeting of SRZM of 2 October 1952, SA.
[59] Minutes of the board meeting of SRZM of 3 March 1953, SA.
[60] I.e. the 'Kraloërheide'

Commission ('Staatsbosbeheer'). So this was a very quiet region that would be free from interference for a long time and hence it was considered to be perfect. However, the astronomers themselves were in doubt whether it could be justified to 'spoil' such a beautiful area.[61]

Indeed, with the choice of Dwingeloo as a possible location, the real trouble only began.

Huge resistance came from the village administration. On 24 August 1953, the city council of Dwingeloo voted almost unanimously against the construction of the radio telescope in Dwingeloo. This decision was widely reported in the media. The astronomers were very upset that they were in no way informed by the council and that they had to read about the decision in the newspapers. They were also convinced that, if the mayor – who had discussed the plans with the astronomers - would have informed the council, the attitude of the council would not have been so negative:

> We regret that the mayor has been of the opinion that confidentiality had to be maintained. The unfamiliarity with the efforts of the Foundation has without doubt caused the council to overestimate the disadvantages and to disregard the positive side.[62]

The village council and the inhabitants of Dwingeloo too were not happy with this secrecy. Mayor Stork had not informed them in any way and they only knew about the plans through 'all kind of rumours that are circulating'.[63]

The council was especially worried because of the need of a large interference free area surrounding the telescope. According to the council, this would have the following consequences:

(a) The farmers would suffer severe restrictions when doing their jobs. For example, the use of motorised machinery would be forbidden and electric fences around the pastures would not be allowed.

(b) Part of the road between the village of Lhee and the city of Hoogeveen had to be displaced, which implied a fragmentation of several agricultural plots.

(c) Tourism would seriously diminish, because the nature reserve would be spoiled by a 30-m tower with a mirror of 25 m diameter. Moreover, the area would be difficult to access, as cars and motor cycles would be hindered.[64]

In its opposition, the village council found a partner in the Society for the Preservation of Nature Monuments ('Vereniging tot Behoud van Natuurmonumenten'). Being a green lobby group, it is not surprising that the Society for the Preservation of Nature Monuments was against the construction of a radio telescope in a nature reserve. The Society for the Preservation of Nature

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[61] Minutes of the board meeting of SRZM of 3 March 1953, SA.

[62] 'Betreurd wordt dat de burgemeester gemeend heeft geheimhouding te moeten betrachten. De onbekendheid met het streven van de Stichting heeft de raad ongetwijfeld de nadelen te zwaar laten wegen en de positieve kant over het hoofd doen zien.' Minutes of the board meeting of SRZM of 8 September 1953, SA.

[63] 'allerlei geruchten die er gaan', in: Dwingelo laat zich niet dwingen. Protestmotie tegen het plaatsen van radiotelescoop. Belemmeringen gevreesd voor landbouw en vreemdelingenverkeer, in: *De Waarheid*, 25-8-1953.

[64] Dwingelo laat zich niet dwingen. Protestmotie tegen het plaatsen van radiotelescoop. Belemmeringen gevreesd voor landbouw en vreemdelingenverkeer, in: *De Waarheid*, 25-8-1953.

Monuments was founded in 1905. In a propaganda leaflet of 1906, the society made its goals explicit:

> (…) the preservation of special parts of the Dutch soil and special animals, plants and ecological communities that live in the Netherlands, as well as important remains of prehistoric human activity, which threaten to disappear because of the expansion of culture or other causes (…).[65] (Quoted in Roenhorst, 2007, p. 183)

In a report of 24 August 1953, the society concluded that the location near Dwingeloo 'did not satisfy the requirements of SRZM'. This was in the first place due to the presence of several nearby roads. But Oort replied that these roads were either little used or located at a sufficient distance from the telescope. Furthermore, although the society presented no less than sixteen alternative locations for the telescope, all of them were entirely unsuitable. Often, there was too much interference because of nearby roads, but more important was that about half of the alternatives were located on the coast. And constructing a radio telescope near the sea was absolutely impossible according to the astronomers. First of all, the heavy winds would demand a heavier construction which in turn would increase the cost considerably. Moreover, sea wind and sea salt would severely corrode the apparatus.[66]

Fortunately for the astronomers, not all the reactions were that negative. The trade association ('Handelsvereniging') of Dwingeloo, for example, thought Dwingeloo would greatly benefit from the construction of the radio telescope: as a lot of people would like to see this gigantic telescope, tourism would – despite the traffic regulations - greatly increase, the association believed. This would be beneficial to shopkeepers, craftsmen, guesthouse owners etc.[67]

But more important was that the provincial and the national governments too supported the plan. In June 1953, the executive council of the province of Drenthe, wrote to the Government Service for the National Plan ('Rijksdienst voor het Nationale Plan'):

> The construction of a radio telescope (…) to the north of the Kraloërheide (…) is considered to be favourable (…). From a scenic point of view, the radio telescope will be a rather disturbing element; on the other hand we should not forget that the presence of the installation is a much better guarantee for the preservation of the nature reserve in its present state than anything we could obtain until now.[68]

Here, we see a very strong new argument in favour of the construction of the telescope: the telescope would be one of the best guarantees for the preservation of the nature reserve. Indeed,

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[65] '(…) het behoud van merkwaardige deelen van den Nederlandschen bodem, merkwaardige in Nederland levende dieren, planten en levensgenootschappen, alsmede belangrijke overblijfselen van voorhistorische menschelijke werkzaamheid, welke door uitbreiding der cultuur of andere oorzaken dreigen verloren te gaan (…)'

[66] Oort to the executive committee of the Society for the Preservation of Nature Monuments, 29 September 1953, SA, NWO. (The society report itself of 24 August 1953 could not be found.)

[67] Radiospiegel opent grootse perspectieven voor Dwingeloo, in: *Friese Koerier,* 31-8-1953.

[68] 'Plaatsing van een radiotelescoop (…) wordt langs de Noordrand van de Kraloërheide (…) gunstig geacht. Landschappelijk bezien zal de radio-telescoop een enigszins storend element opleveren; daarnaast dient niet uit het oog te worden verloren, dat de aanwezigheid van deze installatie een veel betere waarborg biedt dan tot dus verre kon worden verkregen voor de handhaving van het natuurgebied in de huidige vorm.' The executive committee of Drenthe to the Government Service for the National Plan, 3 June 1953, SA, NWO.

because of the necessity of a large interference-free zone, the nature reserve had to be kept in its original state.

The Department of Waterways and Public Works ('Rijkswaterstaat') – responsible for the safe flow of traffic and the national water system – was rather neutral. As the department was aware of the objections against a location in Dwingeloo, it proposed the Wadden Islands, in the north of the country, as an alternative. This suggestion was communicated again to the Government Service for the National Plan, which in turn communicated it to the astronomers. The astronomers, however, rejected this, mainly because of the problem of corrosion.[69]

The Government Service for the National Plan ('Rijksdienst voor het Nationale Plan') – to whom the executive council of Drenthe and the Department of Waterways and Public Works communicated their advices - was responsible for environmental planning. It had an advisory function towards the government. It was founded in May 1941 as a service of the Ministry of Internal Affairs. In 1945, it came under the administration of the Ministry of Public Works and Reconstruction, from 1947 onwards called the Ministry of Reconstruction and Public Housing. The service had an important say in the administration of nature reserves. In 1942, it started to list the recognised nature reserves. Since 1950 this list had evolved into a national plan for nature protection and outdoor recreation. The service often used the list to oppose 'undesirable' planning developments, initiated by local governments, companies and private persons (Blom, Jansen and Van der Heide, 2004, p. 7). This, however, did not mean that this service was per se hostile towards industrial, scientific or other initiatives. On the contrary, it had to reconcile the different interests in the first place.

After the Government Service for the National Plan had consulted several parties involved (the astronomers, the executive councils of Friesland and Drenthe and the Society for the Preservation of Nature Monuments) and after it had listened to the Department of Waterways and Public Works and the advice of several independent engineers, the standing committee ('vaste commissie') of the service advised the Minister of Reconstruction and Public Housing that 'it had found no reason to suggest to you a proposal to object to the work in question'[70]. It further explained why the telescope had to be built in the Netherlands, preferably in Dwingeloo:

> One should set great store by the scientific importance of the construction of this installation in the Netherlands , also with regard to the preservation of the leading position of our nation in this field. (…) Although the damage to the (…) nature reserve is to be regretted, at the same time the preservation of this area in its present state is rather advanced than endangered by the presence of this installation and the associated requirements for quiet in the surrounding area.[71]

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[69] Minutes of the board meeting SRZM of 24 July 1953, SA; Government Service for the National Plan to the Minister of Reconstruction and Public Housing, 28 July 1953, SA, NWO.
[70] 'geen aanleiding wordt gevonden U een voorstel tot het maken van bezwaar tegen het onderhavige werk in overweging te geven.' Government Service for the National Plan to the Minister of Reconstruction and Public Housing, 28 July 1953, SA, NWO.
[71] 'Het wetenschappelijk belang van de stichting der onderhavige installatie in Nederland moet zeer hoog worden gewaardeerd, mede in verband met behoud van de voorsprong van ons land op dit gebied (…). Hoewel de schade voor (…) het natuurgebied uiteraard moet worden betreurd, wordt overigens handhaving van dit gebied in zijn huidige staat door de aanwezigheid van de installatie en de daaraan verbonden eisen

On 5 August 1953, the Minister of Reconstruction and Public Housing in turn communicated to the Minister of Education, Arts, and Sciences that – following the advice of the Government Service for the National Plan – he had no objections against the construction of the radio telescope in Dwingeloo. The latter communicated this decision to Bannier, the director of ZWO, who in turn communicated this decision to the astronomers. The fact that the government was on the side of the astronomers, meant that they were now completely 'free' to choose this location.[72]

Some other meetings followed with the Forestry Commission - which did not object to the arrival of the telescope –, the Ministry of Agriculture and Fisheries – which had to give formal permission to build the telescope on the grounds of the Forestry Commission -, the Ministry of Education, Arts, and Sciences, and the Society for the Preservation of Nature Monuments. It was 'generally agreed' that Dwingeloo was the best place to build the telescope.[73]

On a meeting on 24 November 1953, SRZM engineer B. G. Hooghoudt (see below), together with the Society for the Preservation of Nature Monuments, the Forestry Commission and the Provincial Planological Service of the province of Drenthe agreed about the precise location of the telescope. It had to be in the most western part of the area, as this was the furthest away from roads.[74]

From the fall of 1953 onwards, the Forestry Commission let the astronomers use the grounds.[75] But a formal agreement still had to be concluded. The Forestry Commission proposed to give the land on a long lease for an annual amount of Dfl 893.[76] Bannier, however, tried to get the most out of the deal and asked the Ministry of Education, Arts and Sciences whether it would be possible to give the land for free. His reasoning was that SRZM was entirely dependent on the state through ZWO.[77] This Ministry forwarded the question to the Minister of Agriculture and Fisheries.[78]

It was a nice try, but unfortunately for the astronomers, the Ministry of Agriculture and Fisheries did not agree to give the land for free, because:

> By doing that [giving the land for free] we would create a precedent for many other useful projects. Moreover, the expenses of the aforementioned Foundation [SRZM] are covered by a subsidy of the Dutch Organisation for Pure Scientific Research and as a matter of fact, the free provision of land would be a second subsidy at the expense of the Forestry Commission.[79]

Then Bannier tried something else: he asked the Minister of Education, Arts and Sciences whether he could urge the Minister of Agriculture and Fisheries to lower the lease amount. However, the

voor de rust in het omliggende terrein eerder bevorderd dan in gevaar gebracht.' Government Service for the National Plan to the Minister of Reconstruction and Public Housing, 28 July 1953, SA, NWO.

[72] Bannier to Cramer, commissioner of the Queen in the province of Drenthe, 21 September 1953, SA, NWO.

[73] Minutes of the board meeting of SRZM of 27 October 1953, SA.

[74] Minutes of the board meeting of SRZM of 22 December 1953, SA.

[75] Minutes of the board meeting of SRZM of 27 October 1953, SA.

[76] The inspector of the Forestry Commission to Hooghoudt, 21 June 1954, SA, NWO.

[77] Bannier to the Minister of Education, Arts and Sciences, 20 August 1954, SA, NWO.

[78] The Minister of Education, Arts and Sciences to the Minister of Agriculture and Fisheries, 22 September 1954, SA, NWO.

[79] The Minister of Agriculture and Fisheries to the Minister of Education, Arts and Sciences, 2 November 1954, SA, NWO.

Minister of Education wrote that he could not possibly do that, as the lease amount of Dfl 893 was already very low.[80] Eventually, Bannier and the astronomers agreed to the situation.

It is striking that the Society for the Preservation of Nature Monuments continued to raise problems even after the astronomers had formally acquired the land on long lease. As late as 1958, two years after the inauguration of the telescope, the society continued to ask the astronomers to make the presence of the radio telescope less visible in the landscape. In their board meeting of 18 June 1958, for example, the astronomers discussed a proposal of the society 'to paint the telescope green'. This, however, was impossible, as the colour green absorbs warmth, which would make the temperature in the observation room rise too much.[81] Four months later, the society asked *again* – this seems to have been the last time - that the telescope would be masked as much as possible. Muller wrote back that 'this matter has our full attention'[82], but nothing was ever undertaken in this respect.

That there was a lot of opposition against the construction of the telescope had to do with several factors. Some people (especially farmers), for example, saw their jobs threatened. But from our point of view, the opposition illustrates in the first place that radio astronomy was still a very young field that was not yet accepted by the general public. As will be seen in Chapter IV, it was completely different in the late 1960s when the radio telescope in Westerbork was built.

2.7 POPULARISATION AND RELATIONS WITH THE PRESS

In the early post-war period, science popularisation in the Netherlands was still at a low ebb, compared to, for example, the USA, Britain and France. In the 1950s, Dutch science was still in its 'ivory tower' to a large extent. In the middle of this decade, however, academics started to worry about the lack of social esteem of science. (Dalderup, 2000, p.172). Indeed, in the Netherlands as in the rest of the world, critical voices were raised about the moral status of some kinds of scientific research. Sometimes, these critical voices came from *within* the scientific community itself. A well-known example was the foundation of the Pugwash-movement ('Pugwash Conferences on Science and World Affairs') in 1957 as a consequence of the release of the Einstein-Russell Manifesto on 9 July 1955. This manifesto called for a conference to assess the dangers of weapons of mass destruction. The first conference was held in July 1957 in Pugwash, a small village in Nova Scotia (Canada) and was attended by twenty-two scientists from ten countries (Rabinowitch, 1958). Besides the concern about weapons of mass destruction (which were only nuclear weapons at that time), there was also a growing concern about the consequences for the environment of the large-scale application of new technologies in the late 1950s (Dalderup, 2000, p. 171).

It was in this context that, in 1957, in the Netherlands an interuniversity committee (the 'Bender Committee') called for 'a systematic promotion of good relations with those groups in society on which the university is dependent on to a certain extent, and gaining trust'[83] (Dalderup, 2000, p.172). In practice, this led to the appointment of the first university science information officers

[80] Woltjer of the Ministry of Education, Arts and Sciences to Bannier, 2 February 1955, SA, NWO.
[81] Minutes of the board meeting of SRZM of 18 June 1958, SA.
[82] Minutes of the board meeting of SRZM of 21 October 1958, SA.
[83] 'het op systematische wijze bevorderen van goede betrekkingen met die groepen in de maatschappij waarvan de universiteit in zekere mate afhankelijk is, en het winnen van vertrouwen.'

('wetenschapsvoorlichters'), who were to inform the public about the research that was going on. It is noteworthy that, at that time, the initiatives concerning 'science and the public' were explicitly directed at the *appreciation* of science: there was a strong belief that if people understood science, they would appreciate it. This was not only the case in the Netherlands. The American professor of science communication Bruce Lewenstein, for example, showed that in the USA, in the period 1945-1960, the term 'public understanding of science' became equated with 'public appreciation of the benefits that science provides to society' (Lewenstein, 1992).

As will be illustrated in Chapter III, the Netherlands were not only late with coordinated initiatives for science popularisation. In comparison with other countries, they were late with a science policy in general. This was very different from for example Belgium, were there was already a very well-developed science policy in the 1950s (with special councils, (inter)ministerial committees etc.). This difference between the two countries created tensions in the radio astronomical cooperation that was set up for several years. In the Netherlands, it was not until the late 1960s that the first initiatives for a Dutch science policy were taken (Dalderup, 2000, p. 173).

This lack of a national Dutch effort for science popularisation was in sharp contrast with the efforts the Dutch astronomers *themselves* made to inform the public about their research. As a matter of fact, Dutch astronomers had already been great popularisers since the days of the nineteenth-century Leiden astronomer Frederik Kaiser. Nowadays, Kaiser is especially remembered for his foundation of a new observatory in Leiden in 1860, but beside that, he was also a famous populariser of astronomy. In 2011, a special issue of the journal *Studium* was dedicated to Frederik Kaiser on the occasion of the restoration of his observatory. In several contributions, Kaiser's efforts to bring astronomy closer to the public through the writing of popular astronomical works were highlighted. Kaiser's popular writings can be roughly divided into three categories: publications in general cultural or popular scientific journals, translations and adaptations of other – mostly German – books, and of course his own popular books and leaflets (Van Lunteren, 2011, p. 30). The number of popular works Kaiser wrote was enormous. To give an example, in the first eight years after his appointment as director of Leiden Observatory in 1837, he completed no less than 50 (!) publications (Zuidervaart, 2011, p. 17).

One of the reasons why Kaiser undertook this effort was – as he said himself – the following: by means of enhancing the population's knowledge about astronomy, he wanted to create social support for astronomy – a discipline that was rather neglected in the Netherlands (Van Lunteren, 2011, p. 40). Without doubt, he succeeded in this aim. Because of his stream of popularising books and articles, Kaiser himself created ample social support for his observatory. In the Dutch newspaper *Handelsblad* of 10 February 1851, a review appeared of Kaiser's book *On the history of the discovery of the planets* ('De geschiedenis der ontdekking van planeten'). This review was accompanied by an – anonymous – call on 'the rich people in Amsterdam, Rotterdam, Middelburg and elsewhere'[84] (Zuidervaart, 2011, p. 19) to bring together about Dfl 10 000 for the foundation of a new observatory, equipped with new instruments. This initiative was the beginning of a series of actions that finally led to the foundation of the observatory (Zuidervaart, 2011, p. 19).

And the Dutch astronomers maintained their reputation as famous popularisers. Marcel Minnaert, for example, published many popular works in astronomy and physics – for example his three-volume work *De natuurkunde van 't vrije veld* ('The physics of the open air')- and he also actively

[84] 'de veelvermogenden in Amsterdam, Rotterdam, Middelburg en elders'.

supported several popularisation initiatives. In these efforts, he continually emphasised that popular publications had to be *high quality* publications, preferably written by *professional* astronomers. This is proven e.g. by his work for the foundation for amateur astronomers MACRO ('Meervoudig Centrum Ruimtewaarnemingen en Onderzoek'), which issued a monthly journal with the same name. Minnaert was often asked to review the articles before publication. He was often very critical in his comments. An illustrative example is the following. At the beginning of 1969, the director of MACRO had received two contributions – one about the Sun and one about cosmic radiation - from a Belgian amateur astronomer, a certain G. Janssens, which he sent to Minnaert for revision.[85] Minnaert discouraged publication, as the articles were 'superficial and poorly written with several flaws'[86]. And he continued:

> It is clear that you have a serious shortage of collaborators that are real astronomers. A man who has a small telescope and who has read a few popular books is not yet capable of writing a decent article on astronomy.[87]

As a result, Janssens's articles were not published.

Minnaert also tried to pass his ideas on science popularisation on to his students. De Jager is a famous example. He was very active in the Dutch Association for Meteorology and Astronomy (see above) – an amateur association – of which he was also president for a while. Minnaert's biographer Leo Molenaar said: 'His students propagated the values of his 'school': they (…) invariably strove for the popularisation of astronomy and physics in society.'[88] (Molenaar, 2003, pp. 403-404).

Minnaert's efforts for science popularisation seem to have been a very memorable aspect of his versatile career. Following Minnaert's death, the Dutch journalist Gerton van Wageningen published two articles in the newspapers *Nieuw Utrechts Dagblad* and *Het Parool* on 28 October, 1970 entitled: *Professor Minnaert: fighter for the popularisation of astronomy* ('Prof Minnaert: strijder voor popularisering sterrenkunde').

Another aspect of the popularisation of astronomy was the relation with the press. Around 1950, when the astronomers tried to get a ZWO grant for the large radio telescope, strict guidelines were developed for dealing with the press. This was especially pressing after a small incident had taken place in January 1950. In one way or another, rumours about the plans for the large radio telescope had come to the ears of journalist Idenburg, working for the Dutch newspaper *Het Vrije Volk*. Idenburg had asked Bannier for some information about the possible grant for this project. Next, he made a phone call to Minnaert, after which he visited the radio telescope in Kootwijk behind the astronomers' backs. Finally, a meeting took place at Utrecht Observatory with Idenburg, Minnaert and Houtgast. Minnaert insisted that Idenburg should hold up publication at least until the next board meeting of SRZM on 17 January 1950. Idenburg did so. It even seems that in the

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[85] The director of MACRO, A.C. Sabelis, to Minnaert, 8 February 1969, MA, 838, Box 8, Folder 1.

[86] Minnaert to Sabelis, 13 February 1969, MA, 838, Box 8, Folder 1.

[87] 'Het is wel duidelijk dat U groot gebrek heeft aan medewerkers die echt sterrekundigen zijn. Een man die over een klein kijkertje beschikt en een paar populaire boeken gelezen heeft, is nog niet in staat een behoorlijk artikel over de sterrekunde te schrijven.' Minnaert to Sabelis, 13 February 1969, MA, 838, Box 8, Folder 1.

[88] 'Zijn leerlingen droegen de normen en warden van zijn 'school' uit: ze (…) zetten zich steevast in voor de popularisering van de sterrenkunde en de natuurwetenschap in de samenleving.'

end, he never published this article, as we could not find it in *Het Vrije Volk* of early 1950. Nevertheless, at the meeting of 17 January, the matter was thoroughly discussed. Minnaert insisted that clear guidelines should be developed for dealing with the press. He thought that the very first radio astronomical results that were obtained with the radio telescope in Kootwijk should not be made public yet, as research was still in an embryonic stage. When the results appeared in the newspapers, there was a reasonable chance that their importance would be overemphasised. People might then get the impression that the astronomers were trying to 'force' a grant from ZWO. Only when the astronomers judged it the right time for publication should a press release be given to the press agency ANP ('Algemeen Nederlands Persbureau'). Minnaert's point of view got the support of De Voogt and Van der Wijck of the PTT and Veldkamp of the KNMI, who were strongly opposed to the appearance of 'uncontrolled messages' in the media. At the same time, it was said that it was impossible – and also undesirable – to prevent publication in general. Therefore, it was concluded that from then on each newspaper article about the Dutch radio astronomical research should be censored *before* publication.[89]

Nevertheless, these guidelines for dealing with the press were often re-negotiated. It even seems that after they were made, they were easily forgotten. Indeed, at the board meeting of 23 October 1950, we read: 'Following the visit of a reporter to the Observatory of Utrecht (…) it is desirable to develop guidelines concerning the provision of information to the press.'[90] Then, a rather halfhearted decision was taken: in the future, the astronomers would only generally inform ANP. This meant that individual journalists could be sent away. However, each board member of SRZM was free to follow this guideline or not.

At the beginning of 1953 when construction of the large radio telescope came closer, it was decided that no press release should be sent to ANP until there was enough information available about the construction, the price, the location etc. A premature press release had to be avoided, as this could give way to all kinds of rumour and speculation.[91] It was not until in March 1954 that the press release was issued. At the board meeting of 16 March, it was decided this should be done after the delivery contract of Werkspoor had arrived.[92] As we mentioned before, this happened on 18 March 1954. So a press release to ANP was issued a few days later. Subsequently, an article appeared in *Het Vrije Volk* on 25 March, in which we read:

> Werkspoor in Amsterdam is going to construct a new radio telescope with the enormous diameter of 25 metres. The installation, which will be completed in 1955, will be located on a moorland in the municipality of Dwingelo[93]. The order for the construction of this apparatus, which is going to cost Dfl 700 000, is given by the board of the foundation "Radio Radiation of the Sun and the Milky Way". The radio telescope consists of a parabolic reflector with a diameter of 25 metres. For the coating, wire mesh is going to be used, which in the wavelength range of 10-100 cm reflects equally well as the mirrors that are

[89] Minutes of the board meeting of SRZM of 17 January 1950, SA.
[90] 'Naar aanleiding van het bezoek van een verslaggever aan de Utrechtse Sterrenwacht (…) is het gewenst richtlijnen vast te stellen betreffende voorlichting aan de pers.' Minutes of the board meeting of SRZM of 23 October 1950, SA.
[91] Minutes of the board meeting of SRZM of 16 January 1953, SA.
[92] Minutes of the board meeting of SRZM of 16 March 1954, SA.
[93] At the time, 'Dwingeloo' was sometimes written as 'Dwingelo'.

used for optical waves.[94]

The reference to a price tag of Dfl 700 000 is somewhat surprising, as in the delivery contract of Werkspoor (see above) an amount of only Dfl 490 810 was mentioned, which would nevertheless increase by Dfl 15 000. It remains unclear whether the astronomers themselves mentioned this much higher amount – and if so, *why* they did that – or whether this was done by the press agency or the newspaper. (In any case, no reaction from the side of the astronomers followed about a 'mistake' in the article.)

The attitude of the Dutch astronomers towards the media can be summarised in one word: *paternalistic*. The above makes it clear that the astronomers wanted full control about what information was made public at what time. By doing this, they obviously thought the general public would take a positive attitude towards the project. This was not exceptional. As said before, it was a feature of the *Zeitgeist* that it was believed that 'public understanding of science' would automatically lead to 'public appreciation of science'. However, the astronomers were far from succeeding in controlling the media. The articles that appeared based on press releases that were issued by the astronomers themselves were generally low-impact articles. The aforementioned article in *Het Vrije Volk* of 25 March 1954, for example, was a short article, with merely some superficial factual information that appeared on page seven of the newspaper. A quick search in the Dutch National Library's database of historical newspapers[95] indicated that there was no other newspaper either that reported this information (or at least: none of the newspapers that is included in the database). This was in sharp contrast with e.g. the articles that appeared in August-September 1953, after the city council of Dwingeloo had voted against the construction of the radio telescope. Another quick search in the Dutch National Library's database of historical newspapers showed that no less than twelve articles covered this event. In the *Friese Koerier* of 31 August 1953, it was even front-page news. So this news was of a much higher impact, notwithstanding the fact that these articles appeared without the astronomers even knowing about it.

Besides informing the newspaper media about their project, the astronomers also did something else to inform the general public about the radio telescope: they made a documentary film. In early 1954, the board of SRZM agreed that the making of a documentary film about the construction of the large radio telescope was 'very worthwhile'.[96] ZWO, Werkspoor and the Leiden amateur film maker Herman Kleibrink - who was employed at Leiden Observatory as observer/photographer - were contacted. Initially, it was decided that the film would be about 20 minutes long. Werkspoor itself possessed filming equipment and was willing to lend it to the astronomers to reduce the costs. The total cost was estimated at Dfl 2000, a budget that was asked from ZWO as an 'extra subsidy'.[97] Filming began in the summer of 1954.[98] In the spring of 1955, it became clear that a

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[94] 'Werkspoor te Amsterdam gaat een nieuwe radiotelescoop bouwen met de enorme doorsnee van 25 meter. De installatie, die in 1955 zal worden opgeleverd, wordt geplaatst op een heideterrein in de gemeente Dwingelo. De opdracht voor de vervaardiging van dit apparaat, dat f 700.000 zal kosten, is gegeven door het bestuur van de stichting "Radiostraling van Zon en Melkweg." De radiotelescoop bestaat uit een parabolische reflector met een doorsnee van 25 meter. Voor de bekleding wordt gaas gebruikt dat voor het golflengtegebied van 10-100 cm, waarmee men gaat werken, evengoed reflecteert als de voor lichtgolven gebezigde spiegels.' *Het Vrije Volk*, 25 maart 1954.
[95] http://kranten.kb.nl (accessed on 22 December 2012).
[96] Minutes of the board meeting of SRZM of 16 March 1954, SA.
[97] Minutes of the board meeting of SRZM of 27 April 1954, SA.
[98] Minutes of the board meeting of SRZM of 9 July 1954, SA.

film of 40 minutes was preferred over one of 20 minutes. This, however, also meant that the cost more than doubled: an additional budget of Dfl 2050 was needed and obtained.[99]

The film was finished in late 1957 and was entitled *De Bouw van een Radiotelescoop* (The Construction of a Radio Telescope). Today, one can still watch it on the website of ASTRON.[100] It explains *why* the telescope had to be built, *how* it was built, and what kind of research could be done with it.

The film was regularly shown in secondary schools, companies, community colleges etc.[101] The press was very enthusiastic about it. A journalist of the Dutch newspaper *De Tijd* even called it 'the first popular-scientific film about astronomy that has been made in the Netherlands'.[102] It is not certain whether this film was really 'the first' Dutch popular-scientific film about astronomy, but in any case – like all kinds of science popularisation - in the late 1950s popular-scientific films and television programmes were indeed still scarce in the Netherlands. This situation would remain the same for decades. To give an example: in 1978-1979, out of a total of 3000 hours of broadcasting on Dutch television, only 10 (!) were dedicated to science programs. In Belgium, this was 110 hours out of a total of 2800 broadcasting hours in the same period (Dalderup, 2000, p. 175).

In hindsight, it is very hard to say whether, and if so, to which extent the 1950s attempts of the Dutch astronomers to bring astronomy closer to the 'general public' really helped Dutch radio astronomy forward. We do not have examples available were we can clearly pinpoint the effect of popularisation. The counterfactual question on what would have happened if there had been no popularisation, seems also impossible to answer. What we know for sure is that *De Bouw van een Radiotelescoop* did not bring about a more positive attitude of the general public towards the *building* of the telescope, as it was only shown *after* the opening of the telescope. Hence, it had mostly a legitimising function.

2.8 THE FIRST RADIO ASTRONOMICAL RESULTS

While the radio telescope in Dwingeloo was built, observations in Kootwijk were in full swing and remarkable astronomical results were obtained. From July 1952 to August 1955- the few years of its scientific use – the Kootwijk dish was used almost exclusively for hydrogen-line studies of the Galaxy (Strom and Van Woerden, 2006, p. 7). The first – and maybe also the most remarkable survey – was the one of the spiral structure of the Galaxy. In June 1952, people from SRZM and some Leiden students started the survey. Van de Hulst did the reduction of the data by hand (a very laborious procedure), initially alone, later with the help of two PhD students (Westerhout, 2002, p. 29). A quick analysis of the first results allowed Oort to derive locations of hydrogen

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[99] Minutes of the board meeting of SRZM of 31 May 1955, SA.
[100] http://www.astron.nl/about-astron/history/footage/historic-footage (accessed on 26 December 2012).
[101] Wetenschappelijke nieuwsgierigheid verfilmd. Cineast geeft populaire les in sterrenkunde, in: *De Tijd*, 12 April 1958.
[102] '(…) de eerste populair-wetenschappelijke film over sterrenkunde, die ooit in Nederland werd gemaakt.' Wetenschappelijke nieuwsgierigheid verfilmd. Cineast geeft populaire les in sterrenkunde, in: *De Tijd*, 12 April 1958.

concentrations in the Galactic Plane (the most dense part of the galactic dish). These locations gave him hints of *spiral arms*.

In 1953, Van de Hulst was invited to give the Halley Lecture at Oxford University about this research on the Milky Way. In his talk, he did not hesitate to emphasise how important these results were:

> It is not necessary to emphasize the importance of these investigations: they stand out against the hopes and desires of several generations of astronomers. To observe the spiral arms in our own galaxy has been the distant aim of many researches. (Van de Hulst, 1953, p. 138)

The first results of the survey were published by Van de Hulst, Muller and Oort in 1954. It is in this article that the well-known HI (neutral hydrogen) map of the Galaxy, showing the spiral structure, was published for the first time (later, many other versions of this map appeared).

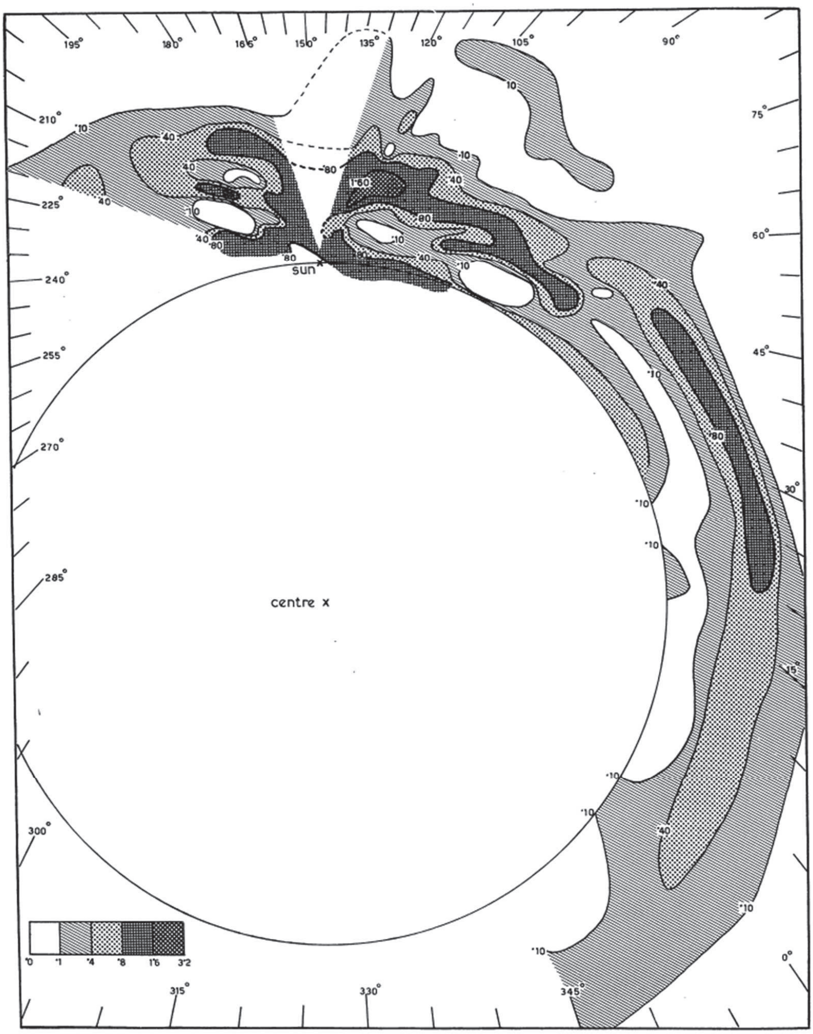

FIGURE 3. Contour map of hydrogen density in the galactic plane (Van de Hulst, Muller, and Oort, 1954, p. 146)

The first survey was completed in June 1953. A second one was started in November 1953 and finished in August 1955 and aimed at a three-dimensional mapping of the Milky Way. Reduction of the data was this time mainly done by the PhD student Gart Westerhout. In a 1957 article, Westerhout published the following map of the hydrogen distribution:

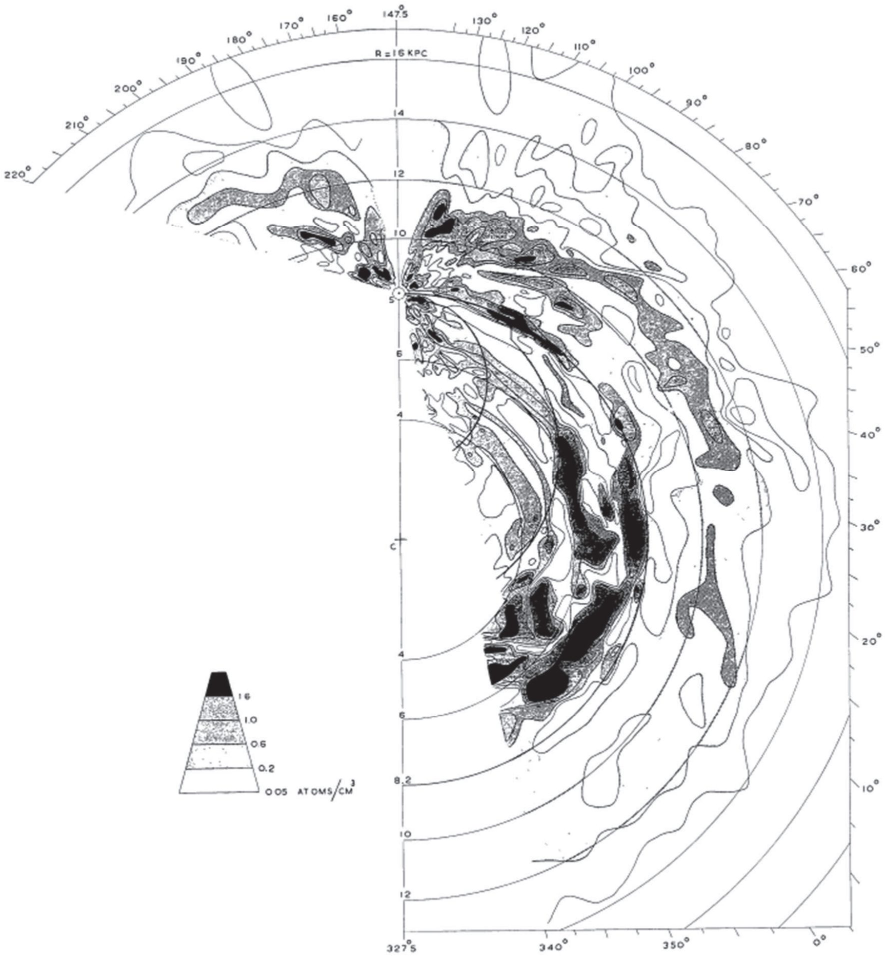

FIGURE 4. Contours of equal density of neutral hydrogen in the Galactic System (Westerhout, 1957, Plate B)

As one can see, these maps only cover half of the Galaxy. This is of course due to the fact that from the Netherlands, only the northern part of the Galaxy is visible. Fortunately, in the southern hemisphere some research was going on too. As mentioned in the previous chapter, shortly after the detection of the 21-cm line in the Netherlands, confirmation came from Australia. There too, follow-up research was done. In 1951, a three-month survey was undertaken by Christiansen and Hindman who had also found a hint of a spiral arm by then (see Christiansen and Hindman, 1952).

The search for the 21-cm line was the beginning of an intense cooperation between Dutch and Australian astronomers (see also Chapter IV). There was a regular exchange of data and results between the two groups. The manuscript of the article of Christiansen and Hindman of 1952 was discussed at the board meeting of SRZM in May 1952.[103] Following this early work, the Australian astronomer F.J. Kerr and collaborators from the CSIRO Division of Radiophysics undertook new surveys of the Southern part of the Galaxy, using an 11-metre reflector at Potts Hill, near Sydney (Strom and Van Woerden, 2006, p. 11) In 1957, Kerr came to Leiden for several months and he and Gart Westerhout joined together their respective maps to derive the first overall look at the hydrogen in the Galaxy. This map became known as the famous 'Leiden-Sydney map of the Milky Way' (Oort, Kerr and Westerhout, 1958) (see also Chapter IV) and shows the spiral structure of the Galaxy in both the northern and southern hemisphere.

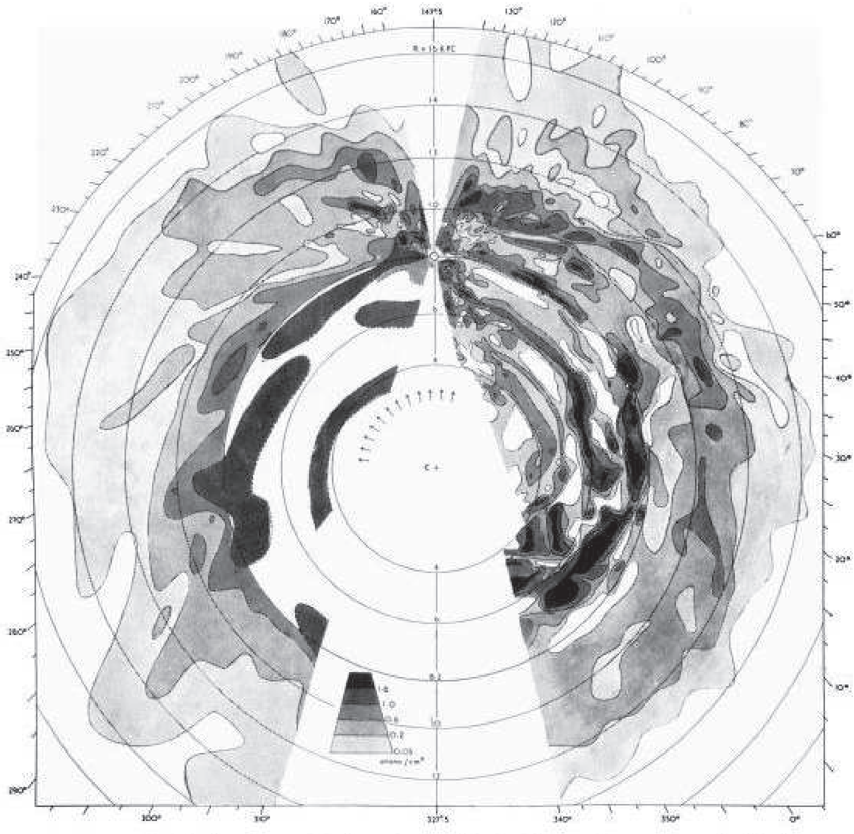

FIGURE 5. Distribution of neutral hydrogen in the Galactic System (Oort, Kerr and Westerhout, 1958, Plate 6)

Another important aspect of the radio telescope in Kootwijk was its role in the new Galactic Coordinate System. The Dublin General Assembly of the IAU of 1955 appointed a sub-commission to investigate the desirability of a revision of the Galactic Pole and of the zero point of Galactic

[103] Minutes of the board meeting of SRZM of 27 May 1952, SA.

longitude. The sub-commission reported to the Moscow General Assembly in 1958 (Strom and Van Woerden, 2006, p. 12). This Assembly endorsed a resolution which was reproduced in the final report of the Sub-Commission (Blaauw et al., 1960). The main clauses in this resolution were:

(a) that a standard system of Galactic coordinates be adopted for which the pole is based primarily on the distribution of neutral hydrogen in the inner parts of the Galactic system
(b) that the zero of longitude be chosen near the longitude of the Galactic nucleus
(c) that Commission 33b be authorised to define exact values of the coordinates of the Pole and of the zero of longitude immediately after the final reduction of the relevant observations is finished (Blaauw et al., 1960, pp. 127-128)

The final report of the sub-commission contained - besides the coordinating paper of Blaauw et al., 1960 - four other papers (Gum, C.S., Kerr, F.J. and Westerhout, G., 1960; Gum, C.S. and Pawsey, J.L., 1960; Blaauw, 1960; Oort, J.H. and Rougoor, G.W., 1960). From these, it becomes clear that the definition of the Galactic Pole (and hence, of the Galactic Equator) was essentially based on the 21-cm line observations carried out at Kootwijk and Potts Hill (Strom and Van Woerden, 2006, p. 12).

The Würzburg in Kootwijk was not the only one used for radio astronomical research. Since 1952[104], SRZM had been making plans to get some additional Würzburg dishes from Norway. The plan was to use these dishes for solar research, while the large radio telescope would primarily be used for Galactic research. The dishes arrived in the fall of 1954.[105] In 1955, they were installed in Dwingeloo, one to the east and one to the west of the large radio telescope. As planned, they were mainly used for solar research, as a two-element interferometer, but one of them also as a single dish in early polarisation studies. The fate of these dishes is documented. In 1962, the eastern dish moved to the receiving station NERA in Nederhorst den Berg to strengthen the solar effort there. In 1973, it was returned to Dwingeloo as the PTT receiving station was being wound down. This dish was dismantled in the late 1980s (Strom and Van Woerden, 2006, p. 15). The western dish ended up in the Deutsches Museum in München in 1991.

Despite the pioneering work that had been done with the radio telescope in Kootwijk, nothing is known about its fate after 1955, when observations started with the radio telescope in Dwingeloo. Several authors (e.g. Strom and Van Woerden, 2006; Beekman, 1999) have investigated the mystery of what happened with it.

It is uncertain whether the Kootwijk dish was ever transported to NERA. The PTT archives do not seem to give any clarification on this matter either (Beekman, 1999, p. 157). It is rather improbable that it still exists somewhere. Van Woerden recalls hearing that it might have broken down in 1956. If this is correct, it seems likely that it has been scrapped (Strom and Van Woerden, 2006, p. 15).

On 11 May 2011 the detection of the 21-cm hydrogen line 60 years before, was celebrated. But by then the telescope was no longer there. There did not even remain anything special visible at the 'Turfberg' - the place where the old radio dish once stood – that would remind one of the telescope.

[104] Minutes of the board meeting of SRZM of 30 June 1952, SA.
[105] Minutes of the board meeting of SRZM of 30 November 1954, SA.

Therefore, on 11 May 2011 an information board was inaugurated at the 'Turfberg' to make people aware of the glorious past of this place.[106]

FIGURE 6. Information board at the 'Turfberg' (www.pressart.nl)

The radio telescope in Kootwijk was only used for a few years. After 1955, observations were carried out with the radio telescope in Dwingeloo. The first scientific programme of the Dwingeloo telescope was a continuum survey at 21.6 cm of which the results were published in 1958 (Westerhout, 1958). The survey contained the positions, sizes, fluxes (i.e. the apparent brightness) and identifications of 82 discrete sources (Westerhout, 1958, pp. 236-239). Later, it would be called the 'W catalogue' (Westerhout's Catalogue) (Strom and Van Woerden, 2007, p. 379).

The first 21-cm line observations were carried out in the fall of 1956. They concentrated on the motion of the gas. This was a follow-up of research that had been done in Kootwijk in 1954, when deviations from circular motion had been found near the Galactic Centre.

Although spectral line work would take the lion's share of research with the 25-m dish, continuum studies continued to be important throughout its active period (Strom and Van Woerden, 2007, p. 380). Not only were large-scale Galactic HI (i.e. neutral hydrogen) studies carried out, also several investigations of smaller structures were made. For example, the structure and motion of HI in specific regions (e.g. Orion) were mapped, and systematic studies of structure and motions of interstellar HI clouds were carried out. Moreover, studies of HI in external galaxies were performed, first of the Andromeda Galaxy (1957) and later also of other galaxies. Some solar research was carried out, but this was only in the beginning of the 1970s, when a 60-channel spectrograph was built.

[106] Several videos about the inauguration board can be found on the internet, for example: http://vimeo.com/23760815 (accessed on 10 March 2013).

After 40 years of performing frontline research, the radio telescope in Dwingeloo was decommissioned in 1999. Maintenance costs had become a problem and it was clear that new research projects could be carried out better by the radio telescope in Westerbork (Strom and Van Woerden, 2007, p. 386). As maintenance was no longer carried out, the instrument started to rust and metal pieces started to fall down. Hence, plans were made to demolish it. However, thanks to the creation of the foundation CAMRAS (C.A. Muller Radio Astronomy Station) in 2007, the future of the telescope looks very different. CAMRAS is an organisation of volunteers that set out the following goals:

(a) making the radio telescope available for (amateur) astronomers and radio amateurs
(b) stimulating young people's interest in science and engineering by giving school groups the opportunity to use the telescope
(c) the conservation of the radio telescope as scientific industrial monument[107]

Since 2009, the radio telescope in Dwingeloo has been a protected monument, thanks to a large extent to the efforts of CAMRAS. Restauration of the dish started at the beginning of June 2012. It was a huge effort to lift the 38 ton dish off its pedestal. All parts were sandblasted and repainted, some parts were replaced. On 19 November 2012, the dish was successfully replaced. The full restauration of the telescope was completed in September 2013.[108]

2.9 THE IMPORTANCE OF BEING FIRST: BETWEEN COMPETITION AND COOPERATION

Sometimes, early radio astronomy is presented as a field characterised by openness, (international) cooperation, interdisciplinarity etc. rather than by competition. Often, these accounts are told by (radio) astronomers themselves. Woody Sullivan, for example, sees the early days of the 21-cm hydrogen line as an example of international cooperation and not as the 'usual kind of race' (Sullivan, 2009, p. 414). But historians also sometimes defend the view that early radio astronomers worldwide constituted an open and cooperative scientific community. For example, in his recent book *A Single Sky* (2013), historian of science David Munns characterises the community of the first radio astronomers primarily as an open and cooperative scientific community. He sees this alleged cooperative spirit also as an important explanatory factor of the success of early radio astronomy. Thus, he writes that 'competition didn't drive the production of scientific knowledge in radio astronomy; sharing of data did' (Munns, 2013, p. 106).

We believe, however, that this kind of characterisation of early radio astronomy is at least partly a myth. It is true that in the radio astronomical community, overlapping research and other overlapping projects were avoided. In the late 1940s, for example, correspondence between Martin Ryle's group at Cambridge and Joe Pawsey from Australia revealed the wish of both groups to avoid overlapping research. On 3 November, Pawsey forwarded a list of his projects to Ratcliffe of Cambridge as a 'means of avoiding possible clashes of interest between our two laboratories' (quoted in Munns, 2013, p. 57). Munns considers this to be a proof of the strong desire of both

[107] http://www.camras.nl/ (accessed on 7 October 2013).
[108] Pictures and video's about the restauration can be found on the website of CAMRAS.

groups to forge new community ties (Munns, 2013, p. 57).

However, the strong desire to avoid overlap mostly had merely to do with matters of funding. Indeed, funding organisations were less inclined to provide funding for research that was also done elsewhere or for instruments that had duplicates abroad. When the Dutch planned to build the radio telescope in Dwingeloo, they were anxious to be the first to have such an instrument, as this would facilitate funding. In the summer of 1949, the Dutch construction company Werkspoor had made an estimate of the price tag of the large telescope and thought the construction would cost around Dfl 200 000. This would be about 16% of the entire ZWO-budget for 1950 (which was Dfl 1 410 293: Annual report ZWO, 1950). The board of SRZM realised this was a very large amount of money. Before asking a grant to ZWO, it was considered whether, similar plans existed abroad. If this was the case, it was doubted whether it would be useful to continue, because then the chances to get funding seriously diminished. The Dutch felt threatened by the Americans in the first place. Letters were written to Cornell University and the Bureau of Standards in Washington to find out whether similar plans existed there.[109] Some members, for example Van de Hulst, thought that if America was also preparing the construction of such a telescope, the Dutch plans had to be abolished.[110]

However, the fear for competing American projects proved to be groundless. Soon, an answer came from America that there were no similar projects. In the existing American plans, either the mirrors were smaller or they were fixed (the Dutch one would be fully steerable).[111] But the relief about the non-existence of competing American plans did not last long. A few months later, alarming news arrived from England, when the astronomer Spencer Jones wrote the Dutch that there were plans to build a 250-feet reflector in Manchester, which meant that the Dutch telescope would soon be surpassed by that instrument. Again, the board of SRZM discussed the question whether the Dutch project had not better be given up. In the end, however, it was decided to go ahead.[112] In the grant proposals, not a single mention was ever made about the British competing plans.

This fear of competing projects threatening funding was not groundless. Remember that when an ad hoc advisory committee of ZWO advised positively on the building of the 25-m radio telescope, an important argument was that ‘in other countries, there were no plans to build such a 25-m dish and so Dutch radio astronomy would stay at the international top’ (see above). In the aftermath of the war, enhancing the national prestige of the country was an important issue. And great importance was attached to being ‘the first’, ‘the best’, ‘the biggest’ etc. in matters of science.

Even when the decision to give the grant for the radio telescope had already been taken, the Dutch feared that similar projects abroad would be completed *before* the Dutch one, because of the huge delays in the construction caused by Werkspoor. In the meeting of September 1954, we read that the board of SRZM ‘regrets the delay, especially because of the radio telescope projects elsewhere’.[113]

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[109]Minutes of the board meeting of SRZM of 20 September 1949, SA.
[110] Minutes of the board meeting of SRZM of 20 September 1949, SA.
[111] Minutes of the board meeting of SRZM of 1 November 1949, SA.
[112] Minutes of the board meeting of SRZM of 23 May 1950, SA.
[113] ‘betreurt de vertraging, vooral wegens de elders op staple staande projecten voor radiotelescopen’. Minutes of board the meeting of SRZM of 14 September 1954, SA.

This very competitive attitude was not typical for the Dutch, it was a general feature of the community of the first radio astronomers. Maybe the most prominent example of this was the British astronomer Martin Ryle. Ryle is both remembered as a highly talented scientist and as a very difficult person. His temper was well-known. A story that has often been retold is that when Ryle was working at TRE during the war, he once threw an ink-bottle at a senior officer. These kind of intense outbursts seem to have been an on-going feature. As Jane Gregory – reader in science and technology studies at University College London - said:

> (…) colleagues have described him as obsessive, fervent, passionate and religious (in the least complementary sense – Ryle was well known to consider himself a Humanist); and he has been credited with both genius and paranoia. According to Gold[114] he was 'a very egocentric, absolutely unbelievably intense person…he had too much intensity of beliefs that were not compatible with the science.' (Gregory, 2005, p. 56)

Ryle's personality became also clear at the OECD *Symposium on Large Antennae for Radioastronomy* that was organised from 12 to 14 December 1961. At this symposium, two possible designs of what would become the radio telescope in Westerbork were discussed (see also Chapter IV). Although the British were by then also preparing an instrument, Ryle did not describe it at the symposium. Later that month, he explained why to Oort:

> When I got back to England, I heard that the D.S.I.R.[115] has decided to make us a grant for our new radio telescope and this should be announced within the next few days. I am sorry that the timing of this announcement should have been such that I did not know in time for the Paris meeting. We had some discussions before I left on whether or not I should describe our instrument, but eventually for several reasons, concluded that I should not. This is partly because it was quite uncertain whether we should get support soon, at some time in the future, or whether the application would be turned down indefinitely. In the case of the second possibility it seemed a pity from our point of view because there would be a number of other groups at the conference both in Europe and the U.S.A. who might wish to take up the construction of an instrument of our design before we could, and with the financial state of our country this probably represents the only chance of our being able to build an instrument of large resolving power.[116]

Although Ryle may be a rather atypical example, his behaviour is still illustrative for the competitive environment of early radio astronomy. In Munns' book, in which Ryle is frequently mentioned, this side of the story is entirely neglected.

Of course, it is absolutely true that the early community of radio astronomers was a very international community. But this was nothing exceptional. (Radio) astronomy is almost by definition an international field: to map the complete sky, observations needed to be done as well in the northern as in the southern hemisphere, which made international cooperation necessary (see the example of the Leiden-Sydney map of the Milky Way); international agreements had to be made on frequency allocations etc. (see also Chapter III). We believe, however, that this strong international cooperation does not imply that there was not much competition, as Munns suggests

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[114] The astronomer Thomas Gold (1920-2004).

[115] The Department of Scientific and Industrial Research (DSIR) (founded in 1915/16) was a government organisation - comparable to the Dutch ZWO – for the support of scientific research.

[116] Ryle to Oort, 21 December 1961, OA, 114c.

in his book. On the contrary, international cooperation and competition went hand in hand. In his article on the history of universalism, the Dutch historian of science G. Somsen claimed that in the nineteenth century, the international organisation of science went hand in hand with scientific nationalism. While the new institutions were presented as vehicles for international cooperation, they were also meant to assess and acknowledge scientific accomplishments. After all, national achievements can only be measured by international standards. So Somsen concludes scientific internationalism was not a counterforce to nationalism, but effectively channelled and facilitated it (Somsen, 2008, p. 366). When radio astronomy emerged after the Second World War, the international political context was of course no longer the same as in 1900. However, we think that although ideas of 'nation states' and 'nationalism' were typically nineteenth century ideas that may have faded by the middle of the twentieth century, international cooperation was still a means of furthering the goals of a smaller entity, be it a nation, a research group or an individual. In our story of Dutch radio astronomy, it becomes abundantly clear that Oort furthered his own projects by means of international cooperation.

The community of early radio astronomers did not only cross national boundaries, it also traversed disciplinary boundaries. It was an interdisciplinary scientific community, consisting of radio physicists and optical astronomers, but also engineers and technicians. Like Munns says: 'The radio astronomers emerged when several groups of scientists coalesced around a set of new research tools – highly sensitive radio receivers – which became understood as new astronomical instruments.' (Munns, 2008, p. 54). However, this does not mean that there was no antagonism between the different groups.

The gap between optical astronomers and radio astronomers is dismissed by Munns as a 'foundational myth' that has been told and retold, for example by Woody Sullivan (2009). This myth, based on the recollections of 'those who were there', must be treated with care, says Munns. 'When we rely on archival sources, a very different picture emerges – a picture not of antagonism and competition, but of community with a substantial degree of cooperation and interchange.' (Munns, 2008, p. 81). However, first of all, authors such as Woody Sullivan used a great deal of contemporary sources to illustrate this point – and no 'recollections of those who were there'. As could be read in Chapter I, sources from the late 1940s and the early 1950s already mention the often very difficult relation between optical astronomers and radio astronomers.

When radio astronomy emerged, the new field did not only have to deal with a gap between optical astronomers and radio astronomers, but also with a gap between scientists and engineers. Although engineers made very essential contributions to the field, their visibility remained relatively low compared to that of the astronomers. This brings us to our following section.

2.10 WHAT ABOUT THE ENGINEERS?

De Voogt, who was an engineer, was crucial for the beginning of Dutch radio astronomy. As mentioned above, early Dutch radio astronomy embarked on an era of success when Muller was hired as the leading engineer of SRZM. And Muller was not the only engineer who was a key person for Dutch radio astronomy. At about the same time as Muller, another engineer was also hired: Ben G. Hooghoudt. Hooghoudt was an engineer from Delft who had joined the PTT. While Muller was specialised in electronics, Hooghoudt was specialised in mechanics and construction, so it was an ideal situation for SRZM to hire both persons. In October 1950, it was decided that Hooghoudt would remain employed by the PTT, but that he would be seconded to SRZM. SRZM would then pay a part of his salary to the PTT.[117]

Hooghoudt's work for SRZM can hardly be overestimated. He played a crucial role in the construction of the radio telescope in Dwingeloo as well as in the construction of the radio telescope in Westerbork, as will be explained in Chapter IV.

Hooghoudt was not merely a good engineer; he was also the contact person with Werkspoor. In early 1953 he went to Manchester to study the plans for the 'Lovell Telescope' in Jodrell Bank. With what he learned in Jodrell Bank in mind, he discussed the construction of the Dutch telescope with Werkspoor.[118] When Werkspoor had considerably increased the price of the telescope, to Dfl 586 000, it was thanks to a thorough discussion with Hooghoudt that the price was brought down to Dfl 530 000.[119]

Besides being the contact with Werkspoor, Hooghoudt was also the main negotiator in the discussions with the Forestry Commission and the Society for the Preservation of Nature monuments in the search for a suitable location for the telescope.[120]

Although the engineers played a crucial role in Dutch radio astronomy, the radio telescopes in Kootwijk, Dwingeloo and later also in Westerbork are in the first place tied to the name of Oort. Van Delft, for example, presents the construction of the first radio telescopes as an almost exclusive 'Oort matter' (Van Delft, 2008), and historian Van Berkel also sees radio astronomy as a field that was entirely dominated by the person of Oort (Van Berkel, 2000). On the other hand, in historiography several efforts have quite recently been undertaken to emphasise the importance of the role of these engineers. It is the more remarkable that the efforts to lend the engineers more visibility in historiography, are mostly taken not by professional historians, but by radio astronomers themselves, such as Richard Strom and Ernst Raimond. Richard Strom, for example, published an article on De Voogt, whom he calls a 'radio pioneer' who set up the first radio astronomy group in the Netherlands (Strom, 2007). (Indeed, as explained in Chapter I, De Voogt set up a radio astronomy group at the PTT to study how the ionosphere influenced radio propagation and what effect solar activity had on it.) And in his description of the making of the radio telescope in Westerbork, Raimond emphasises the crucial role of the engineers in the development of the different designs of the telescope (Raimond, 1996). Not only in scientific articles, but also in the 2009 film *Spiral Galaxy, the Milky Way unraveled*, the role of engineers and technicians in the history of Dutch astronomy becomes clear. Film maker Maarten Roos – a Dutch astrophysicist by training – stresses the importance of excellent engineers - such as Muller -, in the first place for the development of good receivers. And he even goes further: the story is told by four contemporary protagonists of early postwar Dutch radio astronomy: Blaauw, Van Woerden, De Jager and… technician Arie Hin. By presenting the story this way, Roos explicitly wants to put the technicians on an equal footing with the astronomers.

But when we play the devil's advocate, we can also say that it is not entirely surprising that Oort is often seen as the embodiment of Dutch radio astronomy. In the end, we should not forget that

[117] Minutes of the board meeting of SRZM of 3 October 1950, SA.
[118] Minutes of the board meeting of SRZM of 3 February 1953, SA.
[119] Minutes of the board meeting of SRZM of 27 October 1953, SA.
[120] Minutes of the board meeting of SRZM of 22 December 1953, SA.

in the Netherlands, the initiative for radio astronomy was taken by astronomers, while in most other countries, it was taken by engineers and physicists with a background in war industry. The latter entails that in radio astronomy it is often hard to privilege the position of scientific motivations and results vis-à-vis technological motivations and results (Sullivan, 2009, p. 450). (Early) radio astronomy was indeed very much instrumentation-driven. As will also be shown in the following chapters, a technical problem early radio astronomers had to deal with, was the *poor angular resolution* of their equipment. This meant that positions in the sky could not be adequately determined. This in turn, influenced the results that could be obtained and – more fundamental – the status of the very field. The British astronomer Scheuer, for example, wrote in his PhD thesis of 1954: 'Radio astronomy cannot, as yet, claim to be an exact science.' (Scheuer, 1954, p. iv; also quoted in Sullivan, 2009, p. 450).

In general, it can be said that radio astronomers faced severe technical problems, which they tried to solve as soon as possible to better answer the questions about the radio sky. But sometimes, especially in the first years, this went so far that radio astronomers were in the first place driven by applying – and improving – their instrumentation. As Sullivan says, many of the investigators had the Baconian point of view that one should look up at the sky and see what showed up. As one early radio astronomer told Sullivan in an interview: 'We felt we were opening up the frontiers of physical knowledge … [Our work] wasn't to prove any particular theory or fill in any particular gap in knowledge.' (S.J. Parsons to Sulllivan, 1978; quoted in Sullivan, 2009, p. 450)

The point is now that the situation in the Netherlands was rather different. While in most countries, early radio astronomy was strongly instrumentation-driven, it was strongly science-driven in the Netherlands. There, technology was only a *means* to what was considered the more important *end* of scientific knowledge (Sullivan, 2009, p. 452). Not only was the initiative for radio astronomy in the Netherlands taken by astronomers, the field would be dominated for several decades by the astronomers, by one person in particular: Oort. The engineers were responsible for the instrumentation, for the contacts with construction companies etc. So they were vital to the success of early Dutch radio astronomy. However, the observational programme was developed by Oort and his colleagues. It was the astronomers who decided what would be investigated and the engineers were serving them. So in the end, it is not entirely surprising that the three telescopes – in Kootwijk, Dwingeloo and later Westerbork – are in the first place remembered as 'Oort's telescopes'.

The cooperation between the Dutch astronomers and the engineers also seems to have been very good in general. No traces of severe struggles for authority could be found. Everybody seems to have accepted that in the Netherlands, radio astronomy was 'a matter of astronomers' in the first place.

The situation in Britain was very different, more specifically in Jodrell Bank. As explained in the previous chapter, the early radio astronomy group in Jodrell Bank was led by B. Lovell, a physicist who had been involved in radar research during the War at TRE. In the post-war decade, Lovell's group was the world leader in the development of techniques to measure the trajectories and velocities of meteors. Moreover, like the Dutch group, Lovell's group started the construction of a huge fully steerable radio telescope in the early 1950s. This telescope became operational in August 1957. It had a dish of 76 m and was then the largest telescope in the world. In his book on the history of Jodrell Bank, historian of science Jon Agar pays a great deal of attention to the question of *authority* in the construction of the telescope. He emphasises that Lovell 'was the telescope as the telescope was him' (Agar, 1998, p. 133). Lovell's prestige was at the expense of the visibility of the engineer. Charles Husband, a Sheffield engineer, designed this telescope. After a few years, however, a conflict of authority arose between Lovell and Husband. The question was who should be in control of the telescope: the engineer or the astronomer?

The conflict became apparent after the launch of Sputnik. A few months after the radio telescope had become operational the Russians launched Sputnik on 4 October 1957. It was indeed originally intended to use the telescope e.g. on American satellites 'to obtain fundamental data which would be necessary as a first stage in the detection and tracking of enemy long range missiles' (Agar, 1998, p. 75). But the surprise of Sputnik now allowed the potentialities of the instrument to be demonstrated. The radio telescope was funded by the British government (by DSIR, an organisation comparable to ZWO) and by a private foundation: the Nuffield Foundation. As in the end the cost of the telescope was found to be much higher than originally planned, additional funding was needed. But money was not so easy to find. As a consequence, at the moment the telescope was inaugurated, it still had a debt to pay of £ 150 000.[121] It has often been told that the appearance of Sputnik marked a turning point in the telescope's financial history. Lovell himself said about this episode:

> The time from the autumn of 1952, when work began on the foundations (…), to October 1957 when we first used the telescope, was a period of immense anxiety exacerbated by the political and financial problems which (…) nearly destroyed Jodrell Bank as a research establishment. Nevertheless, the success of the telescope in detecting by radar the carrier rocket of the first Russian Sputnik in October 1957 (…), and the few years afterwards when it became a part of the American deep space network, created the conditions which enabled us to overcome those problems. We survived, and the instrument has now for over a quarter of a century been in continuous use. (Lovell, 1984, p. 209)

Jon Agar, on the other hand, shows that the appearance of Sputnik was neither decisive in the additional government funding of Jodrell Bank, nor in persuading the industry to donate to the telescope. The industrial partners that donated to the telescope were often persuaded – often by Lovell himself – by entirely other arguments than satellite tracking (Agar, 1998, pp. 77-81).

The role of Sputnik in obtaining additional funding is in itself of minor interest for our story. What *is* important, on the other hand, is that the above shows that the history of the radio telescope in Jodrell Bank is very different from the history of the Dutch radio telescope. In Dwingeloo, the radio telescope was exclusively used for 'pure' astronomical research. The research programme was developed by university-based astronomers and all the funding came from the government. In Jodrell Bank, on the other hand, the situation was mixed. The initiative for the telescope was taken by a university-based scientist, Lovell, but the research programme was only partly an academic one. A part of the observation time was reserved for satellite tracking. Moreover, funding did not come only from the government, but also from industrial partners and private foundations. And it was exactly in this non-academic part of the programme that the tensions between Lovell and Husband became apparent. The day after the launch of Sputnik, Kington (of Husband & Co) had offered to 'come forthwith to Jodrell Bank in order to carry out any movements [Lovell] might require on the 250ft telescope to track the Russian satellite' (Agar, 1998, p. 119). But Lovell refused.

[121] Jodrell Bank Radio Telescope Appeal, in : *Nature,* 182 (1958), p. 1484.

Husband was very disappointed. He interpreted the refusal as Lovell being in doubt whether the telescope could already be relied upon to perform. But the reality was different. In a letter of 10 October 1957 to Mansfield Cooper, Vice-Chancellor of Manchester University, Lovell wrote that it was 'an unusual and most undesirable state of affairs that a consulting engineer should attempt to dictate the research policy of a University department about whose functions he knows extremely little' (quoted in Agar, 1998, p. 120). This answer clearly illustrates that Lovell's hesitation had in the first place to do with 'ownership' of the telescope. Secondly, as Agar points out, in Lovell's explanation there was the assertion of his authority and responsibility for policy, which included the separation of the 'scientific' from other activities. And it was clear that Lovell esteemed 'academic' work much higher than satellite tracking. As he continued in his letter to the Vice-Chancellor: 'the primary function of this instrument is to explore the remote parts of the universe, … plans for using it on satellite work have a relatively low priority' (quoted in Agar, 1998, p. 121).

The tension between Lovell and Husband can, according to Agar, be related to the scale and complexity of research that the telescope represented (Agar, 1998, p. 141). We think Agar is absolutely right in this. Moreover, Agar's thesis can also be used to explain why these kinds of tensions were non-existent in the Netherlands. There, the research was of a purely academic character. In no way was the telescope ever used for satellite tracking or other defence-related purposes. Nevertheless, this matter had occasionally been discussed since the late 1950s. In 1959, when preparations were made for the 'cross antenna', the question arose whether the Dutch astronomers should (occasionally) participate in other than purely astronomical activities with this radio telescope. In June 1959, the Dutch Minister of Foreign Affairs, Joseph Luns, wrote to Oort that, as the cross antenna would be very expensive, it was worth considering asking financial support from NASA (National Aeronautics and Space Administration). However, this support would not be unconditional:

> The condition for this support will without doubt be that the telescope makes a contribution to the activities of NASA. In the strict sense, this could be done by means of the tracking of satellites, which is also done by the English telescope in Jodrell Bank. In the broader sense [it could be done] by the participation in the pure astronomical research which is undertaken by NASA too.[122]

However, the astronomers did not accept this offer.

The next year, an analogous matter was discussed during a board meeting of SRZM. Van de Hulst had asked whether in 1961, the radio telescope in Dwingeloo could be used for satellite tracking for NASA during about a month. However, the reactions from the board were not positive, as it was doubted whether this could be brought in line with the other activities of SRZM.[123] In the end no satellite tracking was done, neither with the radio telescope in Dwingeloo, nor with the one in Westerbork.

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[122] 'Voorwaarde voor deze steun zal ongetwijfeld zijn, dat de telescoop een bijdrage levert in de activiteit van de NASA. In engere zin zou dit kunnen geschieden door het traceren van satellieten, zoals ook wordt gedaan door de Engelse telescoop te Jodrell Bank. In ruimere zin door de deelneming aan het zuiver astronomisch onderzoek dat ook door de NASA wordt verricht.' J.C. Kruisheer voor Luns aan Oort, 16 June 1959, SA, NWO.

[123] Minutes of the board meeting of SRZM of 4 October 1960, SA.

The fact that in the Netherlands the research programme was purely astronomical made the role of the engineer there very clear and straightforward. Indeed, there was no way that the engineer could have a say in this, as this fell outside his domain.

In historiography, it is sometimes said that the public effacement of the engineer – and the simultaneous prominence given to the scientist – is a typically European matter. As Peter Galison said:

> (…) American physicists had an entirely different relation to engineers than did their European counterparts. In particular, the Americans considered the joint physics-engineering projects of accelerator building to be a worthy collaborative endeavor. (…) European physicists (…) tended to segregate engineering tasks from physics concerns, and the physicists in the early years tended to shun the "dirty" details of engineering. (Galison, 1992, p. 5)

However, a comment should be made on this quote. It is true that in America, university physics departments undertook much more efforts to engage in research with industrial companies, engineers etc. but these co-operations often entailed a lot of tensions. Often, there were concerns over the *control* of the research, as Galison himself, Hevly and Lowen demonstrate in their contribution on physics research at Stanford (1992). Galison also mentions the American industrial company Du Pont as an example in favour of his thesis. But according to us, Du Pont is a good example to illustrate exactly the contrary. First of all, the history of Du Pont itself illustrates the often difficult relation between industrial and academic scientists. Moreover, the relations between Du Pont and external partners also illustrate the tensions between scientists and engineers.

Du Pont was founded in 1802 by a French immigrant: Eleuthère Irénée du Pont de Nemours. A century later, in 1902, the company founded its first formal research and development laboratory. Since then, the firm has been among a handful of USA corporations pursuing industrial research and development on a consistently large scale (Hounshell, 1992, p. 236). Du Pont developed a wide range of chemical products: paints, plastics, explosives, cellophane etc. These products possessed a common scientific basis. Charles Stine, the head of Du Pont's central research organisation, thought that the company could benefit if this scientific basis was better understood. Therefore, 'fundamental' research had to be done by the central research unit, which would then fulfil its logical role as the central laboratory in the diversified chemical company, Stine reasoned. So in the early 1920s, Stine tried to attract some researchers of 'higher caliber'. This, however, was not as easy as he initially thought. Several scientists declined his offer, as they were suspicious of industrial chemistry.

Finally, Stine succeeded in composing a fundamental research group consisting of about eight recently minted PhD's and headed by Harvard chemist Wallace H. Carothers. For several years, this group massively documented the nature of polymers and polymerisation, supporting the theories proposed by the German chemist Hermann Staudinger (Hounshell, 1992, p. 239). However, this 'academic research era' of Du Pont was short-lived. In 1930, it came to an end. This had to do with two things: the fact that Carothers and his group quite unexpectedly discovered neoprene synthetic rubber and the first wholly synthetic fibre, and the fact that Stine was then succeeded by Bolton, a hard-nosed industrial research director who wanted *products* from Stine's programme. Both developments led the group into the direction of applied research that had to investigate how these products could be turned into valuable commercial goods (Hounshell, 1992, pp. 239-240).

So this episode illustrates that academic research in an industrial company is not always so obvious. The other problem – the tension between scientists and engineers – becomes clear in the episode of the Manhattan Project, in which Du Pont was an important partner. In September 1942, Leslie Groves became the leader of the new Manhattan Project and was thus charged with the construction of industrial-size plants for the manufacturing of uranium and plutonium. The next month, Groves asked some representatives of Du Pont whether the company could assume the sole responsibility for the design, the construction and the operation of the plutonium production complex. Du Pont, however, wanted some more information before accepting the offer. Consequently, Groves arranged for eight Du Pont representatives to go to the University of Chicago to evaluate its Metallurgical Laboratory's research. In this laboratory, the research to develop an atomic bomb was done.

In December 1942 Du Pont agreed to do the job for the Manhattan Project. To this end, it created a special division, called TNX, within its Explosives Department. (Hounshell, 1992, pp. 245-247). However, almost immediately a conflict erupted between the scientists at Chicago and the Du Pont Company. The Metallurgical Laboratory physicists feared that they would be controlled by an industrial organisation. When Greenewalt, head of the research section of TNX, visited Chicago, he remarked that people there held 'peculiar ideas as to the difference between 'scientific' and 'industrial' research.' (Hounshell, 1992, p. 248) Greenewalt argued that this difference was rather semantic than real and he tried to convince the Chicago physicists of Du Pont's abilities and sincere motives.

According to Hounshell, this conflict illustrates the unequal relation between physicists and engineers: 'Physicists (…) failed to appreciate the extent of the engineering problems surrounding the project and generally underestimated the importance of engineering. Here was a classic case of "science" versus "engineering".' (Hounshell, 1992, p. 250)

Hence, we can conclude that the relation between scientists and engineers in the USA seemed to be pretty much the same as in Europe. Both in the USA and in Europe, there were tensions caused by the struggle for authority and the different interests of both groups. In Dutch radio astronomy, however, the subordinate role of the engineers was clear from the start, which made this relation between scientists and engineers much easier.

2.11 BEYOND AMERICAN HEGEMONY

As a final topic of importance in this chapter, we will position early Dutch radio astronomy in a Cold War world that was dominated by the USA.

As radio astronomy arose during the Second World War and came to full bloom the first decades after the war, the field is a nice example of science in the Cold War.

However, the history of radio astronomy does not fit into the general historiography of science during the Cold War. A feature of this historiography is the continuing emphasis on America's dominance and leadership. But in early radio astronomy, the United States was definitely *not* the leader. It was even seriously lagging behind Europe and Australia. Although in recent years, there has been a renewed attention for the history of science in the Cold War, the general picture of American dominance is hardly ever challenged. In 2006 for example, historian of science John Krige published his famous book *American Hegemony and the Postwar Reconstruction of Science in Europe*. Krige analyses how the US rebuilt European science after the Second World War. He explains that by stimulating European science, the USA was able to establish and to maintain its world leadership. So Krige shows that America needed Europe to establish its own dominant position. Yet, America's world leadership itself is not questioned. He writes:

> The immense scientific and technological achievements in the United States during the war and the ongoing support for research in the country after 1945 contrasted sharply with the situation in postwar Europe. There, laboratories were ill-equipped, destroyed, pillaged (…); researchers were poor, cold, hungry, and demoralized; and national governments had far more pressing concerns than scientific (and technological) reconstruction. (Krige, 2006, pp. 1-2)

So Krige contrasts the post-war leading position of the USA with the poor situation in Europe. We believe, however, that this statement is somewhat exaggerated. It is not true that national governments had far more pressing concerns than scientific reconstruction. As has already been explained, for several European governments, including the Dutch government, scientific reconstruction was a key factor in the rebuilding of the country after the war. Even though the Dutch country was impoverished because of the war, large budgets were made available for science.

Krige's book was the inspiration for the journal for the history of science *Centaurus* to publish a Spotlight with the title 'Post—WW2 transatlantic science policies' in 2010, as mentioned in the introduction. The articles in this volume do not consider the world during the Cold War as a (merely) bipolar world, but rather as a multipolar world. Transnational science policy played a major role in the (re)positioning of regions, countries, institutions and individuals in a multipolar world that was characterised by competition for economic resources, political leadership and military strength (Abir-Am, 2010, p. 273). However, despite this very promising introduction, none of the articles really questions America's hegemony.

In the same year 2010, the journal *Isis* published a focus issue with the promising title: 'New perspectives on science and the Cold War'. In their introduction, Hunter Heyck and David Kaiser write:

> (…) recent work on science during the Cold War has defined both science and the Cold War more broadly than did earlier studies, which tended to focus on the physical sciences in America. Given this focus, the central story in earlier works usually revolved around the rise of Big Science and the military-industrial-academic complex in the United States (…). Recent work, however, is much more international and multidisciplinary in perspective (…). (Heyck and Kaiser, 2010, p. 363).

And a few pages later, one can read:

> Cold War shaped science in profound ways, but there was no single, monolithic Cold War Science. (…) Rather, science during the Cold War took many forms in many places, with science-state relationships varying markedly form nation to nation, agency to agency, institute to institute, and individual to individual. (Heyck and Kaiser, 2010, p. 366)

So the aim of this *Isis* focus is to give a much more varied picture of science in the Cold War.

However, this introduction leaves us with an uneasy feeling. First of all, it is not entirely true that older historiography on the Cold War usually focusses on the physical sciences in America and that this historiography was monolithic. As early as the 1960s, quite a lot has been written on developments in Russia for example. An influential author in this respect is the American historian of science Loren Graham (e.g. Graham, 1973, 1978). A lot of attention has also been paid to the fact that in the USA, there was no consensus at all on post-war (international) science policy. See for example the work of the American historian of science Ronald E. Doel (e.g. Doel, 1992). Moreover, despite its very promising title, the *Isis* issue does not come up with really *new* insights in science and the Cold War. Again, America's hegemony is not questioned.

Although it is absolutely fair to say that in strategic fields like (nuclear) physics and the geophysical sciences the USA was the world leader, there were some other – maybe less strategic - fields in which the USA was lagging behind. Radio astronomy was such a field (see also DeVorkin, 2000, p. 58). In radio astronomy, developments in Britain, Australia and the Netherlands were far ahead. A comparison between the situation in the Netherlands and the situation in the USA may enable us to lay bare the structural and incidental factors which caused the USA to be seriously behind in radio astronomy for at least the first fifteen years after the war. The comparison also shows why the Dutch group was so successful.

First, it has been explained that during the early years of radio astronomy, optical astronomers were indifferent and sometimes even hostile towards radio astronomers. This became already apparent when Reber had to face the skepsis of the astronomical community when he wanted to get an article published in the *Astrophysical Journal.* The problem between optical astronomers and radio astronomers, however, was not a problem that existed only in the USA. In the USA, however, this problem was reinforced by the fact that by the 1940s, American astronomy dominated the world in large optical telescopes, which were controlled by less than a half-dozen institutions, such as the Yerkes-McDonald Observatories, Mount-Wilson-Palomar Observatories and the Lick Observatory. Very influential scientific work had been done with these telescopes. In the early 1920s, for example, Edwin Hubble concluded from his observations at Mount Wilson Observatory that entire galaxies existed outside of our own. Therefore it is not surprising that in the USA there was a strong conviction amongst astronomers that the future of observational astronomy lay in larger and better optical telescopes (Lovell, 1977, p. 152; DeVorkin, 2000).

An illustrative example in this respect is Owens Valley Radio Observatory (OVRO) at Caltech, a major player in early radio astronomy in the USA. In 1948, Greenstein was called to Caltech to build an astronomy department in the Division of Physics, Mathematics and Astronomy, an offer he could not refuse. Long before 1948, Greenstein had been convinced by the work of Jansky and Reber and later by British and Australian radio astronomical work, that radio astronomy was of vast importance to the field of astronomy (Gunn, 2003). But radio astronomical developments in the USA at that time were far behind developments in other countries. When in a 1982 interview Greenstein was asked whether he had the feeling the USA was behind other countries, he answered: 'Oh yes. We were non-existent.' (Greenstein, 1983, p. 18)

In January 1954, a conference was organised in Washington to discuss the status of radio astronomy in the USA. Greenstein was its secretary. According to Greenstein, the reason for organising the conference was the following:

> It was organised largely because of Lee DuBridge [president of Caltech]. Walter Baade, Rudolph Minkowski, and I had been yelling that radio astronomy observation was essential for optical astronomy, because the interpretation of extragalactic radio sources based on the identification by Baade and Minkowski had shown that we were finding more exciting galaxies, for example, by radio means than by others. (…) Well, I wanted radio astronomy at Caltech. It couldn't be under the Mount Wilson and Palomar Observatories, since it's too radically a different technique. DuBridge needed a little convincing; he worried whether radio astronomy would run out of problems in five years and we would be stuck with a dead-end science. So it was quite reasonable to have a conference (Greenstein, 1983, p. 18-19).

At the conference, several ideas were expressed, amongst others the founding of a national radio astronomy observatory (which would be established in 1956, see below).

It was not only difficult to get institutional acceptance for the founding of a radio observatory at Caltech, there was also a matter of getting funding. After some difficulties, federal funding was obtained from the Office of Naval research. (It is important to note that astronomy in the USA had until then almost exclusively been privately funded and the Caltech radio astronomy observatory was amongst the first departures from this norm.) (Gunn, 2003) Owens Valley Radio Astronomy Observatory was finally created in the late fifties. As the leading radio astronomers at that moment were to be found in Britain and Australia, Greenstein 'imported' several British and Australian radio astronomers (Greenstein, 1983, p. 18). An important person was the British-Australian John Bolton, who played a key role in the setup of the group. He was soon followed by his close colleague Gordon Stanley.

The first telescope at OVRO was a prototype 32-foot telescope built by Bolton and Stanley at Palomar. It was moved to OVRO in 1958. The main scientific motivation for the radio telescope was to obtain accurate position information on radio sources to better correlate them with high-resolution optical images obtained with the Palomar observatory. In the late 1950s, construction began on the first interferometer at OVRO. It became operational in 1959 – 1960. At that time, the OVRO telescopes were the most sensitive in its existence. [124]

Besides illustrating the gap between optical astronomers and radio astronomers, Reber's career was also illustrative for a second element early American radio astronomers had to deal with: military patronage. There were several radio astronomical initiatives in the USA after the war, but because of the military patronage, these were guided into specific directions. During the Second World War, funding Reber's work was completely out of the question. Nevertheless, he produced several radio intensity maps of our Galaxy. The post-war attempts of Grote Reber to get funding are illustrative of the science policy of the American government. The National Bureau of Standards (a USA government agency that developed economic and scientific standards) was interested in the radio research of Grote Reber. This was because NBS had many programmes studying radio propagation through the ionosphere, and solar observations could allow improved predictions of ionospheric conditions. This was important from a military point of view: solar radio bursts affected the ionosphere, which affected communications, which affected military operations. With modest equipment, Reber did a lot of solar monitoring for NBS during 1947 and 1948, but he found the work very dull and all his plans to build new equipment and to do

[124] http://www.ovro.caltech.edu/ (accessed on 3 August 2014).

measurements at new wavelengths that could be of interest for astronomy where swept aside. Reber became tired of this government work and left to spend the rest of his life as an independent astronomer, working on telescopes in Hawaii and Tasmania (Sullivan, 2009, p. 72).

In his 1987 article *Behind quantum electronics*, Paul Forman stated that the exponential growth of military funding of science after the Second World War thoroughly influenced scientific research, especially in physics. Although Forman's picturing of the physicists as victims who lost control of their discipline - without even being aware of that - may be a bit one-sided, the case of radio astronomy indicates that the influence of military patronage was indeed non-negligible.

There were several radio astronomical initiatives in the USA after the war, but because of the military patronage, these were often guided into very specific directions. In fact, it was exactly because radio astronomical research was often confined to subjects and wavelengths that were interesting from a military point of view, that from an astronomical point of view this research was lagging behind European research; military patronage was beneficial for some research subjects, but detrimental for others (DeVorkin, 2000).

In many countries, and also in the USA, several persons who took the initiative for radio astronomy held academic positions at physics departments before the war. During the war, they had been working in the war industry and after the war many of them went back to their physics departments. There, some of these physicists established radio astronomy groups, for example in Britain and also to a certain extent in France and Belgium. They had both the freedom and the support to use their newly acquired technical skills to pursue some scientific problems, which were suggested by unexpected discoveries they had made during their wartime research. In the USA, this was less common. The reason is that the American government heavily supported nuclear physics and related fields in physics departments.

So government patronage led some people away from radio research and the people who did stay in it performed this research mainly in practically-minded electrical engineering departments, such as those at Stanford and Cornell Universities, or mission laboratories, such as the US Naval Research Lab (NRL) and the National Bureau of Standards (NBS). Researchers there went after the large contracts available for research related to military communications and radar needs, and these, it turned out, were seldom ideal for obtaining by-products of use to radio astronomy. The Stanford meteor-radar group, for example, did its astronomy as a small part of an overall research program in ionospheric propagation and communications technologies. By the mid-1950s they and others had developed the transient meteor trails into a new means of communications. At a 1948 meeting of the National Academy of Sciences, they emphasised that meteor data said something about temperatures, pressures, and winds in the ionosphere, which was important to… national defence. A concurrent *New York Times* article (16 November 1948) headlined *Meteors 'clocked' as aid in defense*. When this meteor research is compared with meteor research at Jodrell Bank, it becomes clear that there it was more directed towards astronomical problems. There, questions such as 'Did any of the meteors originate from outside the solar system?' were asked (Sullivan, 2009, p. 444).

In practice, militarily useful radio research was generally done at shorter wavelengths (less than 30 cm), a technical direction that was less successful in producing first-class astronomical research. Ever since the 1930s radar development had tended toward shorter operating wavelengths that allowed superior detection and location of targets at greater distances (Sullivan, 2009, p. 447).

Last but not least, differences in approach between individuals and resulting tensions, together with a huge bureaucracy caused serious delays in the founding of a national facility for radio astronomy in the United States. Let us explain.

In the early 1950s, the idea of a federally funded national observatory for USA radio astronomy attracted widening support (Gordon, 2005, p.1). In May 1954 the National Science Foundation (NSF) established a Panel on Radio Astronomy, consisting of prominent astronomers and physicists for advice on how best to promote the emerging science of radio astronomy. By this time, the gap between radio astronomers and optical astronomers had sufficiently narrowed to have both groups in this committee. The chair of this committee was the geophysicist Merle Tuve, Director of the Carnegie Institution of Washington's Department of Terrestrial Magnetism.

Amongst the members of this NSF panel, there was wide disagreement on how this national radio observatory should operate. Astronomer Donald Menzel (Director of Harvard College Observatory), for example, thought it was a good idea to organise American radio astronomy in a way like Brookhaven National Laboratory (BNL) – this was a high-energy physics laboratory in Long Island (New York). He got the support of the physicist Lloyd Berkner, the president of the university consortium Associated Universities Incorporated (AUI), a science management corporation founded shortly after the war. AUI managed BNL. Berkner started to promote the idea rather aggressively. The geophysicist Merle Tuve – chair of the committee - on the other hand, had a completely different opinion. He thought research flourished best not in big-science settings, but in small settings like university departments. Therefore Tuve tried to block the plans for this observatory. The disagreement between Berkner and Tuve stemmed in fact from larger conceptions of the role of science during the Cold War. The rather conservative Tuve thought that federal funding for the basic sciences undermined science as the focus shifted towards larger and larger projects. Berkner on the other hand became increasingly convinced that science should act to serve the state and be fully supported by governments (Munns, 2003, p. 99). The disagreement between Berkner and Tuve would result in a serious clash.

But also amongst the other members of the NSF Panel on Radio Astronomy, there was wide disagreement on several topics (Munns, 2003, p. 103), for example:

- *Who* can be called a radio astronomer? (Does he or she have to be trained as an astronomer, an engineer, a physicist or as something else?)
- Are there *enough* (radio) astronomers to fill the national facility?
- Should funding not be given to universities for the training of radio astronomers and the expansion of staff at universities in the first place instead of to a large radio astronomy facility?
- Would the expansion of radio astronomical facilities not be at the expense of university-based projects?
- Etc.

All these disagreements seriously delayed things. The huge bureaucracy only made this worse. Several organisations, several (sub)committees and many people were involved. In the end, Berkner's ideas prevailed. The NRAO was formally established on the 17th of November 1956. In August 1958, the construction of a radio telescope of 140 ft (43 metres) in Green Bank (West-

Virginia) began. It was completed in February 1965. Only then did the USA seriously began to make up its arrears in radio astronomy.

To conclude, we may indicate the following reasons why American radio astronomy was lagging:

(a) There was a huge gap between (optical) astronomers and radio astronomers, reinforced by the strong tradition of optical astronomy in the USA.
(b) Military patronage had a huge impact on the research content.
(c) Clashing visions on the role of science during the Cold War and resulting personal tensions delayed the foundation of a national facility for radio astronomy.
(d) A huge bureaucracy worsened the delays.

It is clear that in the Netherlands none of these situations occurred. There, radio astronomers and optical astronomers were the very same persons, so there was no antagonism between the two groups. Military funding was non-existent, Dutch radio astronomy was entirely funded by ZWO. The protagonists were also on rather good terms. The field was still so small and ZWO was still in an embryonic state, that things could be arranged very quickly.

2.12 CONCLUSION

Despite all the hard work and good intentions, early Dutch radio astronomical observations were not very successful. A major problem was that good engineers were hard to find. In late 1948, engineer Hoo was hired. But he was a man whose competence was very soon doubted. When in 1949, the plan for the large radio telescope was presented to ZWO for the first time, it was not approved. The main reason was that the usefulness of this instrument was unclear. Indeed, even in Kootwijk no significant observations had been made yet, so why should another (very expensive) instrument be built? Fortunately, with the hiring of Muller and the visit of Van de Hulst to Harvard College Observatory – where the latter heard of the principle of the 'Dicke switch', things proceeded quickly: in May 1951, the Dutch succeeded in detecting the 21-cm hydrogen line. In August 1951, the definitive plan for the 25-m radio telescope was presented to ZWO. This time, the plan was approved, despite an estimated construction cost of Dfl 436 000. The detection of the hydrogen line was a *direct* event that certainly helped the approval, but there were deeper reasons why ZWO thought this instrument was worth funding: radio astronomy was a field in which the Dutch could play a vital role and the research would have positive effects on related disciplines. Another – merely procedural – reason why the project was easily approved was that the group of people involved was still very small. Hence, people were often judge and party at the same time.

When the decision about the funding of the radio telescope had been taken, the question arose *where* this instrument should be built. Cooperation with the Belgians was considered, the plan was to locate it on the Belgian-Dutch border. But as no suitable sites were found there, other locations were considered. In the end, the 'Kraloër veld' near the village of Dwingeloo (Drenthe) was chosen, as this was an interference-free zone in a nature reserve. However, the astronomers had to deal with serious resistance from the village council of Dwingeloo and the Society for the Preservation of Nature Monuments. The latter even persisted in its resistance several years after construction had been completed. Several devastating articles about the radio telescope plans appeared in the press. Fortunately for the astronomers, some parties involved where rather positive: the trade association of Dwingeloo, the Government Service for the National Plan, and most importantly: the provincial and the national governments. So in the end, permission was given to build the telescope.

We believe, however, that this opposition against the construction of the radio telescope illustrates in the first place that radio astronomy was still a very young field that had not yet won the acceptance of the general public. Nevertheless, the Dutch astronomers made great efforts to bring their activities closer to the general public. In doing that, they followed the popularising tradition that had existed since the days of the 19th century Leiden astronomer Frederik Kaiser. Around 1950, when the astronomers tried to get a ZWO grant for the plans for the large radio telescope, strict guidelines were developed for dealing with the press. The attitude of the Dutch astronomers towards the media (especially the written press) was very paternalistic: they wanted full control of what information was made public at what time. They obviously thought that by giving good information, the general public would take a positive attitude towards the project. However, the attempt to control what appeared in the newspapers failed, as said before. Besides giving information to press agencies and newspaper journalists, the Dutch also made a documentary film about the building of the radio telescope, something that was still highly unusual in the Netherlands at the time. Indeed, in the 1950s, Dutch science was still in its 'ivory tower' to a large extent. Science popularisation in the Netherlands was still at a low ebb, compared to what was going on in, for example, the USA, Britain, France and Belgium. As a matter of fact, the efforts the Dutch astronomers undertook to inform the public about their research were in sharp contrast with the lack of popularisation efforts that were undertaken on a national scale.

Whether all these efforts of Dutch astronomers to bring radio astronomy closer to the general public really helped Dutch radio astronomy forward, is hard to say. There are no examples available were the effect of this popularisation can clearly be pinpointed.

Seen from an international perspective, early radio astronomy is sometimes presented as a field characterised by openness, (international) cooperation, interdisciplinarity etc. rather than by competition. We believe, however, that this view needs to be qualified. Early radio astronomy has been shown to be a very competitive field. On the other hand, there is not necessarily a contradiction between cooperation and competition, and this applies to radio astronomy, where international cooperation was often a means to strengthen the position of a (national) research group or an individual. Concerning the Dutch, it is abundantly clear that Oort furthered his own projects – and hence strengthened his competitive position – by means of international cooperation.

The community of early radio astronomers did not only traverse national boundaries, it also traversed disciplinary boundaries. Engineers also made vital contributions to the field. Nevertheless, most telescope projects were mainly presented as an 'astronomers' matter' and the contributions of the engineers were often overlooked. Dutch radio astronomy would never have been so successful if engineers such as Muller and Hooghoudt had not been there. Nevertheless, Kootwijk, Dwingeloo and later also Westerbork are in the first place linked to the name of Oort. It is remarkable that the efforts to give the engineers more visibility in historiography are mostly made not by professional historians, but by radio astronomers. At the same time, in the case of Dutch radio astronomy this 'public effacement' of the engineer is not too surprising. In the Netherlands, the research programme was entirely developed by astronomers and it was a purely *astronomical* one. The telescope was not used for other (for example defence-related) purposes in which the engineers could have a say. So in the Netherlands, engineers had a subordinate role, although a crucial one. This clear and straightforward role of the engineer had the positive effect that there was no struggle for authority between engineers and astronomers, unlike in other countries. In Jodrell Bank, for example, the relation between astronomers (Lovell in the first place) and the engineers was tense. We believe, however, that this had to do with the mixed character of the research in Jodrell Bank: the telescope was not only used for astronomical purposes, but also for satellite tracking and other defence-related purposes. In these, it was not clear whether the engineer or the astronomer had the dominant position, which in turn entailed a struggle for authority.

It is sometimes said (for example by Galison) that the public effacement of the engineer – and the simultaneous prominence given to the scientist – is typically European. However, several American examples – Du Pont's involvement in the Manhattan Project has been discussed - indicate that the situation in the USA was pretty much the same.

Last but not least, early Dutch radio astronomy is a prime example to moderate the still dominant historiographical picture that America was the world leader in matters of science during the early Cold War. In early radio astronomy, America was definitely lagging behind European and Australian developments. We believe that this was due to several factors: the strong tradition of optical astronomy in the USA; military patronage; clashing visions on the role of science; a huge bureaucracy.

CHAPTER III: A COOPERATION WITH BELGIUM

As soon as the first observations with the telescope in Dwingeloo were made, ideas came up to build an even larger and better instrument. As it was estimated that this instrument would be very expensive, the Dutch started looking over the border. By finding a partner, the cost of the project could be shared and that would make the project more acceptable to the Dutch government. The initial idea was to make this project a joint undertaking of three countries: Belgium, the Netherlands and Luxemburg. The telescope would be a cross interferometer (see below). Therefore, the project was called 'Benelux Cross Antenna Project' (BCAP) for several years. However, in practice Luxemburg never did join. Belgium on the other hand, would be a partner for several years. When the Dutch approached the Belgians in 1958, the idea of jointly constructing a large radio telescope was enthusiastically received by several Belgian astronomers. However, this did not prevent the ultimate failure of the cooperation in 1966.

In this chapter, we explore, on the one hand, why the Dutch decided to cooperate with the Belgians and, on the other hand, why this cooperation ultimately failed. The latter is a very complex matter. As we will see, it has to do with the diverging astronomical traditions after the Second World War, with different science policies of the two countries since the late 1950s, the different political cultures, and – more general – different 'mentalities'.

First, however, the factors that can explain why the Dutch chose Belgium to be their partner will be analysed.

3.1 BELGIUM AS THE MOST OBVIOUS POTENTIAL PARTNER

As a matter of fact, the choice to cooperate with Belgium marked a continuity with the history of Belgian-Dutch relations.

First, the two countries had a history of cultural cooperation. In 1927, a first Dutch-Belgian Cultural Treaty was concluded to reinforce the intellectual relations between the two countries. Although (or because) the implementation of this treaty yielded rather poor results – it brought about only a modest exchange of university professors and students – a second Cultural Treaty between Belgium and The Netherlands was concluded in 1946. This treaty aimed to establish good relations in matters of science, arts and education and can be seen as a follow-up of the treaty of 1927. However, the treaty is also a typical product of the immediate post-war era in which there was a general inclination towards cultural cooperation in Western Europe after years of obstructions and isolation. This was reflected in several bilateral cultural treaties and in the founding of UNESCO. In Belgium and the Netherlands, two small countries, the idea prevailed that they *had* to cooperate if they wanted to keep any international significance. The advantage of a common language (Dutch) would facilitate this cooperation.[1] In practice, the Cultural Treaty of 1946 led to the exchange of art events (the organisation of Belgian art events in the Netherlands

[1] In 1944, negotiations between the Dutch and the Belgian governments in exile in London had already led to the foundation of a joint committee for spelling (Gemengde technische commissie, 1951, pp. 6).

and vice versa), intensive exchange of scientific staff, initiatives for mutual recognition of diplomas etc. (Gemengde technische commissie, 1951, pp. 6-7).

Equally important, besides the cultural relations, were the Belgian-Dutch economic relations. In October 1943, the governments in exile of Belgium, the Netherlands and Luxembourg concluded a monetary agreement, and in September 1944 they signed a Customs Convention which entered into force on 1 January 1948. This Customs Convention has since then been known as the 'Benelux'. It stipulated that intra-Benelux commerce was free of import duties. The goal of the treaty was to establish the most favourable conditions for an Economic Union. Indeed, the three small countries had everything to gain from protecting their interests as effectively as possible. Ten years later, on 8 February 1958, the Treaty establishing the Benelux Economic Union was signed in The Hague. It entered into force on 1 November 1960 and served as a consolidation of the ten years of pragmatic cooperation (Peaslee and Xydis, 1974, p. 165).

Of particular importance in this story, however, is that since the interwar period, there had also been a quite intensive cooperation in astronomical matters. As Belgian and Dutch astronomers shared many interests, they frequently exchanged scientific staff.

The Belgian astronomer and engineer Armand Van Hoof (professor at Leuven University since 1935), for example, had been a regular visitor of Leiden Observatory since the 1930s. In Leiden, Van Hoof started research on variable stars under the direction of E. Hertzsprung, who was the director of the observatory at the time. Under the direction of Oort, Van Hoof did some research on stellar statistics (Smeyers, 1987, p. 36). This resulted in some publications in the *Bulletin of the Astronomical Institutes of the Netherlands* (Van Hoof, 1934 and 1935).

In 1937, Van Hoof started – at the instigation of Oort – star counting in the constellations of Scorpius, Ophiuchus, Corona Australis and Sagittarius. He finished this job in 1941 (Smeyers, 1987, p. 37), but did not publish his results until much later (Van Hoof, 1969).

The Belgian-Dutch connection was maintained by some of Van Hoof's collaborators. In 1949, M. Deurinck went to Utrecht Observatory ('Sonnenborgh') to study the structure of line profiles in the spectra of Cepheids under the direction of M. Minnaert. Another collaborator, M.F. Bertiau worked for a short time in Leiden in 1948. In 1952, he went to the United States, where he worked at Lick Observatory and Yerkes Observatory. At Yerkes, he met the Dutch astronomer A. Blaauw (Smeyers, 1987, p. 39). Bertiau followed Blaauw to Groningen when the latter was appointed professor there in 1957. In Groningen, Bertiau determined the parallaxes of the stars in the Scorpio-Centaurus stream (Houziaux, 2001, p. 137). Also worth mentioning is that the Dutch astronomer Kees de Jager was professor of astronomy at the Free University of Brussels from 1961 until 1973.

Oort himself had a very close relationship with the Liege astronomer Polydore Swings, as they had a shared strong interest in comets. During the first post-war years, there was an intense correspondence between the two astronomers on spectra and brightness of comets.[2] That Oort greatly valued the opinion of Swings is confirmed by the fact that he often had his lectures and articles revised by Swings. In the course of 1950, for example, Oort and his PhD student Maarten Schmidt prepared an article on the differences in spectra of new and old comets (Oort and Schmidt, 1951). When it was ready for publication, Oort let Swings know that he would very much

[2] OA, 103f.

appreciate his comments.[3] On the first of May 1951, Oort gave a 'Halley Lecture' at Oxford University on the origin and development of comets. This lecture was later published in *The Observatory* (Oort, 1951). Before publication, Oort again sent his text to Swings to ask for his opinion.[4]

Swings in turn greatly valued Oort's work and he believed that his contributions and his cooperation with Belgian astronomers had also greatly advanced Belgian astronomy. He expressed his appreciation by asking the rector of the University of Liege to recommend to the Belgian Minister of National Education that Oort should be awarded a National Order. Indeed, in 1950, Oort became 'Commander of the Order of Leopold II' in Belgium, because of his 'support for Belgian astronomy'.[5]

Given this history of fruitful Belgian-Dutch astronomical exchanges and mutual appreciation, it is not surprising that in 1951, Oort invited the Belgian astronomers to be involved in SRZM. In September, he wrote to the director of the Royal Belgian Observatory, Paul Bourgeois:

> I gave M. Swings, several students of whom are interested in this field, some information on the work and projects we started in radio astronomy several years ago. We hope that M. Nicolet[6] or Swings himself could stay in touch with SRZM on a regular basis. By doing so, they could keep you informed on our projects in this field[7]

The Belgians responded enthusiastically to this invitation. Moreover, radio astronomy in Belgium had also taken off, as becomes clear from the subsequent answer of Bourgeois:

> Concerning radio astronomy (…) you will certainly be glad to hear that since last month the Royal Observatory of Belgium possesses a Wurzburg Riese of 7,50m that we are equipping as a radio telescope. We are also preparing a second radio telescope of 6m that we will send to Léopoldville for the observation of the eclipse of February 1952. At that time, an identical instrument will be put into operation at the station of the Institute of Scientific Research in Central Africa (IRSAC) in Kivu, where the observations will be done under the direction of M. NICOLET. M.R. COUTREZ[8], who is in charge of the radio

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[3] Oort to Swings, 1 September 1950, OA, 103f.
[4] Oort to Swings, 7 May 1951, OA, 104 f.
[5] Oort to Swings, 6 June 1950, OA, 103b.
[6] Marcel Nicolet graduated as a physicist at the University of Liege in 1934 with a thesis (under the direction of Swings) on the spectra of O and B stars. This was later published in the *Astrophysical Journal* (Swings and Nicolet, 1934). In 1935, Nicolet became a staff member of the Royal Meteorological Institute of Belgium. In 1937, he received his doctoral degree with a PhD thesis *L' étude du spectre et de la composition des atmosphères solaire* (A *study of the spectra and the composition of solar atmospheres*) under the direction of Swings. Despite the fact that Nicolet made regular study trips abroad – especially to the USA – and he held professorships at Pennsylvania State University and the Universities of Brussels and Liege, he would remain at the Meteorological Institute throughout his career. In 1964, he became the first Director of the Institut D'Aeronomie Spatiale De Belgique (Institute of Spatial Aeronomy of Belgium), which became a separate entity. For further information on Nicolet, see : Ackerman and Jaumotte, 1998.
[7] 'Je viens de faire parvenir à M. Swings, dont plusieurs élèves se sont intéressés à cette domaine, quelques informations relatives aux travaux et aux projets que nous avons inaugurés il y a quelques années sur la radio astronomie. Nous espérons que M. Nicolet ou lui pourront maintenir un contact plus ou moins régulier avec notre Stichting Radiostraling van Zon en Melkweg et qu'en faisant cela ils pourront vous tenir au courant de nos projets dans cette domaine.' Oort to Bourgeois, 17 September 1951, OA, 104b.
[8] Coutrez of the Royal Observatory, later also professor at the University of Brussels, was in fact the pioneer of radio astronomy in Belgium, as we will see.

> telescopes of the Royal Observatory of Belgium, is working closely together and in complete agreement with M. NICOLET. Needless to say that it is with the greatest pleasure that we will become affiliated with your National Foundation for Radio Astronomy[9]

Swings became a member of the board of SRZM in 1951. On 27 November 1951, he attended a meeting of the board for the first time.[10]

Apparently, the Dutch were hoping for an intense Belgian-Dutch collaboration in radio astronomy. Initially, they even considered to build the 25-m radio telescope on the Belgian-Dutch border near the nature reserve of the Benedictine Abbey 'Achelse Kluis'.[11]

After a while, however, it became clear that the Belgian-Dutch cooperation was not as close as Oort had hoped for. Oort considered Swings' presence on the board of SRZM rather useless and thought he would be better off without him. When Swings' mandate expired on 31 December 1955, Oort took his chance. He wrote him a letter of which the message was crystal-clear:

> As you have not found it possible in practice to come to the Board meetings, and as in general these cannot offer enough that is of direct interest to you to make it desirable or profitable for you to spend a whole day or more to attend such meetings, you may find it more practical and more satisfactory for yourself, to withdraw from the official membership of the Board. If you should look upon it this way, I think the same arguments hold likewise for other Belgian colleagues, so that it might be better in that case not to appoint another Belgian member. At the time when you came into our Foundation, we thought that this project would be more directly tied to Belgium and that we would have more common interests, as we were then hoping to build the station right on the border. At present it will be more realistic, I think, to restrict ourselves to arranging now and then a meeting on radio-astronomical problems together with Belgian astronomers, at times when there is a special desirability or need for such a combined meeting. (…)[12]

Swings immediately agreed. He resigned and confirmed that it was unnecessary indeed to appoint another Belgian representative.[13]

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[9] 'En ce qui concerne la radioastronomie (…) il vous intéressera certainement de savoir que l'Observatoire Royal de Belgique dispose depuis le mois dernier d'un Wurzburg Riese de 7,50m que nous équipons en radio-télescope. D'autre part, nous réalisons pour le moment, un second radio-télescope de 6m. que nous enverrons à Léopold-ville pour l'observation de l'éclipse de février 1952. Un instrument identique sera mis en service à ce moment à la station de l'Institut pour la Recherche Scientifique en Afrique Centrale (IRSAC) au Kivu où les observations s'effectueront sous la direction scientifique de M. NICOLET. M.R. COUTREZ qui a la charge des radio-télescopes de l'Observatoire Royal de Belgique travaille en liaison étroite et en complet accord avec M. NICOLET. Inutile de vous dire que c'est avec le plus grand plaisir que nous serions en rapport avec votre Stichting Radio- straling van Zon en Melkweg.' Bourgeois to Oort, 19 September 1951, OA, 104b.

[10] Minutes of the executive committee meeting of SRZM of 27 November 1951, SA.

[11] Minutes of the board meeting of SRZM of 8 January 1952, SA.

[12] Oort to Swings, 19 December 1955, OA, 168.

[13] Oort to Swings, 20 December 1955, OA, 168.

Oort and Swings may have been different personalities with different priorities, which can to a certain extent explain why the presence of Swings in the board of SRZM was unsuccessful, but there was more at stake. Despite the many shared astronomical interests, the above episode is also illustrative of the different astronomical developments in Belgium and the Netherlands since the beginning of the twentieth century. And this in turn is one of the explanatory factors of the failure of the Belgian-Dutch cooperation.

Like the Dutch, the Belgians could rely on a very strong tradition in astronomy. The interwar period in Belgium was dominated by the world-famous catholic priest, physicist, astronomer and cosmogonist Georges Lemaître, who can be considered as the pioneer of cosmogony. He is especially known for his development of a model of expansion of the universe out of a 'primeval atom' (Marage, 2001, p. 86). This theory later developed into the 'Big Bang' theory. And with Armand Van Hoof and some of his collaborators, Belgium made great contributions to (Galactic) astronomy in the interwar period.

Stellar and interstellar physics – an important part of astrophysics – was the favourite topic of several Belgian astronomers. It comprises theoretical and observational aspects. The latter, however, were rather problematic in Belgium. First, in the interwar period only the Royal Observatory of Belgium had enough resources to equip itself in a decent way for this kind of (expensive) research. Moreover, the Belgian climate is unfavourable for astronomical observations. Therefore, during the interwar period many Belgian astrophysicists went to the United States, the 'fatherland for astrophysics' (Houziaux, 2001, p. 138). These Belgian émigrés could often rely on the Belgian American Educational Foundation.[14] Polydore Swings for example, went to the observatory of Yerkes in 1931 as a 'CRB Advanced Fellow'. In the 1930s and 1940s, several other Belgian astronomers made a trip to the US as CRB fellows: Marcel Migeotte, a colleague of Swings, went to Michigan in 1938 and Paul Ledoux, a former student of Swings, went to Yerkes in 1940. All of them had European international experience too. They had previously been working at observatories in Paris, Warsaw, Leiden or Oslo (Houziaux, 2001, p. 138).

This internationalism, especially the orientation to the United States, was a shared feature of Belgian and Dutch astronomy. Dutch internationalism in astronomy can be traced back to the Groningen astronomer J.C. Kapteyn. In 1877, Kapteyn became the first professor in astronomy at Groningen University. He wanted to establish an observatory at the university, but the Dutch government did not approve (Krul, 2000, p. 56). There was already an observatory in Leiden and in Utrecht, and three observatories in a small country like the Netherlands would be too costly. Therefore, if Kapteyn wanted to be internationally recognised, he had no choice but to look over the border. Kapteyn approached the Scottish astronomer David Gill, director of the observatory in Kaapstad (South-Africa). From the 1880s forward, Gill and Kapteyn cooperated on the *Cape Photographic Durchmusterung*, a star catalogue of the southern hemisphere. This catalogue was based on plates that Gill had taken between 1885 and 1890 and that were processed by Kapteyn

[14] The Belgian American Educational Foundation was founded in 1920 and was the heir of the Commission for relief in Belgium (CRB), as it rose out of a small portion of the funds remaining in the treasury of the Comission after World War I. (BAEF, n.d., accessed 2 April 2012). The CRB in turn was founded by Herbert Hoover (American president since 1929), after Belgium was invaded by the Germans and had to face a severe food crisis in 1914.

and his staff, which enabled him to get international status as 'astronomer without a telescope' (DeVorkin, 2000a, p. 132). Kapteyn did a lot of research abroad too - he regularly went to Mount Wilson (California) for research – and encouraged his students to do the same. Willem de Sitter, for example, - director of Leiden Observatory since 1918 - stayed in Cape Town for two years to collect material on Jupiter's satellites. P.J. Van Rhijn – Oort's supervisor – went to Pasadena to collect material on the brightness of the night sky. Kapteyn and his successors were certainly not focused on United States only, but the number of Dutch astronomers that went to America – and often stayed there - during the interwar period was considerable. This leads historian Klaas van Berkel to the conclusion that Dutch astronomy anticipated the general brain drain that took place after the Second World War. (Van Berkel, 2000a, p. 154). As is shown above, exactly the same can be said about Belgian astronomers.

Thus, both in Belgium and in the Netherlands, astronomers frequently travelled and emigrated during the interwar period. In Belgium, the main incentive for this was the bad climate for astronomical observations. In the Netherlands, the shortage of jobs for professional astronomers (Van Berkel, 2000a, p. 166) was probably the most important 'push' factor.

Since the Second World War, however, this bad climate had for Dutch astronomers – Oort in the first place - also been an incentive to shift their focus towards radio astronomy, as we saw in Chapters I and II**.** Belgium, on the other hand, did not make this choice. It took radio astronomy on board rather late. We can probably explain this because Milky Way structure and stellar dynamics were in those days negligible research topics in Belgium. In the Netherlands, unravelling the structure of the Milky Way had been one of the main objectives of astronomical research since the beginning of the twentieth century. And it was especially here that radio astronomy could make crucial contributions.

This did not mean, however, that there was no interest at all amongst Belgian astronomers in this new field. The pioneer of Belgian radio astronomy was Raymond Coutrez. Graduated as a physicist at the Free University of Brussels, Coutrez did some important work on spiral nebulae in the 1930s. Groundbreaking was his article *Sur la Dynamique des Nébuleuses spirales* ('*On the Dynamics of Spiral Nebulae'*) (Coutrez, 1938). In this article, Coutrez applied wave theory to explain the spiral structure of galaxies, a topic for which observations at radio wavelengths could be very useful (Gonze, 1998, p. 163). In 1945, he entered the Royal Observatory of Belgium. Realising that radio astronomy could play an important role in research on the Sun and the Galaxy, he initiated this new research field in Belgium in 1949. Working together with the École Normale Supérieure de Paris and the Institut pour la Recherche Scientifique en Afrique Centrale (Institute for Scientific Research in Central Africa, IRSAC[15]), radio astronomical observations of the two solar eclipses of 1952 (in Congo: this was the expedition Bourgeois talked about in his letter to Oort of 19 September 1951, see above) and 1954 (in Sweden) permitted him to define the relations between solar corona, observed at radio waves and active photospheric and chromospheric regions (Gonze, 1998, p. 163).

[15] IRSAC was established in 1947 to conduct scientific research in the Belgian colony Congo and the mandate Rwanda-Urundi. Together with INEAC (founded in 1933 for agricultural research) it was the largest Belgian scientific organisation for research in the colonies (Smith, 1967, p. 23).

In 1954, Coutrez founded the station for radio astronomy at Humain (Marche-en-Famenne). It was equipped with the two radio telescopes the Royal Observatory had possessed since 1951: a Würzburg Riese with a parabolic mirror of 7.5 m and a radio telescope with a parabolic mirror of 6 m. In 1955, an interferometer consisting of 48 paraboloids was constructed (Gonze, 1998, p. 164). Although Coutrez himself had previously done a lot of research in galactic astronomy, these radio telescopes were (almost) exclusively used for *solar* research (research of the solar corona, solar flares, solar bursts etc.) (Koeckelenbergh, 1971).

So not only did Belgium enter radio astronomy relatively late, it also strongly focused on solar research, unlike the Netherlands, where the focus was on galactic research.

It is not clear whether it was a conscious policy of the Belgians not to make radio astronomy one of their priorities. In any case, as Milky Way structure was not one of their major research topics, they probably thought they had little to gain from it. On the other hand, one can ask why the Belgians did not shift their research interest to Milky Way structure and stellar dynamics.[16] Indeed, astrophysics remained their favourite astronomical topic, despite the unfavourable climate for doing observations. Part of the explanation for this may be the very strong international tradition of Belgian astrophysics since the interwar period.

The international activities of Polydore Swings are illustrative in this respect. In 1928, Swings went to Paris with a scholarship of the Belgian government. During his stay, he had close contacts with astrophysicists at the observatory of Meudon. His experiences in Meudon inspired him to found a Laboratory for Spectroscopy in Liege in 1931. The numerous other trips Swings undertook during the interwar period - to Warschau in 1929-1930, to Chicago during the Second World War (where he met Otto Struve) – and the contacts he forged there, facilitated his creation of the Colloques Internationaux d'Astrophysique de Liège (Liege International Astrophysical Colloquia) since 1949. These colloquia enhanced the international reputation of the Liege astrophysics school (Houziaux, 2001, p. 139).

Perhaps it is exactly this strong position in astrophysics that made the Belgians somewhat 'blind' to other possible new fields such as radio astronomy. It seemed natural to focus on the same questions as before and to continue in the same way after the war as they did before. Perhaps this is an example of the 'law of the handicap of a head start', similar to the situation the Americans suffered from. As we saw in Chapter II**,** America's strong tradition in optical telescopes in the interwar period made this country insensitive to other options in the first post-war years.

To compensate for the bad Belgian climate for doing optical astronomical observations, the Americans had shown the Belgians the way to observatories in Chile and South-Africa during the interwar period. After the Second World War, the Belgians just continued in this direction. Noteworthy was their presence at Boyden Observatory near Bloemfontein (South Africa), which had served as Harvard University's southern observatory since 1927. In the early 1950s Harvard chose to discontinue financing the observatory. Therefore, it was decided to put it under international sponsorship. The 'Boyden Council' was formed in 1955. Its members were the observatories of Harvard, Armagh (Northern Ireland), Dunsink (Ireland), Uccle (Belgium), Hamburg (West-Germany) and Stockholm (Sweden). This consortium operated until 1976

[16] This did happen, but only much later. Especially at Ghent University, important contributions to stellar dynamics were made by Herwigh Dejonghe (Houziaux, 2001, p. 147).

(Jarret, 1979). Between 1959 and 1965, several Belgian astronomers served as directors of Boyden Observatory (Houziaux, 2001, p. 140).

A reinforcing factor – and this should certainly not be underestimated - that made the Belgians continue their astrophysical tradition and optical observations, was that during their frequent stays abroad, friendships were forged between Belgian and foreign astronomers. As Houziaux rightly suggested, this may partly account for the fact that the young scholars after the war just followed the same path (Houziaux, 2001, p. 138).

3.3 PLANS FOR 'A LARGE CROSS ANTENNA'

Taking into account the diverging astronomical traditions in Belgium and the Netherlands in the post-war period, and Swings' rather unsatisfactory spell on the board of SRZM in the early 1950s, it seems a little odd that Oort approached the Belgians *again* to cooperate in 1958. However, in 1958, Oort wrote to Swings:

> Since a considerable time our radio-astronomy group has had plans to develop a large cross antenna. The 25-metre telescope in Dwingeloo works marvellously and produces very beautiful results. But in a few years' time it will no longer be able to compete with much larger instruments which are being built elsewhere. We therefore feel that we have to start on plans for new instruments to be ready in 3 or 4 years time. These instruments will, in our opinion, have to be large and will be expensive. As size will be a determining factor in obtaining adequate equipment in this branch of astronomy I am of the opinion that it would not be wise for each small country to continue alone, but that we must join forces where this seems practicable. In the present case it would seem indicated to combine with your country.[17]

At that time, informal talks had already taken place between Oort, Paul Bourgeois - the director of the Royal Observatory of Belgium (Uccle) – and Raymond Coutrez, astronomer at the Royal Observatory and the Free University of Brussels (ULB). Bourgeois and Coutrez believed it would be possible to get financial support for the project in Belgium:

> I have informally discussed this possibility with Bourgeois and Coutrez, and found that both were not only very willing to take part in a joint enterprise of this sort, but that Bourgeois was also extremely optimistic about the possibility of obtaining the required financial support (we estimate that the initial cost would be several million guilders, to be spent over a construction period of from 3 to 4 years). It was our intention to spend the year 1959 on experiments involving only very small expense.[18]

We do not exactly know when the idea of the new radio telescope came up, but the first time funding was reserved for this project was in the budget of SRZM of 1958. In it, Dfl 5000 was set aside for the 'preparations project large cross antenna'.[19] Indeed, that year, some preliminary

[17] Oort to Swings, 10 September 1958, SA, NWO.
[18] Oort to Swings, 10 September 1958, SA, NWO.
[19] Budget SRZM for 1958, SA, NWO.

research for the cross antenna was done by Van de Hulst and Charles L. Seeger (brother of the American folk singer and guitarist Pete Seeger). Seeger was an American engineer and radio amateur who played a key role in the founding of a radio astronomy group at Cornell University in 1946. In 1950, he went to Europe for twelve years. First he went to Sweden for one year and then he moved to Leiden Observatory where he stayed for a decade. As Sullivan explains, the Dutch group was the perfect place to be for Seeger, as 'Seeger had felt from the beginning that radio work should be part of astronomy, not radio engineering, and this attitude melded well with the Dutch' (Sullivan, 2009, pp. 210-211). Prior to the preparations for the cross antenna, Seeger had done a great deal of work for the Dwingeloo telescope. For example, he had developed a receiver to do observations for wavelengths of 75 cm.

It was Seeger who wrote the first conceptual proposal for a large cross-shaped radio telescope. The idea was to construct a large array of small moveable antennas mounted on a horizontal plane and covering two perpendicular strips about 3 km long and about 30 metres wide. The antennas were to be designed for work at a wavelength of between 50 and 100 cm. This proposal was discussed for the first time at the meeting of the board of the SRZM on 21 October 1958.[20]

One may wonder why the idea came up that the new radio telescope should be an interferometer in the shape of a cross. In an interview in 1986, Oort says this idea came up 'spontaneously' (Oort, 1986, p. 252). Taking into account the context of the time, this is a plausible answer. Interferometry and cross telescopes were not new in those days. In this respect, Dutch radio astronomy followed the developments in other countries. The problems Dutch radio astronomers had to deal with were the same problems that radio astronomers in other countries had to deal with during the late forties and the fifties. It became clear that poor angular resolution[21] – a problem inherent in observing at long radio wavelengths – could not be overcome by constructing ever larger single radio telescopes. The solution was to combine two or more telescopes at some distance from each other, working as an interferometer. Interferometry[22] has been used in radio astronomy since 1946, when Ryle and Vonberg constructed a radio-interferometer near Cambridge. It consisted of two dipole arrays, tuned to a wavelength of 1.7 metres (Raimond, 1996, p. 15).

Important developments in interferometry took place in Australia. In 1946, in Australia the first interferometric observations of the Sun were made by McCready, Pawsey and Payne-Scott. They used one of the Australian coastal radar installations to combine the direct image of the Sun and its image reflected by the sea. With this 'sea interferometer', Bolton and Stanley isolated Cygnus A as a discrete radio source in 1948 (Harris, 1994, p. 615).

Observations with these early interferometers made possible the optical identifications of some radio sources. In order to allow optical identifications, accurate determination of the positions of these radio sources was necessary. In 1948, John Bolton, Bruce Slee and Gordon Stanley were the first to identify radio sources within galaxies other than our own, using the sea interferometer to

[20] Minutes of the meeting of the executive committee of SRZM of 21 October 1958, SA.

[21] Angular resolution is the ability to produce separate images of closely placed objects.

[22] Interferometry is the process in which electromagnetic waves are combined in order to extract information about the waves. An instrument used to combine the waves is called an interferometer. An astronomical interferometer is an array of telescopes acting together as a single telescope, to produce high resolution images. On interferometry in optical astronomy, see Monnier, 2003. On interferometry in (early) radio astronomy, see: Burke and Tuve, 1956.

obtain accurate positions (Goddard and Milne, 1994). The radio source Taurus A was identified with the Crab Nebula and the radio sources Centaurus A (NGC 5128) and Virgo A (M87) with extragalactic nebulae (Bolton, Stanley and Slee, 1949).

In 1952, the first suggestion for a cross-type antenna was made by the Australian radio astronomer Bernard Mills (Bowen, 1984, p. 97). The 'cross type' offered the possibility to construct an aerial system of high resolution but small surface area and low cost (Mills and Little, 1953). In 1953, an experimental model operating at a frequency of 97 MHz (about 3 metres) was set up at Potts Hill, the field station of the CSIRO[23] Division of Radiophysics. It successfully gave an image of the Sun and of several radio sources. This success encouraged the Division to increase the size and therefore the resolving power.

In 1954 a field station was founded at Fleurs in order to erect a type of radio telescope tested at Potts Hill field station. This Mills Cross, the 'brain child' of Mills consisted of a North-South and East-West array, each about 450 m long and each consisting of two rows of 250 dipoles, arranged in a cross. The cross operated at a frequency of 85.5 MHz and gave a 49 arcminute beam, which was very good in these days for that frequency. Neither arm was steerable, but by altering the phasing of the dipoles in the N-S arm it was possible to observe different declination strips across the celestial sphere. Between 1954 and 1957, Mills, Hill and Slee carried out a detailed survey of the sky and recorded more than 2000 sources of discrete radio emission (Orchiston and Slee, 2002). The following years, two other cross telescopes where built at Fleurs: the 'Shain Cross' (19.7 MHz) in 1956 and the 'Chris-Cross' (1410 MHz) in 1957 (Bowen, 1984, p. 97). In the meantime, in 1955, M. Ryle and A. Hewish had constructed a large radio interferometer in the UK, consisting of four antennas at the corners of a rectangle of 580 by 49 metres (E-W and N-S respectively) (Raimond, 1996, p. 16).

This is a rough sketch of the background against which the idea of building a cross interferometer came up 'spontaneously' in the minds of the Dutch radio astronomers at the end of 1957. However, the cross shape was eventually given up and a linear array of 14 antennas was chosen (see Chapter IV).

3.4 THE BUMPY PATH TO AN AGREEMENT WITH THE OEEC

At the instigation of the Belgians, the first thing to be done was to submit a request for funding at the Organisation for European Economic Co-operation OEEC.

The OEEC was founded in 1948 to administer the Marshall Plan for the reconstruction of Europe after the Second World War. Its Special Office for Scientific and Technical Personnel (OSTP) in turn was founded in May 1958. This Office was set up in the aftermath of the launch of Sputnik, which emphasised the shortage – or at least the 'perceived' shortage[24] - of scientists and engineers in the West. The OSTP was set up to direct the campaign undertaken by the OEEC to increase the number of research scientists, technicians and engineers needed by the European industry, and to improve the quality of their education and training (OECD, 1996, p. 108). A Steering Committee

[23] Commonwealth Scientific and Industrial Research Organisation
[24] The launch of Sputnik was actually used as an excuse to greatly exaggerate the shortage of engineers and scientists in the West, see: Kaiser, 2006.

(the Governing Committee on Scientific and Technical Personnel), consisting of representatives of all the Member countries of the OEEC and the United States, directed the activities of the OSTP. The financial resources of the Steering Committee were divided in two parts: the 'General Fund' - supplied by contributions from all the Member countries and the United States, which was used to finance projects of general interest to the countries participating in the programme - and the 'Limited Fund', which financed projects that only concerned a limited number of countries with common interests. These projects were financed for 50 per cent by the OEEC and for 50 per cent by the countries participating in the project concerned. On 30 May 1961, the Steering Committee was replaced by the Committee for Scientific and Technical Personnel (OECD, 1996, pp. 108-109).

In October 1958, a formal discussion took place between Oort, Bannier, Bourgeois and a delegate of the Belgian government. During these talks, the Belgians proposed that an application for funding should be submitted to the OEEC Governing Committee on Scientific and Technical Personnel to support the preliminary study for the telescope. They believed that if a budget could be obtained from the OEEC, the Belgian government would be much more inclined to fund the project.[25]

The OEEC was contacted on 3 November 1958:

> The undersigned, Prof. P. Bourgeois and Prof. J.H. Oort (...) wish to inform the O.E.E.C. Governing Committee on Scientific and Technical Personnel of their intention to design and construct as a project of Netherlands-Belgian cooperation a large "cross antenna" for radio-astronomical research, and to ask your committee for a grant in aid which would enable the organisations mentioned to defray the expense of the development stage.[26]

At that time, however, the astronomers had no idea how much this whole project would cost:

> It is not possible in the present stage to give a fair estimate of the total cost. It will be of the order of several million guilders. The cost of the preliminary studies in 1959 is estimated at 100 000 guilders. It is only through this development stage that the governments concerned can obtain the budgetary data required for a decision on the entire project. The Board of the Netherlands Foundation for Radio Astronomy and the director of the Royal Observatory at Uccle, Belgium, would greatly appreciate it if your Committee could give a grant in aid of 50 000 guilders towards this preliminary study.[27]

The Belgian delegation, however, seems to have met some problems to get the authorisation of the Ministry of Public Education to apply for funding from the OEEC. According to the rules, if the Limited Fund would provide Dfl 50 000 (which was 50 percent of the total sum), Belgium and the Netherlands each would have to contribute Dfl 25 000 (which made up the other 50 percent). The Belgian Ministry of Education, however, did not seem to be willing to provide this money immediately:

> I was much disturbed yesterday, when after a conversation (...) with Mr Piekaar, head of

[25] Minutes of the meeting of the executive committee of SRZM of 21 October 1958, SA.
[26] Oort and Bourgeois to OEEC Governing Committee on Scientific and Technical Personnel, 3 November 1958, SA, NWO.
[27] Oort and Bourgeois to OEEC Governing Committee on Scientific and Technical Personnel, 3 November 1958, SA, NWO.

> the Division of Higher Education at the Ministry of Education, he showed me a letter he had received from the head of our O.E.E.C. delegation in Paris. In this letter it was stated that the Belgian delegation had not been able to obtain authorization from their Minister of Education to put in a request for support from the so-called "Limited Fund" for our cross-antenna project. The letter says that the Belgian delegation in Paris is very co-operative, and has done all it could to support the project, but that it appeared to be impossible to obtain from the Ministry of Education the equivalent of 25000 guilders which your government would have to contribute for 1959 according to the rules for this Limited Fund.[28]

To overcome this problem, a typical 'Oort-solution' is proposed: the Belgian astronomers should go *directly* to the ministry or try to obtain the money elsewhere:

> (…) Is there really no possibility of obtaining the small amount needed for 1959 directly from the Ministry of Education, would there be no other way of finding this sum (...)? Or would it be possible to have the Belgian astronomers (…) make a combined appeal to the Minister?[29]

No further information could be obtained on this episode[30], but a few days later, Bourgeois gave a short, rather evasive reply in which he said that according to him, everything seemed to be okay.[31]

After several months, indeed, a definitive proposal to get support from the Limited Fund was submitted by the Dutch and Belgian governments to the Governing Committee for Scientific and Technical Personnel of the OEEC. In their argumentation to get the project funded, it was emphasised that the new telescope would have the best resolving power on the European continent and that this resolving power was necessary to study the universe:

> In fact, the largest telescopes at present in operation on the European continent (viz. those at Dwingeloo, Netherlands, and Bonn, Germany) have a beam of 15 minutes of arc at the shortest wavelength for which they can be used. For the large radio telescope at Jodrell Bank near Manchester the minimum beam is of the same order. For a successful investigation of the universe a resolving power at least ten times better is required.[32]

As in the proposals that were submitted to ZWO to build the telescope in Dwingeloo (see Chapter II) in the early 1950s, it was emphasised that the building of this new radio telescope would have a much broader significance than merely a radio astronomical one. It was said that, as part of the study and design stage, experts would have to undergo advanced training in the latest developments in specialised engineering techniques such as the design and control of highly directive, steerable antenna arrays; the economic design of ultra-low-noise, ultra-stable ultra-high-frequency amplifiers; the development of automatic, high speed, multi-channel data recording and computational equipment. The importance of these techniques was not restricted

[28] Oort to Bourgeois, 28 January 1959, SA, NWO.
[29] Oort to Bourgeois, 28 January 1959, SA, NWO.
[30] The archives of the Belgian Ministry of Education are kept in the State Archives in Belgium (Brussels). Unfortunately, they are very incomplete and no information on the BCAP has been preserved.
[31] Bourgeois to Oort, 31 January 1959, SA, NWO.
[32] 'Proposal for the development of a Benelux Growing Point in the Field of Radio Astronomy', s.d., SA, NWO.

to radio telescopes, they were the basis of the modern field of communications.[33]

The proposal was approved during the meeting of the Committee in the beginning of June. The decision was communicated by J.R. Gass, head of the programming section of OEEC, to Miss A.A. de Vos van Steenwijk of the Dutch delegation of OEEC.[34]

Despite this approval, a formal agreement could not yet be concluded due to – again – problems in Belgium. The problem was that the Belgians had to await the adoption of the budget for 1960 by the Belgian parliament. However, a solution was finally found by which the necessary contribution of about Bfr (Belgian francs) 330 000 could be made available from the 1959 budget.[35]

On 21 September 1959, a meeting took place at Uccle Observatory. Here, the 'official' name of the project was set: from now on, the project was to be referred to as 'The Benelux Radio Telescope', although Luxembourg was not involved in the project yet.[36] At the same time, Oort presented the provisional budget for the Benelux Radio Telescope for 1960. The estimates were as follows:

Scientific personnel (4 radio engineers or physicists, of which two would work on the project for the antenna, one on the development of the receivers and one on the plans for data handling)	Dfl 48000
Technical personnel (4 radio technicians and 1 instrument maker)	Dfl 34 000
Work by other institutions and by advisory engineers	Dfl 15 000
Laboratory instruments	Dfl 10 000
Material	Dfl 15 000
Traveling in Europe	Dfl 2000
Journey to Sydney for study of cross antennas	Dfl 6000
Unforeseen	Dfl 5000
Total	**Dfl 135 000**

So by then, Oort's estimate exceeded his original estimate of Dfl 100 000. During the meeting, a draft agreement - prepared by the OEEC Office for Scientific and Technical Personnel - was discussed and some modifications were proposed. For example, OEEC had proposed that the

[33] 'Proposal for the development of a Benelux Growing Point in the Field of Radio Astronomy', s.d., SA, NWO.
[34] Gass to De Vos van Steenwijk, 5 June 1959, SA, NWO.
[35] Draft report on the Discussion at the Uccle Observatory on September 21st, 1959, SA, NWO.
[36] In practice, the project was almost never referred to as 'Benelux Radio Telescope'. It was referred to by different names, such as 'Benelux Cross Antenna Project, BCAP, BCAP Project, Cross Antenna etc.

'sponsor' of the project - the partner that was authorised to conclude the agreement - would be the Netherlands Ministry of Education, Arts and Sciences. The Dutch however, wanted this sponsor to be a 'Benelux Board' specially formed for this project, so that the parity between the Netherlands and Belgium would be maintained.[37]

Bannier, director of ZWO, sent this modified draft agreement to Fredi Darimont, the Director of Higher Education of the Ministry of Public Education in Belgium and asked his opinion.[38] Darimont, however, did not respond to this letter. In the meantime, the modified agreement was informally discussed with J.R. Gass, head of the programming section of the OEEC. Gass explained that, according to the rules, it was not possible to let a Benelux Board act as sponsor, because the sponsor had to be a government. And taking the history of the project into account, it was obvious that this should be the Dutch Ministry of Education, Arts and Sciences. On the other hand, this sponsorship was rather a formality. The real responsibilities would lie in the hands of an 'organiser', which could be a Belgian-Dutch committee. Bannier communicated this to Darimont and asked him whether he agreed with the text of the modified draft agreement and with the fact that the Dutch Ministry – as 'sponsor' - would sign the agreement. At the same time, he carefully suggested that Darimont should react quickly, as the 'project had to start now first of all'.[39]

Again, Darimont did not answer. It is not clear whether there was a special reason for his silence or whether it was merely negligence. In any case, Bannier started to lose his patience. On 11 December he wrote:

> If we want this collaboration between our two countries to succeed, we can no longer wait to take the necessary measures. Moreover, it is very disparaging towards the OEEC, which we asked for help on your advice, that the help that this organisation has offered us so benevolently goes unheeded, because our two countries do not agree yet on matters which do not seem so difficult to resolve[40]

The Belgian astronomers too were not happy with the delay and the fact they could not obtain any information from the government, as Bourgeois said to Oort: 'Personally, I am as annoyed as you about the lack of information from the Belgian Ministry of Public Education regarding the status of the talks on the cross antenna.'[41]

On 4 April 1960, both countries finally succeeded in coming to an agreement about the organisation of the project.[42] That day, a discussion took place between the Ministries of Education of Belgium and the Netherlands. It was decided that for the execution of the project, a 'Council for the Benelux Cross Antenna Project' would be appointed. This Council would consist

[37] Oort to Van de Hulst, 25 September 1959, SA, NWO.
[38] Bannier to Darimont, 5 November 1959, SA, NWO.
[39] Bannier to Darimont, 5 November 1959, SA, NWO.

[40] 'Si nous voulons faire réussir cette collaboration entre nos deux pays, nous ne pouvons plus tarder à prendre les mesures nécessaires. En outre il me semble désobligeant à l' égard de l'O.E.C.E., dont nous avons invoqué le secours à votre proposition, que l'aide que cette organisation nous a offerte d'une façon si bienveillante reste sans écho parce que nos deux pays ne sont pas encore tombés d'accord sur des affaires qui ne semblent pas si difficiles à régler.' Bannier to Darimont, 11 December 1959, SA, NWO.

[41] Bourgeois to Oort, 18 December 1959, SA, NWO.
[42] It is not clear what exactly happened in the months between December 1959 and April 1960, as no further information on the matter could be found.

of the following members: for the Netherlands: Prof. Oort (president), Prof. Van de Hulst, Prof. Blaauw, H. Rinia, engineer, and Prof. Seegers; for Belgium: Prof. Coutrez (secretary-treasurer), Prof. Bourgeois, Heck, engineer, Prof. Van Hoof and Prof. Ledoux. The Council had to do the preparatory research into the possibility and desirability of building and using the cross antenna. It had to prepare the budgets and it had to appoint the people for the project. The Council in turn would be supervised by a 'Committee of Three', the 'organiser' of the project. This committee would be appointed by the Ministries of Education of the countries involved. The Belgian representative would be Darimont, who would be president and the Dutch representative would be Bannier, who would be commissioner. A representative of Luxembourg still had to be appointed. This committee would in the first place be responsible for the financial matters of the project. For example, it had to send the budget, prepared by the Council, with advice to the Ministries of Education of the three countries for approval; it had to approve the salaries of the participants etc.[43]

The fact that both countries agreed on the organisation of the project is an important step in the right direction. However, the agreement with the OEEC could not be signed yet. Some administrative matters still needed to be arranged. As sponsor of the project, the Dutch Ministry of Education, Arts and Sciences had to be accountable to the OEEC for the resources that were spent on the project in order to obtain the contribution of the OEEC. In the Netherlands, these financial data could be obtained from ZWO. In Belgium, however, it was not clear whether any arrangements in this respect were made. At the end of April, Bannier contacted Coutrez of Uccle Observatory – who was appointed as the secretary-treasurer of the project – to have a meeting on this issue as soon as possible.[44]

We have no further information on this meeting, but on 9 June 1960, J.H. Ferrier, chief advisor of the Dutch Ministry of Education, Arts and Sciences, wrote a letter to Bannier with a provisional budget of the 'second year' (1961) for the OEEC enclosed.[45] The budgetary estimates were as follows:

Scientific personnel	Dfl 86 000
Technical personnel	Dfl 50 000
Administrative secretary	Dfl 8000
Work by other institutions and by advisory engineers	Dfl 25 000
Laboratory instruments	Dfl 10 000
Digital computing	Dfl 5 000
Laboratory instruments	Dfl 15 000
Material	Dfl 30 000
Travelling in Europe	Dfl 4000
Return Journey and extra expenses Prof.	Dfl 10 000

[43] Cals, the Dutch Minister of Education, Arts and Sciences to the Belgian Minister of Public Education, 13 April 1960, SA, NWO.
[44] Bannier to Coutrez, 29 April 1960, SA, NWO.
[45] Ferrier to Bannier, 9 June 1960, SA, NWO.

Christiansen[46]	
Unforeseen	Dfl 22 000
Total	**Dfl 255 000**

In this document, an overview was also given on the progress of the project (some preparatory studies had started under the direction of Seeger). The 'unavoidable complication of an international set-up' was used to explain the delay. [47]

As this document was primarily meant for the OEEC, things were rather optimistically presented. In reality, it was still entirely unclear how far the Belgians had come with their administrative arrangements. Indeed, the same day Ferrier sent this proposal for the OEEC to Mr. Deloz, an official of the Department of Higher Education and Scientific Research of the Belgian Ministry of Public Education. In the accompanying letter, he insisted – again - that the necessary things should be done:

> I hope that you have now progressed so far (…) that the signing of the "Agreement" with the O.E.E.C. could take place before the consideration of the proposal for the contribution of the second year in the Governing Committee.[48]

Finally, on 21 June 1960, the Agreement with the OEEC was signed in Paris.[49] In total, the OEEC would contribute Dfl 144 780 (Dfl 22 121,45 for 1960; Dfl 77 041,05 for 1961 and Dfl 34 637,50 for 1962). This sum was paid partly in 1961, partly in 1962.[50]

It is not entirely clear why the procedures in Belgium to prepare the OEEC agreement took much longer than in the Netherlands. It could be explained by a lack of interest in the project, but also because of the fact that Belgian science policy – as we will see - was at the time in the middle of a huge reorganisation, which made it very bureaucratic. Moreover, around 1960, Belgian science policy had other priorities than (radio) astronomy.

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[46] Prof. W.N. Christiansen, head of the Department of Electrical Engineering at the University of Sydney would come to Leiden to cooperate on the Benelux Radio Telescope for 14 months, beginning on 1 November 1960.
[47] Proposal for the Development of a Benelux Growing Point in the Field of Radio Astronomy 2nd year, s.d. [9 June 1960], SA, NWO.
[48] 'Ik hoop, dat U inmiddels zo ver gevorderd bent (…) opdat ondertekening van de "Agreement" met de O.E.E.S. zo mogelijk plaats kan hebben vóór de behandeling van het voorstel voor de 2e jaarbijdrage in de Governing Committee.' Ferrier to Deloz, 9 June 1960, SA, NWO.
[49] Rapport intermédiaire sur le projet Benelux pour l'antenne en croix Benelux cross antenna project (B.C.A.P.) 22 February 1961, SA, NWO.
[50] J.H. Bannier, 'Nota over de Belgische achterstand in de betaling voor de radioastronomische samenwerking', 26 July 1966, SA, NWO.

3.5 THE OEEC AS A DIVISIVE ISSUE

Not only did it take a very long time before an agreement with the OEEC was concluded, the OEEC itself and its actions also deeply divided the Dutch and the Belgians.

The main stumbling block was the fact the OEEC was eager to internationalise the project further. This suggestion was very much welcomed by the Belgians, but opposed by the Dutch.

The first time this possible further internationalisation was discussed, was at the meeting of the Governing Committee for Scientific and Technical Personnel of the OEEC in the beginning of June 1959. In the letter Gass – head of the programming section – sent to Miss de Vos van Steenwijk of the Dutch delegation of OEEC, we read:

> At the meeting a number of other countries referred to the great interest that the proposal was likely to arouse in their countries, and asked whether there would be an opportunity for participation. In order that possible participation by other countries might be discussed on a satisfactory basis, the Secretariat suggested, and the Committee agreed, that it might be useful to hold a meeting of the interested scientific authorities in order to discuss the possible basis of participation by other countries. I should be glad if you would confirm that your authorities would be willing to arrange such a meeting, should other O.E.E.C. countries express an interest in the project.[51]

Whether this meeting with the interested scientific authorities actually took place, remains unclear. However, both Dutch and Belgian astronomers must have known these plans, as we found a letter in which Bourgeois said to Oort: 'Personally, I am of your opinion that it is better to maintain the Benelux character of the project.'[52] This reaction of Bourgeois also illustrates that the different viewpoints did not always follow the national boundaries. While Belgian science administrators were very much in favour of this internationalisation, the Belgian astronomers were often less enthusiastic.

Things were pushed to extremes in 1961. This was partly due to a reorganisation within OEEC. In 1961, the OEEC was reformed into the Organisation for Economic Co-operation and Development (OECD). With this reform, the organisation increasingly turned to questions of science policy. Science was now definitely recognised as a factor of economic growth. In order to contribute optimally to progress, however, science and technology policies had to be developed. (Godin, 2001, p. 22). OECD undertook a great deal of effort to turn science policy in the member states into a regular part of established government policies (Tindemans, 2009, p. 8). A Directorate for Scientific Affairs was founded, primarily concerned with education. It was established 'to take charge of activities of the Organisation relating to scientific research and to the expansion and rational utilization of the scientific and technical personnel available so as to meet the needs arising from economic growth.' (Beck, 1970, p. 173). In the member states there was a great need for highly qualified manpower in technical and scientific fields. The Directorate for Scientific Affairs tried to stimulate action in this regard. OECD also encouraged each of its member countries to study educational policy and planning. To this end, the Directorate undertook various statistical

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[51] Gass to De Vos van Steenwijk, 5 June 1959, SA, NWO.

[52] 'Personellement, je suis de votre avis qu'il vaudrait mieux laisser au projet son caractère Benelux.' Bourgeois to Oort, 27 June 1959, SA, NWO.

activities on science and technology (Godin, 2001, p. 23).

What we see is that this emphasis on science policy in the member states also meant a more direct influence of OECD on the scientific projects they sponsored. In our case, this was reinforced by the fact that the Head of the Special Scientific Activities Division of the Directorate for Scientific Affairs of OECD was Armand H. Delsemme. Delsemme was a Belgian astrophysicist from the University of Liege who became one of the most influential cometary chemists of his time. In the 1950s he collaborated in Liege with Swings on comets. At the instigation of Delsemme, Louis Haser of the University of Saarbrücken (Germany) developed a successful model of the distribution of matter in the heads of comets. Together with Haser, Delsemme published the *Atlas of Representative Cometary Spectra* (1955) (Houziaux, 2001, p. 150). In the late 1950s and early 1960s he was the founding director of the Observatoire de Lwiro (Belgian Congo) which he started to build from scratch in 1956. The site, near the equator, gave the one-meter-diameter telescope a view of both the northern and southern hemispheres. This experience in turn led Delsemme to the University of Toledo (Ohio, US) in 1966, where he became professor of astrophysics until his retirement in 1988. (Woods, 1998, p. 28).

Michael F. A'Hearn, a professor of astronomy at the University of Maryland later said about Delsemme:

> In the 1960s and 1970s, there probably were only about a half-dozen people in the world who spent a large fraction of their career on comets. Delsemme was one of the real pioneers. His studies of the chemistry of comets probably rival Whipple and Oort's work in other fields of cometary science. (quoted in Woods, 1998, p. 27).

The fact that Delsemme was at the same time an influential Belgian astrophysicist and a senior official at OECD can partly explain why the Belgians were much less reluctant to accept the interference of OECD in the cross antenna project. In the Netherlands, however, the actions of the OECD were regarded as overstepping its boundaries.

The following illustrates this.

At the General Assembly of the IAU in Berkeley in August 1961, the cross antenna would be discussed in 'Commission 40', the commission for radio astronomy. A few months earlier, Delsemme had put forward the idea of making this discussion a working party of the OECD. Furthermore, he had pointed out that BCAP could only contact countries or institutions through OECD. This was a response to the fact that Oort had been visited by a representative of the National Science Foundation (NSF) and had discussed with him possible financial support of NSF for the cross antenna project. According to Delsemme, however, these matters could only be arranged by OECD and not by the astronomers themselves. [53] The Dutch were quite upset about this. In a letter to Ferrier, Bannier said: 'Professor Oort was not very pleased with the letter of Delsemme and I also must say that I find it very unfortunate that OEEC is intruding into the BCAP-affair much more than necessary.'[54]

[53] This letter of Delsemme could not be found, only the subsequent letter in which these matters were discussed : Bannier to Ferrier, 21 July 1961, SA, NWO.

[54] 'Professor Oort is over de brief van Delsemme nogal ontstemd en ook ik moet zeggen, dat ik het wel bijzonder ongelukkig vind dat OEEC in de BCAP-zaak verder indringt dan strikt nodig is.' Bannier to Ferrier, 21 July 1961, SA, NWO.

Moreover, the Dutch presumed that Delsemme acted merely out of self-interest when he wanted to make the discussion of the cross antenna at the meeting of Commission 40 of the IAU a working party of the OECD: Delsemme wanted to go to Berkeley and otherwise he had no reason to go there.[55] After the Dutch had expressed their dissatisfaction with the whole situation, Delsemme dropped this idea of the working party of OECD. Indeed, during the meeting of Commission 40, nothing was said about OECD, Delsemme was not even present. The cross antenna was only briefly mentioned: 'On the other hand, particularly interesting projects of aerials of the type 'Mills Cross' are being studied in the Benelux countries.' (IAU Transactions, 1961, p. 456).

The Dutch were not only reluctant towards too much interference from OECD, they were not inclined to accept (financial) support from any third parties at all. After all, accepting this support could cause delay in the execution of the project and could make them lose their independence. When it came to accepting support of NSF, Bannier wrote to Oort:

> (...) This brings me now to the question you asked: should we ask for support from the NSF for the entire BCA Project? According to me, this should only be done if it could yield a really large amount, i.e. of the same order as what ESO gets from the Ford Foundation[56]. And we should only do this if Belgium strongly insists on it. Once before we have let ourselves be forced by the Belgians to ask for support elsewhere, namely from OEEC. All this was chicken-feed and caused a lot of fuss and delay. We should not have this happen again (although I expect a much more broadminded attitude and more understanding from the NSF than from OEEC) and we should definitely refuse to let us be forced by the Belgians (or by OEEC) to turn to NSF for minor expenses, as we should refuse support from NSF under restrictive terms.[57]

It is not clear how this discussion continued, but in any case, NSF was never asked for support.

In December 1961, the OECD sponsored an international meeting on 'Large Radio-Telescopes' (Raimond, 1996, p. 18). A few days later, another meeting was planned in Paris by OECD. This meeting was aimed at representatives of countries that were interested in BCAP, but did not participate in the preliminary study. The Dutch disliked this idea of a possible further internationalisation. Delsemme, however, defended his idea: if other countries provided a large part of the funds for BCAP, they had the right to know what happened with their money. Moreover, the OECD felt that radio astronomy could become a field too expensive to be handled by one or two small countries. So the organisation should investigate whether further internationalisation was desirable. [58]

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[55] Bannier to Ferrier, 21 July 1961, SA, NWO.
[56] In September 1964, ESO got 1 million dollars from the Ford Foundation (see below).
[57] 'Daarmee kom ik nu tevens op de vraag die je me stelde: Moet voor het gehele B.C.A. Project steun aan de N.S.F. gevraagd worden. M.I. alleen als dat een werkelijk groot bedrag zou kunnen opleveren, d.w.z. van de zelfde orde als wat ESO van de Ford Foundation krijgt. En dan nog alleen als er werkelijk van België uit sterk op wordt aangedrongen. Wij hebben ons door de Belgen eenmaal laten dwingen steun elders, nl. bij de OEEC, te vragen. Dat heeft niet meer dan chicken-feed opgeleverd en verder een heleboel rompslomp en oponthoud. Zoiets moet ons niet nog eens overkomen (al verwacht ik van de N.S.F. natuurlijk wel een veel ruimer houding en meer begrip dan van OEEC) en we moeten dus beslist weigeren ons door de Belgen (of door OEEC) te laten dwingen ons voor kleine kosten tot de N.S.F. te wenden, zoals we ook moeten weigeren steun van N.S.F. onder bezwarende voorwaarden aan te nemen.' Bannier to Oort, 15 September 1961, SA, NWO.
[58] Delsemme to Oort, 3 October 1961, SA, NWO.

However, when Oort heard that OECD had asked Great Britain and Germany to participate in the project - without consulting the Council of the BCAP – his patience was at an end. He wrote Delsemme a furious letter:

> We have recently been informed by our colleagues in Great Britain and in Germany that they have been approached concerning a participation in the (…) Project. In both countries, the impression has been created that they were being invited to join this Project. We are astonished and embarrassed by this action on your part. Not only has the Council for the (…) Project never asked you to do anything of this sort, but you must have been well aware of the fact that, at least in the present stage of the project, the Council is not considering to invite other countries to join.[59]

In a lengthy reply, Delsemme tried to clarify the situation. He explains he had indeed visited UK radio astronomer Martin Ryle to talk about the BCAP, but this visit was of a 'purely informative character'. Germany, on the other hand, had not been approached at all by OECD. This had to be a misunderstanding. However, Delsemme also clearly pointed out that the reason the OEEC had decided to sponsor the project, was *because* other countries had understood there was some definitive hope of promoting international cooperation outside the three sponsoring countries. He continued:

> It is also clear that up to now neither you nor the O.E.C.D. have been formally committed beyond the study of the project, but the hope of extending the project to other countries is still not excluded from the mind of some governments.[60]

The matter was of course also discussed in the Council meetings of the BCAP. At the meeting of 11 December 1961, for example, Oort repeated that it was strange that if two countries were considering a co-operative project, an organisation which had contributed only a small part of the expenditure would take steps tending to change the character of the project without prior consent of the two Governments primarily concerned. Delsemme, who was always present at these meetings of the council, explained again that the OECD secretariat had had the duty to give full information on the project to the member countries, and he regretted the misunderstandings in this matter. [61]

To conclude, the fact that this intrusion of the OECD into the cross antenna project met with much less resistance in Belgium than in the Netherlands, can be partly explained by the position of Delsemme in the OECD. Also, Delsemme may have 'used' OECD to his own advantage, for example when he proposed to make the discussion of the cross antenna at the meeting of Commission 40 of the IAU in Berkeley a working party of the OECD as this would allow him to go to Berkeley.

[59] Oort to Delsemme, 30 November 1961, SA, NWO.
[60] Delsemme to Oort, 6 December 1961, SA, NWO.
[61] Minutes of the Council Meeting of BCAP of 11 December 1961, SA.

3.6 BELGIAN VERSUS DUTCH SCIENCE POLICY: THE WATER WAS TO DEEP

There were, however, other influences beyond Delsemme's role that can explain why the Belgians were much less reluctant towards the actions of the OECD. For this, we have to take a look at Belgian and Dutch science policies.

The preparations for the cross antenna project coincided with extensive changes in Belgian science policy. As has already been said, these changes can to a certain extent explain the many delays the Belgians caused in the conclusion of the agreement with the OECD, although there is no 'hard' evidence for that. But more important, it can also explain why the Belgians had fewer problems with the 'internationalism' of the OECD.

The changes in Belgian science policy originated in the Second World War. As in other countries, the Second World War had radically changed science in Belgium. In America and the Soviet Union, Big science projects – like the Manhattan Project - mobilised new gigantic financial, technical and human resources and were coordinated by the state. Moreover, these projects brought about a fusion of national policy, science, technology, and engineering. In this context, a scholar no longer had to be merely a good scientist, but he had to be an 'entrepreneur' too who was able to get funding and to perform teamwork. In Belgium too, the realisation grew slowly that the small, traditional pre-war university laboratories, funded by the universities and by NFWO (the Belgian National Fund for Scientific Research, see Chapter I), were no longer sufficient if Belgian science wanted to remain significant in an international context (Halleux and Xhayet, 2001, p. 20). If the country wanted to be a worthy participant in the international big-science projects, change was needed. On the initiative of NFWO director Jean Willems, an international conference was organised in Brussels on 27 and 28 October 1952 (Balthazar, 2008, p. 5). It brought together several representatives of Belgian politics and science and directors of scientific institutions of several European countries, such as Spain, the Netherlands (Bannier, director of ZWO was present), Italy, Switzerland, Sweden, and the UK (NFWO, 1953, p. 81). This conference resulted in the report *De wetenschap ten dienste* ('In the service of science').[62] The common thread in this report is that Belgium needed *more* scientists and that Belgian scientific research was in need of much more *coordination*. As science had also become much more expensive, multi-university and also international organisation of research became crucial. In this post-war context, Belgium should try to participate in all kinds of (new) scientific research. Nevertheless, it should be aware that – despite its great traditions in several scientific fields - it would not be possible to belong to the world top in all fields:

> A small country such as ours cannot hope to be on the forefront in all domains, certainly not when very expensive installations and an extensive staff, charged with many tasks, are involved. Our scholars, however, should not remain indifferent to any important branch of research. (...) In fields in which we rightfully believe we can excel, our research activities have to be maximally supported, both by generously providing the necessary material means, and by encouraging new vocations. As our scholars have acquired international fame, everything should be done so that they could maintain the leadership, at least in

[62] The 'Bush report' is never mentioned in this report, which confirms our view that it was of minor importance in Belgium.

some respects.[63] (NFWO, 1953, pp. 127-128).

After this conference of 1952, several other initiatives to restructure Belgian scientific research were undertaken. It is worth mentioning that with these initiatives, Belgium had in fact anticipated the efforts of OECD since 1961 to turn science policy in the member states into a regular part of established government policies.

In 1957, Willems, together with the rector of Liege University, Marcel Dubuisson, stimulated the foundation of a National Committee – consisting of university rectors, science managers and several experts, and presided by ex-King Leopold III - that had to investigate the future of Belgian science policy. The committee emphasised – again - that the number of scientists and scientific activities should be increased in Belgium. It was also emphasised that science not only served the population's intellectual and moral development, but also its health and economic prosperity (Halleux and Xhayet, 2001, pp. 23-24). This general conclusion was made explicit in the numerous recommendations of the committee: on the organisation of higher education, the coordination of scientific research, the potential maximum activity of a scientific institution, means to increase efficiency, scientific research in the colonies, the situation of students and their living conditions, patronage of scientific research etc. These recommendations led to a Royal Decree on 16 September 1959, which installed a National Council for Science Policy, a Ministerial Committee for Science Policy and an Interministerial Commission for Science Policy. Science Policy was included in the Prime Minister's portfolio (Despy-Meyer, 2001, p. 68). In this manner, Belgian science policy also became an enormous bureaucratic undertaking. Accompanying bureaucratic problems, however, hampered the cooperation with the Dutch, as we will see.[64]

The National Council for Science Policy deserves special attention here. It was responsible for the development of Belgian science policy and it had to advise the government in matters of science. As we will see, it played a crucial role in the cross antenna project from the mid-1960s on.

The National Council for Science Policy strongly emphasised that Belgian science policy should be an 'international science policy'. In the annual report of 1960 of the National Council, we read: 'It is obviously more and more necessary that the actions of the national political authorities in favour of science are developed internationally (...)'[65] To this end, the governments had to include 'spontaneous' scientific cooperation – cooperation that had emerged in a rather informal way - in action programmes, which were specifically developed to this end. For example, several months earlier, the General Delegation for Scientific Research in France had contacted the National Council to formalise the spontaneous cooperation between Belgian and French biologists and economists. On the other hand, the governments also had to cooperate in the execution of extensive research projects, when these could not be executed by only one country. We could say

[63] 'Een klein land als het onze kan niet hopen in alle domeinen vooraan te staan, zeker niet wanneer er erg dure installaties en een talrijk, met velerlei taken belast personeel mee gemoeid zijn. Onze geleerden mogen echter voor geen enkele belangrijke tak van onderzoek onverschillig blijven. (…) In vakken waarin wij rechtmatig menen te kunnen uitblinken, moet ons navorsingswerk maximaal worden gesteund, zowel door vrijgevig de nodige materiële middelen ter beschikking te stellen, als door nieuwe roepingen aan te moedigen. Daar onze geleerden hierbij een internationale faam hebben verworven, moet alles in het werk worden gesteld opdat zij, althans in sommige opzichten, de leiding in handen zouden kunnen houden.'

[64] See also Kersten, 1996, pp. 293-303.

[65] 'Het is kennelijk meer en meer noodzakelijk dat de actie van de nationale politieke autoriteiten ten voordele van de wetenschap zich ontwikkelt op het internationale vlak (...).' (Annual report National Council for Science Policy, 1960, p. 56).

that the cross antenna project was an example of the latter, but it is not mentioned here, as at the time, the National Council did not yet know of this project. Mentioned as examples are European cooperation in nuclear physics, namely the 'Conseil Européen pour la Recherche Nucléaire' (CERN), founded in 1954 and in the foundation of which Belgium had played an important role (Halleux and Xhayet, 2001, p. 22), and European cooperation in space research and oceanography.[66] At the same time, the National Council stressed the importance not only of research itself, but also of methodological and statistical research *about* the research, about the conditions under which it flourished and its economic repercussions. Here, it mentioned the activities of OEEC and it said:

> Here the National Council follows with interest the activities of the OEEC, and wishes this organisation to continue its activities in close cooperation with the participating nations and, in the case of Belgium, with the Council itself.[67] (Annual report National Council for Science Policy, 1960, p. 58)

The strong emphasis on internationalism in Belgian science (policy) was not a new phenomenon in the post-war period. When we take a look at student mobility – only one aspect, but an important one of scientific internationalism - we see that since the late nineteenth century, Belgian science had been heavily internationalised. Belgian students regularly crossed the national borders, while on the other hand, many foreigners came to Belgium. Historian Pieter Dhondt found that between 1876 and 1938 each year on average almost 1200 foreign students were enrolled at the Belgian universities of Brussels, Ghent, Liege and Louvain. They represented more than 90 different countries and regions from all over the world, from Canada to Australia, from Japan to Chile. Immediately before the Second World War, almost thirty per cent (!) of the students in Belgium came from abroad. At Liege University, more than half the students were foreign (Dhondt, 2008, p. 5).

Although Belgium was one of the most – or maybe the most – 'internationalised' European country in matters of science, this internationalisation was certainly not exceptional in the period concerned. Since the late nineteenth century, large numbers of students from Eastern Europe, Russia, Belgium, France and Germany had crossed the borders and at the same time, many of these countries had hosted a great number of foreign students. In France, for example in 1911, twenty per cent of the students were of foreign origin. (Dorsman, 2009, p. 23).

Interestingly, in comparison with most other European countries Dutch science was remarkably *little* internationalised in the same period. That it was very unusual for the Dutch to cross their border can be aptly illustrated by a quote of the Dutch historian Pieter Geyl (1887 – 1966). When discussing his student days in Leiden in his autobiography, Geyl said about a fellow student: 'After his undergraduate studies he went to Ghent and studied there for one year – something very unusual and enterprising'[68] (quoted in Dorsman, 2009, p. 23).

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[66] Annual report National Council for Science Policy, 1960, p. 57.

[67] 'Hier volgt de Nationale Raad met belangstelling de werkzaamheden die door de O.E.E.S. worden ondernomen, en hij wenst dat deze organisatie haar werkzaamheden zal voortzetten en ontwikkelen in nauwe samenwerking met de deelnemende staten en, wat België betreft, met de Raad zelf.'

[68] 'Die was na zijn kandidaats naar Gent getogen en heeft er een jaar gestudeerd – iets zeer ongewoons en ondernemends.'

After the Second World War – despite the general trend towards internationalisation (especially 'Europeanisation') and the efforts of the OECD to promote international cooperation in science – Dutch science remained very nationally oriented. In 1985, the Dutch Advisory Council for Higher Education noted that student mobility in the Netherlands was remarkably poor. Only 1.5 per cent of the total Dutch student population was registered at an institution of higher education abroad. Also the number of foreign students in the Netherlands was low: only 2.1 per cent. As an explanation, the Council cited 'practical obstacles', but also reasons 'that have to do with mentality' (Dorsman, 2009, p. 25).

This lack of Dutch internationalism seems to be in contradiction with what we earlier said about the international orientation of Dutch astronomy. Dutch astronomy had 'successfully internationalised' since the late nineteenth century' (Baneke, 2009, p. 53). Oort, indeed, undertook several initiatives to internationalise Dutch astronomy: he was one of the driving forces behind the founding of the European Southern Observatory (ESO) in 1962; he played an important role in the IAU, of which he was secretary general (from 1935 to 1948) and president (from 1958 to 1961); he founded the Inter-Union Committee on the Allocation of Frequencies (IUCAF), that had to allocate frequencies for space research and radio astronomical research (Sadler, 1980, p. 47) etc.

However, firstly we think it is fair to say that astronomy can be considered to be an exception within Dutch science. This is not surprising: the very nature of the discipline of astronomy necessitates international cooperation to a certain extent (e.g. optical observations can hardly be done in countries with cloudy climates, such as Belgium and the Netherlands). Secondly, also in astronomy, international cooperation in the Netherlands was of a rather different character than international cooperation in Belgium. We could say that in the Netherlands, it had a much more *pragmatic* character. Oort, for example, only was an advocate of international cooperation when he was convinced that this would be advantageous directly or indirectly. He studied each project individually in order to determine whether it would benefit from international cooperation or not. 'Internationalisation just because science had to be international' – an attitude that prevailed in Belgium – did not appeal to him, nor to Dutch science managers such as Bannier.[69]

Beside a greater inclination towards international – or at least 'European' science in Belgium, there was another big difference between the two countries: unlike in Belgium, at the end of the 1950s, Dutch science policy placed a strong emphasis on 'pure science'. In December 1957, the Dutch Minister of Education, Arts and Sciences Cals installed a Commission for the Development of Scientific Research ('Commissie Ontwikkeling Natuurwetenschappelijk Onderzoek'). This was done mainly at the instigation of Oort, who was at that time the dean of the Faculty of Mathematics and Sciences at Leiden University and who was very unhappy with the recent hiring freeze at the university (Baneke, 2012, p. 115). The commission had to investigate how scientific research in the Netherlands could be boosted. The president of this commission was the physicist H.B. Casimir. (Therefore, the commission was often referred to as the 'Commissie-Casimir'.) In 1958, this commission published a report, known as the 'Casimir report'. In this report, a significant expansion of the budget for science was asked for (Baneke, 2012, p. 111). The rhetoric of 'pure' or 'fundamental' research that accompanied this episode is also remarkable, although it remained to a large extent *merely* a rhetoric.

[69] To read more on international cooperation of Dutch astronomers, especially on the relations with Russian astronomers, see : Elbers, 2012.

In Belgium, on the other hand, this pure-science rhetoric was typical for the interwar period and was considered outdated in the 1950s. During the First World War, Belgium was hard hit (much more than the Netherlands, which was neutral). After the war, science – and especially 'pure' science was seen as the key factor in the rebuilding of the country (in the Netherlands, this was the case after the *Second* World War). On 1 October 1927, King Albert I gave a speech in Seraing on the occasion of the 110th birthday of the Belgian iron, steel, and manufacturing company Cockerill. In this speech, there was a passage that, according to historian H. Balthazar, can be considered as the 'starting signal for the creation of NFWO' in 1928:

> In Belgium, there is a real crisis of the scientific institutions and laboratories, and the economic difficulties that have arisen from the post-war period, have made the public powers unable to take the decisive and effective measures that (…) could overcome the evil themselves. Our public is insufficiently aware that pure science is the essential precondition for applied science and that the nations that neglect science and the scholars are marked for ruin by fate (…).[70] (quoted in Balthazar, 2008, pp. 2-3)

After the Second World War, however, things changed:

> Finally, the public opinion had a changing image of the social role of scientific research. After 1945, the old positivistic progressive thinking met with growing skepticism and with new insights in the role of research during the Third Industrial Revolution.[71] (Balthazar, 2008, p. 9)

What indeed changed in Belgium was that whereas the emphasis previously was on pure science – which would inevitably lead to applications - after the Second World War the emphasis clearly shifted towards the *applications.* In the late 1950s, when writing a grant proposal it was – unlike in the interwar period - no longer appropriate only to point to the 'pure' scientific value of the project. In the Netherlands, on the other hand, in the late 1950s, 'pure' science still got priority, as we saw. (Although we must be careful not to overestimate this rhetoric: as we saw in Chapter I, fields in which applications were clearly visible, such as nuclear physics, were also in the Netherlands a priority for the government.) As we will see, this difference was a great obstacle in the cross antenna project. Unlike in the Netherlands, in Belgium the industrial benefits of the project were of primordial importance.

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[70] 'Er heerst in België een echte crisis der wetenschappelijke instellingen en laboratoria, en de economische moeilijkheden, uit de oorlog en de naoorlogse tijd gesproten, hebben de openbare machten buiten staat gesteld om zelf de besliste en afdoende maatregelen te treffen, die (…) het kwaad zouden kunnen verhelpen. Het publiek bij ons is er zich niet voldoende van bewust dat de zuivere wetenschap de onmisbare voorwaarde is voor de toegepaste wetenschap en dat de naties, die de wetenschap en de geleerden verwaarlozen, door het noodlot voor ondergang gemerkt zijn (…).'

[71] 'Ten slotte was er bij de publieke opinie ook een veranderend beeld over de maatschappelijke rol van wetenschappelijk onderzoek. Het oude positivistisch vooruitgangsdenken kreeg na 1945 te maken met zowel een groeiend scepticisme als met nieuwe inzichten over de rol van onderzoek in de Derde Industriële Revolutie.' With the 'Third Industrial Revolution', Balthazar refers to the concept as described in Alvin Toffler's (American publicist) *The Third Wave* (1980). It is the post-war age of nuclear energy and computers. In other contexts, 'Third Industrial Revolution' can also denote the present time of renewable energy, such as described by the American economist Jeremy Rifkin (e.g. J. Rifkin, *The Third Industrial Revolution : how Lateral Power Is Transforming Energy, the Economy, and the World*, New York, 2011)

Further, it is important that ZWO was only founded in 1950, and was more or less copied from the Belgian NFWO, which had been founded in 1928 (see Chapter I). Thus: in the late 1950s, ZWO was still a very young and small organisation. Moreover, the extensive reforms in science policy that took place in Belgium in this period and that made Belgian science policy very bureaucratic, did not take place in the Netherlands. In a 1971-1972 report, OECD criticised this insufficient development of Dutch science policy, while on the other hand, it was positive about the activities of ZWO and foundations such as SRZM (Kersten, 1996, p. 292). This difference between Belgium and the Netherlands seriously hampered cooperation in the cross antenna project. The typically Dutch style of quickly arranging things by having a chat with the right person was no longer possible in the slow and bureaucratic system of Belgian science policy.

Added to this, unlike in the Netherlands, by 1960 Belgian science policy had lost interest in Earth-based astronomy, despite its strong tradition. In December 1961, the Belgian government asked the National Council for Science Policy to pay special attention to molecular biology, space research and human genetics, which it considered then to be 'privileged sectors' that were important and still underdeveloped in Belgium.[72] The sector that absorbed the biggest part of the government funding, however, was – like in the Netherlands – nuclear research. In 1962, for example, it absorbed 826 million Bfr of the total annual budget for science of 4080 million Bfr of the Belgian government.[73]

In the early 1960s, Europe had entered the Space Age. As a matter of fact, Belgium was much more eager to cooperate in the European space research organisations such as ELDO and ESRO than in the radio telescope project. In March 1962, seven countries, including Belgium and the Netherlands – had signed in London the Convention to found the European Launcher Development Organisation (ELDO), which aimed at creating a jointly funded satellite launcher. In June of the same year, ten countries, again including Belgium and the Netherlands, signed a Convention in Paris to create the European Space Research Organisation (ESRO), which aimed at jointly pursuing (basic) research in space in the 1960s. Both organisations swallowed tens of millions of Bfr annually. In 1964, for example, Belgium spent 80.5 million Bfr on ELDO (Laureys, 2003, p.12). As we will see, in 1963 the National Council for Science Policy advised to spend a maximum of only 5 million Bfr annually for the radio telescope, which was of course 'chicken feed' in comparison with what was spent on nuclear physics and space research.

The reason why Belgium was so eager to cooperate in space research (one of the 'privileged sectors'), was again the country's strong emphasis on applications and industrial benefits. In the annual report of the National Council for Science Policy of 1962 about Belgium's contributions to ESRO and ELDO, we read:

> These (…) Belgian commitments and its consequences on the national level relate to the development of research programmes that are of great importance from an economic point of view: viz. under the agreement establishing E.L.D.O., Belgian industry is charged with the design, the study and the development of the third tracking station of the rocket. This means a contract for research and development of 210 million francs (…). Belgian

[72] Annual report National Council for Science Policy, 1962, p. 97.
[73] Annual report National Council for Science Policy, 1962, p. 25.

> industry also has a good chance of obtaining additional contracts for the building of the first stage of a heavy rocket, which will involve an amount of 100 to 140 million.[74]

Indeed, in the autumn of 1963 the Belgian manufacturer of electro-mechanical products ACEC (Ateliers de Construction Electrique de Charleroi) obtained a contract which aimed to establish a pre-project for a satellite designed to study solar astronomy and cosmic rays. For Belgian industry, this pre-study contract was a first important experience in the field of devices to be launched into space. Not only ACEC, but also several other subcontracting companies benefitted from the contract, such as the aerospace company SABCA (Société Anonyme Belge de Constructions Aéronautiques), the telephone manufacturing company BTMC (Bell Telephone Manufacturing Company) and the largest Belgian company of light bulbs and electronic components MBLE (Manufacture Belge de Lampes et Matériel Electronique).

In 1964, a new invitation to tender was launched for ESRO-I, a joint undertaking of ESRO and NASA. The aim was to study the polar ionosphere and auroral phenomena. ESRO-I included two models: ESRO-IA (renamed 'Aurora') and ESRO-IB (renamed 'Boreas'). The project manager was the French telecommunications laboratory LCT (Laboratoire Central de Télécommunications), the Belgian company BTMC was an associated firm. BTMC was responsible for the electrical power supplies for ESRO-IA and ESRO-IB, which were launched on 3 October 1968 and 1 October 1969 respectively (Laureys, 2003, pp. 5-6).

3.7 ESO OR BCAP?

The little attention that has been given to astronomy in Belgian science policy since about 1960 explains why Belgium considered for a while to give up its participation in another European astronomical project that was then being promoted - the European Southern Observatory (ESO) – in exchange for participation in the radio telescope project. Taking into account that Belgium was one of the founding fathers of ESO, this consideration may come as a surprise. The first suggestion towards the creation of ESO arose in the conversations between Oort and Walter Baade of Mt Wilson and Palomar Observatories, during the latter's stay in Leiden in the Spring of 1953. In January 1954, this was followed up by a meeting of astronomers from Belgium (Paul Bourgeois), France, the German Federal Republic, the Netherlands (Jan Hendrik Oort, Pieter van Rhijn and Pieter Oosterhoff), the UK and Sweden. This meeting led to a statement supporting the proposal for establishing a common observatory and encouraging efforts towards government support in the various countries (Blaauw, 1991, p. 87). On 5 October 1962, the Convention was signed by the above mentioned countries (except Great Britain, which finally chose cooperation with Australian astronomy in the Commonwealth context). Between 1954 and 1962, the search for a site and the planning of the instrumentation were done. A series of expeditions was organised

[74] 'Deze (…) door België aangegane verplichtingen en de gevolgen daarvan op het nationale vlak hebben betrekking op de ontwikkeling van researchprogramma's die in economisch opzicht van grote betekenis zijn. Krachtens de overeenkomst tot oprichting van de E.L.D.O. wordt de Belgische industrie nl. belast met het ontwerpen, de bestudering en de ontwikkeling van het derde geleidestation van de raket. Dit betekent een contract voor onderzoek en ontwikkeling van ongeveer 210 miljoen frank (…). De Belgische industrie maakt een goede kans op bijkomende contracten te verkrijgen voor de bouw van de eerste trap van de zware raket, waarmee een bedrag van 100 tot 140 miljoen zal gemoeid zijn.' Annual report National Council for Science Policy, 1962, p. 34.

to test sites in South Africa. In 1961, however, the attention shifted towards South America. Soon after the first explorations there, it was found out that the observing conditions in the Andes Mountains were outstanding. Therefore, the Andes Mountains in Chile were finally chosen as the location for the Observatory (Blaauw, 1991, p. 89).

It is not clear when exactly the Belgians started to be doubtful about participation in ESO, but the first written record about it is from February 1959. If the Belgians were in those days indeed debating priorities between ESO and the radio telescope project, this can explain why it took several months – in the first half of 1959 - before the Belgians got authorisation from the Minister of Education to put in a request for support from the Limited Fund of the OEEC. When the Dutch expressed their worries on this matter, they did not seem to trust Bourgeois' evasive reply that 'everything seemed to be okay'. Bannier subsequently wrote to Oort:

> (...) but now the situation in Belgium seems to be exactly the opposite of what Bourgeois has told us. I hope he can give us some clarification in this matter. In any case, this makes me again a little more pessimistic about the Belgian participation in ESO.[75]

Of course, the fewer countries that would participate in ESO, the higher the financial contribution of each country would be. This was feared by the Dutch astronomers. If the Dutch contribution would be too high, participation in ESO would probably not be accepted by the Dutch government. The solution would then be to get support from the Ford Foundation.[76]

The Ford Foundation was founded in 1936 by Henry Ford and his son Edsel. Around 1950, Ford had become the biggest philanthropic foundation in the world (Krige, 2006, p. 164). In August 1956, Oort had written to the Ford Foundation to ask for financial support for the ESO, which was then still in an embryonic stage. He got a negative reply. However, Oort's letter was written shortly before a major reconstruction of the Ford Foundation took place. When Henry Heald – an engineer by training - became president of the Ford Foundation in 1956, much changed. In 1958, Heald recruited Carl Borgmann – also an engineer by training and president of the University of Vermont - to set up a Science and Engineering Program. From then on, the Foundation put the emphasis on engineering, and a hundred million dollars was the anticipated funding level. Astronomy too became a beneficiary of this Program, partly because of Borgmann's personal interest in astronomy. As soon as Oort and Bertil Lindblad – a Swedish astronomer involved in ESO - knew of this new program, they contacted the Ford Foundation again. On 9 October 1958, Oort and Lindblad met with Heald and Carl Borgmann. During this meeting, little encouragement was given. A year later, however, the Ford Foundation Board of Trustees approved an amount of one million dollars to be granted on condition that at least four of the five nations (Belgium, France, German Federal Republic, the Netherlands and Sweden) would sign the Convention to create ESO (Edmondson, 1998, pp. 311-318).

As mentioned before, Belgium's participation was doubtful, but the participation of France too, was uncertain. And if both Belgium and France withdrew, only three countries would remain,

[75] Bannier to Oort, 6 February 1959, SA, NWO.
[76] Bannier to Oort, 6 February 1959, SA, NWO.

which was insufficient. In spite of the continuous advocacy of leading astronomer André Danjon, the French government was reluctant to embark upon such an expensive project. At the time, the reconstruction of the country that had suffered seriously in the Second World War was still a major concern. Moreover, internal political division which was enhanced by the Algerian independence movement (from 1954 until 1962) caused great political instability within the government and a frequent change of ministers, thus delaying a possible government decision (Blaauw, 1991, p. 88). The French government finally decided to participate, a decision that was announced on 28 June 1960. The grant of one million dollars was paid in September 1964 (Edmondson, 1998, p. 323). The importance of this grant should not be underestimated. As Edmondson says:

> The Ford Foundation's promise of a $ 1.0 million grant was the "catalytic agent" - a term used in the Ford Foundation staff's recommendation - that persuaded the French government to join in creating ESO. Without it, ESO might never have been more than the dream of Baade and Oort (Edmondson, 1988, p. 7).

As we will see, Belgium finally withdrew from the radio telescope project in 1966 and formally joined ESO in 1967 (the Netherlands in 1964). In several sources and in historiography, we read that this was because Belgium had to choose between ESO and BCAP – due to financial reasons – and they thus chose for ESO. Oort for example, said in an interview in 1986:

> As a matter of fact, they [the Belgians] should choose between participation in ESO, the European Southern Observatory, and participation in the Westerbork-project. (...) If Belgium would step out of ESO, the ESO-contribution of the Netherlands would be higher; the Dutch then finally decided: rather give up cross antenna, and stay with ESO![77] (Oort, 1986, p. 252)

And in his history of the Westerbork telescope, E. Raimond says: 'It appeared that simultaneous participation in ESO and in the BCAP would not really be possible in Belgium.' (Raimond, 1996, p. 25).

It should be clear, however, that the statement that Belgium withdrew from participation in BCAP 'because the country had to choose between BCAP and ESO' – as is so often said – is not true. As we saw, in the period concerned, the Belgian government annually spent several thousands of millions Bfr on science. Thus, financially it would have been peanuts to participate in both projects. The underlying reason of the withdrawal, however, was that astronomy was no longer a priority in Belgian science policy.

[77] 'Ze [de Belgen] moesten eigenlijk een keus maken tussen deelname aan de ESO, de Europese Zuidelijke Sterrenwacht, en deelname aan het Westerbork-project. (…) Als België uit de ESO zou treden, zou de ESO-contributie van Nederland hoger worden; van Nederlandse kant werd dan ook tenslotte besloten: geef dan liever die kruisantenne op, en blijf bij de ESO!' (Oort, 1986, p. 252)

3.8 BELGIUM'S 'CONDITIONES SINE QUAE NON': INTERNATIONALISATION AND INDUSTRIAL BENEFITS

In the early 1960s, an Agreement with the OECD was signed and support was received, but the Belgian government still had not officially confirmed that they would contribute to the cross antenna project. After several Dutch attempts to persuade the Belgian Government to make a decision, Bannier made a rather upsetting discovery in August 1963. Through contacts with the Belgian government, he found out that the Belgian bureaucrats had not even presented the project to the National Council for Science Policy yet, the advice of which was needed before there could be a decision about possible cooperation. Both Bannier and Oort were stunned by this fact. It is not clear who exactly was to blame for this state of affairs, but bureaucratic inertia combined with a certain indifference was clearly one of the problems. Bannier instantly wrote letters to Jean Willems, director of NFWO and a member of the National Council, and to Massart, president of the National Council, to ask for an expeditious handling of the matter.[78] Of course, he also tried to promote a positive decision. To Willems, he wrote:

> As I am aware that you have a prominent role in the National Council for Science Policy, permit me to ask you to promote an expeditious handling. You will understand that I do not want to influence in any way the decision of the National Council for Science Policy, but I would greatly appreciate it if not too much time were required to take that decision. Of course, I would be very glad if the decision was positive[79] (…).

An answer of Willems to Bannier followed on 6 September 1963. He wrote that the matter would be discussed at the meeting of the Council on 17 September 1963. The Bureau of the Council would then ask the working party 'Technology' to write a draft recommendation that would first be discussed in the Bureau and then in the Council. The matter would be ready between 15 November and 1 December.[80]

Bannier, however, thought this cumbersome bureaucratic procedure was too time consuming. Moreover, he insisted that the plans should be considered not only by the 'Technology' working party, because:

> The technical realisation of the project, mechanical as well as electronic, is indeed a very difficult problem that may therefore be of great importance for the development of techniques. However, the project is primarily important for astronomy and therefore I hope that the National Council will in the first place ask the opinion of famous astronomers such as Professor Swings and Professor Van Hoof.[81]

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[78] Bannier to Willems, 30 August 1963; Bannier to Massart, 30 August 1963, SA, NWO.
[79] 'Wetende dat U in de Nationale Raad voor Wetenschapsbeleid een voorname rol speelt veroorloof ik mij echter U te vragen een spoedige behandeling te willen bevorderen. U zult begrijpen dat ik op geen enkele wijze wil trachten invloed uit te oefenen op de beslissing, die de Nationale Raad voor Wetenschapsbeleid neemt, maar ik zou het bijzonder op prijs stellen wanneer met het nemen van die beslissing niet te veel tijd gemoeid zou zijn. Het zou mij uiteraard bijzonder verheugen indien de beslissing positief zou zijn (…).' Bannier to Willems, 30 August 1963, SA, NWO.
[80] Willems to Bannier, 6 September 1963, SA, NWO.
[81] 'De technische verwezenlijking van het project, mechanisch zowel als elektronisch, vormt inderdaad een zeer moeilijk probleem, dat daardoor van grote betekenis kan zijn voor het ontwikkelen van technieken. Het project is echter in de eerste plaats van belang voor de sterrenkunde en daarom hoop ik, dat de

Clearly, Bannier wanted the plans to be judged by astronomers because he expected a more receptive attitude from them. The reason for that was obvious: astronomy was still a small world. A working party of astronomers would inevitably include either astronomers cooperating on the cross antenna project or their close colleagues. People would thus – again - be judge and party at the same time. Professor Van Hoof, for example, whose opinion should be asked – according to Bannier – was himself a member of the Council of the cross antenna project. Swings did not cooperate in the project, but he followed it closely and was a confidant of Oort.

On the other hand, it is possible – although we have no direct evidence for this - that Bannier himself doubted the technological value of the project and that he feared that a committee of technological experts would do the same. Most astronomers knew hardly anything about the technology and the technological implications of their project and remained very vague in this respect, but a committee of technological experts could not be fooled, of course.

Despite all the efforts of the Dutch – Oort always tried to use his mainstay Swings as a mediator in the matter[82] - the procedure could not be speeded up. Moreover, the advice was asked of both an astronomical *and* a technological working party. On 17 September 1963, the Bureau of the Council invited the Committee of Scientific Experts to study the project. This Committee in turn composed a study group, presided by astronomer M. Migeotte and with as its members the astronomers Coutrez, Ledoux, Lemaître, Swings, Vanderlinden, Van Hoof and Velghe (the latter was astronomer at the Royal Observatory in Uccle and director of this institute from 1964 until 1983). Defay, working at the National Council for Science Policy was also a member of this study group. It is noteworthy that Coutrez, Van Hoof and Ledoux were all three also members of the Council of the cross antenna project and were thus judge and party at the same time. Moreover, the other astronomers, or at least most of them, knew the astronomers from the project very well. Hence it is not surprising that on 8 October 1963, this group gave a positive advice on the scientific value of the project to the Committee of Scientific Experts and said that cooperation with the Netherlands was desirable.[83]

On the other hand, the Bureau also asked the advice of a working party Development Advanced Technological Research and Space Research ('Ontwikkeling Gevorderd Technologisch Onderzoek en Ruimteonderzoek'). It consisted of several technical experts who were not acquainted with the astronomers. Their advice was noticeably less positive than that of the astronomers. Their main conclusion was that the contribution the project would make to technological development was relatively unimportant. Further, it said that the instrumentation should not be paid for with the funds for scientific research.[84]

The bureau discussed both pieces of advice on 26 November 1963. It composed a draft advice for the National Council. The National Council in turn, approved this advice (with some minor changes) during its meeting of 2 December 1963. In its conclusions, it stressed again – following

Nationale Raad vooral het oordeel zal vragen van befaamde astronomen als Professor Swings en Professor van Hoof.' Bannier to Willems, 10 September 1963, SA, NWO.

[82] Sometimes, Swings was invited to the meetings of the BCAP Council to discuss whether he could force a breakthrough (e.g. Minutes of the meeting of the BCAP Council of 17 October 1963, SA).

[83] 'Ontwerp-advies van de Nationale Raad aan de Regering en toelichtend verslag betreffende het project tot opstelling van een kruisvormige antenne', Brussels, 27 November 1963, NRWB/168 n.

[84] 'Ontwerp-advies van de Nationale Raad aan de Regering en toelichtend verslag betreffende het project tot opstelling van een kruisvormige antenne', Brussels, 27 November 1963, NRWB/168 n.

the advice of the working party Development Advanced Technological Research and Space Research - that it doubted the value for technological research. It said:

> The share of the technological and development research reaches about 10% of the total expenditure (45 million out of 450). Only a tiny part of the total sum would thus be spent on the remuneration of the research teams. (…) The project is different from the research programs (…) where the composition and the remuneration of the research teams are the main expenditure and which contribute thus more directly to the increase of the nation's potential of skilled researchers. (…) The building of the proposed instrument will however bring indirect technological progress in some important fields (reception of short waves, amplification, construction of mirrors and antennas). Some aspects of this progress will find an outlet in important industrial markets. The outlet for scientific instruments, however, is rather limited. The same expenditure for development research in the directions chosen together with industrial outlets would have a more important economic impact. Hence, the industrial consequences should not be overestimated.[85]

Summarising, the National Council advised that participation was only desirable, if the following conditions had been fulfilled:

(a) A detailed estimate of the total cost had to be made.
(b) The Belgian government had to find further international funding to pay for the instrumentation, so that the Belgian budget for science could be reserved for the actual scientific *research*.
(c) Industrial contracts had to be concluded to let Belgium's industry participate. More specific, Belgian companies should have a share in the building of the antennas. Moreover, the National Council advised that Belgium should take the lead in the project's system engineering and data handling.

Furthermore, it was said that a maximum annual sum of 5 million Bfr should be spent on this project.

This advice of the National Council was communicated to the Ministerial Committee for Science Policy, which then in turn recommended the government to postpone the decision until the fulfilment of the above mentioned conditions, which the government indeed did. The decision was communicated by the Belgian Prime Minister Lefèvre to the Dutch Minister of Education, Arts and

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[85] 'Het aandeel van het technologisch en ontwikkelingsonderzoek bereikt ongeveer 10% van de totale uitgave (45 miljoen op 450). Een gering gedeelte van de totale som zou dus besteed zijn voor de bezoldiging van de research-teams. (...) Het project verschilt van de researchprogramma's (...) waar de samenstelling en de bezoldiging van de research-teams, de voornaamste uitgave vormen en derhalve op een meer directe wijze bijdragen tot de stijging van 's lands potentieel aan geschoolde onderzoekers. (...) De bouw van het voorgestelde toestel zal evenwel op enkele belangrijke gebieden een indirecte technologische vooruitgang meebrengen (ontvangst van korte golven, amplificatie, bouw van spiegels en antennes, automatisme). Bepaalde aspecten van deze vooruitgang zullen een afzetgebied vinden op belangrijke industriële markten. Het afzetgebied van wetenschappelijke instrumenten is daarentegen vrij beperkt. Dezelfde uitgave voor ontwikkelingsonderzoek in de richtingen gekozen in samenhang met de industriële afzetgebieden zou een belangrijker economische weerslag hebben. De industriële consequenties mogen dus niet overschat worden.' 'Advies van de Nationale Raad aan de Regering en toelichtend verslag betreffende het project tot opstelling van een kruisvormige antenne', Brussels, 2 December 1963, NRWB/170n.

Sciences, Theo Bot, on 6 January 1964.[86]

The Dutch, of course, were very disappointed. Piekaar, head of the Division of Higher Education at the Ministry of Education, wrote to Prime Minister Lefèvre that it was absolutely impossible to meet the conditions of the Belgian National Council for Science Policy. Firstly, giving a more detailed estimate of the costs was impossible at the time, as it could not be decided *where* the telescope would be built before Belgium had officially decided upon its participation. So there was still uncertainty about the costs of the land. Secondly, a further internationalisation of the project was impossible, as observing time with this instrument was limited. So there was simply no time left for astronomers from other countries to do observations (note that it is the first time this argument of limited observation time comes up). Moreover, further internationalisation would delay the project. To grant contracts to Belgian companies was also not possible now, as Belgium was running behind in its payments for the project.[87]

For the first time, cooperation with Belgium is openly questioned:

> (…) under these circumstances, they [the Dutch astronomers] ask themselves whether it would not be preferable to realise a more modest design without Belgian participation, in connection with Dwingelo if possible (…).[88]

In a memorandum to Piekaar of the same day, Oort emphasises that cooperation under the conditions that Belgium proposed, was not possible. He did not immediately want to end the relations with the Belgians, but the Dutch should be able to decide autonomously about the allocation of the investment funds:

> Given the difficulties in the cooperation with Belgium during the past 2,5 years, given the lack of enthusiasm with which the project was received in the Belgian National Council for Science Policy, given also the emphasis that was placed on potential direct industrial interests and given the restrictions that, according to this advice, would be associated with a possible cooperation with Belgium, we believe we have to conclude that further cooperation in the way that we had in mind up till now, would so seriously endanger the success of the project that no leaders would come forward and that we would have to give up (…). To me, it seems there is no need to break off the relations with the Belgians entirely. But we have to regain the freedom to decide on the allocation of the investment funds.[89]

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[86] The letter of 6 January could not be found, but in a subsequent letter, Bot refers to it: Bot to Lefèvre, 13 January 1964, SA, NWO.

[87] Piekaar to Lefèvre, 13 January 1964, SA, NWO.

[88] '(…) onder deze omstandigheden vragen zij zich af, of het niet verkieslijker zou zijn dan maar een meer bescheiden opzet te verwezenlijken zonder Belgische deelname, zo mogelijk in aansluiting op Dwingelo (…).' Piekaar to Lefèvre, 13 January 1964, SA, NWO.

[89] 'Gezien de moeilijkheden in de samenwerking met België in de afgelopen 2,5 jaar, gezien het gebrek aan enthousiasme waarmee het project in de Belgische Nationale Raad voor Wetenschapsbeleid ontvangen is, gezien ook de nadruk die in het advies van deze Raad gelegd wordt op eventuele directe industriële belangen en gezien de restricties die blijkens dit advies aan een eventuele samenwerking met België verbonden zouden worden, menen wij te moeten concluderen dat verdere samenwerking in een vorm zoals deze ons tot nu toe voor ogen gestaan heeft, het welslagen van het project zo ernstig in gevaar zou brengen dat zich dan geen leiders voor het project beschikbaar zouden stellen, en wij zouden moeten opgeven. (…) Er lijkt mij geen noodzaak te zijn de betrekkingen met de Belgen geheel te verbreken. Maar wij moeten de

As will be discussed in the next chapter, the problems with the Belgians had also forced the Dutch to think about a cheaper design of the telescope since the end of 1963.

Thus, in the beginning of 1964 the Belgian-Dutch relations seemed to have reached a standoff. A few months later, however, the Belgian embassy let the Dutch Ministry of Foreign Affairs know that it had dropped the claim for further internationalisation and it agreed to maintain the bilateral character of the radio telescope project.[90]

On 17 March 1964, a meeting of the Council of the cross antenna project took place in Leiden. New problems arose here. As the Agreement concluded with OECD had come to an end – it had been concluded for the design phase only – the organisational structures that came with it could also be replaced. It was decided that the Council of the project would continue to exist as a kind of advisory body. Both the Belgians and the Dutch had agreed that the 'Committee of Three' (see above) would be replaced by a 'Dutch-Belgian Commission' (as Luxembourg did not participate[91]) which would have about the same tasks as the Committee of Three.

However, at the meeting of 17 March, Darimont explained that the Belgians had decided that the Belgian representatives in this Dutch-Belgian Commission would be the following: one representative of the Ministry of Public Education (Darimont himself); one representative of the Ministry of Finances; one representative of the Ministry of Foreign Affairs and one representative of the National Council for Science Policy.[92] This meant, as a matter of fact, that the Council of the cross antenna project would now be controlled by a huge bureaucratic body, consisting of several government officials. The Dutch were very unhappy with this decision. Piekaar sent a letter to the Dutch Minister of Education, in which he expressed his discontent about the fact that the scientific advice of the Council of the project would now be under the control of a bureaucratic commission of government officials. He also feared that this would entail new delays.[93]

Nevertheless, the project continued. On 27 April 1964, a meeting took place of the – newly formed – 'Dutch-Belgian Administrative Committee' (the aforementioned Dutch-Belgian Commission). Present were the Belgian government officials and J. Spaey as the president of the Interministerial Commission for Science Policy (a subdivision of the National Council for Science Policy). The Dutch delegates were Bannier, Ferrier (chief advisor of the ministry of Education, Arts, and Sciences) and S. Meyer (of the Ministry of Foreign Affairs). In this meeting, Bannier explained that the Dutch had come to a conclusion concerning the allocation of the contracts for the construction of the telescope. Remember that for the Belgians, it was a prerequisite that Belgian industry should benefit from participation in the project. Bannier said that, as in both countries there were qualified companies that could execute the plans, price offers should indeed be asked at companies in both countries.[94]

However, the Belgians did not come up with suggestions about Belgian companies that could be

vrijheid herkrijgen om over de besteding der investeringsgelden zelf te beslissen.' Oort to Piekaar, 'Memorandum over de te bouwen grote radiotelescoop', 13 January 1964, SA, NWO.

[90] Belgian Embassy to the Dutch Ministry of Foreign Affairs, 12 March 1964, SA, NWO.

[91] It is not clear whether Luxembourg had ever formally been approached to cooperate. In any case, they have never been engaged in the project.

[92] Minutes of the 15th Council Meeting of 17 March 1964, SA.

[93] Piekaar to Bot, 26 March 1964, SA, NWO.

[94] Minutes of the Meeting of 27 April 1964 of the 'Nederlands-Belgisch Adminsitratief Comité voor het radiotelescoop project', 12 May 1964, SA, NWO.

contacted to this end. Therefore, Bannier thought the board of SRZM was relieved of the requirement to let Belgian companies tender for contracts.[95]

Several months passed. In October 1964, Oort complained to Spaey that he had not heard anything yet about a decision of the Belgian government on participation, notwithstanding that on the meeting of 27 April 1964 Spaey had said that he would strive for a decision before 1 June.[96] Spaey's reply followed four months later. He said that, as the Ministerial Committee did not meet before December 1964, a decision could not earlier be communicated. However, he was happy that now there finally was a decision:

> Following the latest meeting of the Ministerial Committee I have the pleasure to inform you that the Ministerial Committee has decided that Belgium will participate in the operating costs of the radio telescope (…). The participation of Belgium should however not exceed the amount of 7 million BF annually.[97]

The Bureau of the Interministerial Commission for Science Policy was assigned the task by the Ministerial Committee to elaborate an agreement with the Dutch government. Oort, of course, was very pleased with this response, which he communicated to the members of the Council for the Project.[98]

3.9 THE ANTARCTIC EXPEDITIONS AS THE ULTIMATE BREAKINGPOINT

Notwithstanding that in 1965 it seemed that a great breakthrough had been reached as the Belgian government had officially decided to participate, the next year the Belgians suddenly withdrew because of the developments in a completely different Belgian-Dutch project: the Antarctic expeditions.

From the end of the nineteenth century, people from Great Britain, Russia, and Norway have travelled to the Antarctic. It was actually the Belgians who initiated a long tradition of international explorations of the Antarctic. Indeed, the first international and 'purely scientific' expedition to the Antarctic, was the so-called 'Belgica-expedition' (1897-1899), named after the ship the 'Belgica' with which the expedition was undertaken. It was led by Adrien de Gerlache de Gomery of the Belgian Navy. The ship had an international crew on board, including the Norwegian second mate Roald Amundsen, the American surgeon, anthropologist and photographer Frederick Cook, the Polish geologist, oceanographer and meteorologist Henryk Arctowski, the Romanian zoologist and botanist Emile Racovitza and several others. During the expedition, the Antarctic was explored geographically, meteorologically and biologically. The largest terrestrial animal, a wingless fly of only 2-6 mm, was discovered and named the 'Belgica Antarctica'. (Verlinden, 2009, pp. 108-149). Subsequently, dozens of British, French, Australian, Norwegian, Polish and also Dutch expeditions were undertaken in the first half of the twentieth

[95] Bannier to Ferrier, 21 August 1964, SA, NWO.
[96] Oort to Spaey, 8 October 1964, SA, NWO.
[97] 'Naar aanleiding van de jongste vergadering van het Ministerieel Comité heb ik het genoegen U thans zonder verwijl mede te delen dat het Ministerieel Comité beslist heeft dat België zou deelnemen in de werkingskosten van de radiotelescoop (…). De deelneming van België zou evenwel het bedrag van de 7 miljoen F per jaar niet overschrijden.' Spaey to Oort, 19 February 1965, SA, NWO.
[98] Oort to the members of the Council of BCAP, 1 March 1965, SA, NWO.

century.[99]

After the successful Belgica expedition at the end of the nineteenth century, the Belgians did not return to the Antarctic until the late 1950s. From 1 July 1957 until 31 December 1958, the International Geophysical Year took place. Sixty-six countries participated in a worldwide research programme. Twelve countries built scientific stations on Antarctica and the Peri-Antartic islands: Argentine, Australia, Belgium, Chile, France, Great-Britain, Japan, New-Zealand, Norway, Russia, The United States and South-Africa. Under the leadership of Gaston de Gerlache, son of Adrien de Gerlache, a new scientific expedition was organised. A Belgian crew took off for the Antarctic in November 1957. A scientific base was built, which was opened on 11 January 1958 and was called 'Roi Baudouin base', after the then Belgian king Baudouin. An extensive scientific programme was carried out: meteorological research, ionosphere research, geological research etc. A new mountain chain was discovered in December 1958, which was called the Belgica Mountains ('Belgica Bergen') (Verlinden, 2009, p. 265). This Belgian expedition would last until April 1959.[100]

A further Belgian scientific expedition took place from November 1959 until March 1960, during which several new mountains were discovered (e.g. the 'Queen Fabiola Mountains'). However, this expedition was also the last expedition the Belgians undertook on their own. At the time, the independence struggle of the Belgian colony the Republic of the Congo had begun. (Congo would gain its independence on 30 June 1960.) These problems absorbed attention and especially resources of the Belgian government, so in the beginning of 1961 it was decided that the (expensive) Roi Baudouin base should be closed. (Verlinden, 2009, p. 277).

Now the Dutch enter the story. In 1960, the Dutch Minister of Foreign Affairs Joseph Luns asked the Royal Netherlands Academy of Arts and Sciences (KNAW) whether they were interested in doing scientific research in the Antarctic. Until then, The Dutch had no tradition of scientific expeditions to the Antarctic: their activities over there had been confined to whale hunting. The reply of the KNAW was negative. Antarctic research was 'not attractive, not urgent and unimportant' (Verlinden, 2009, p. 279) for the Netherlands. The Dutch had a reputation and a tradition in the tropics and it was there that the focus of research should remain. Shortly after, however, the Belgian government offered the Dutch government to take over the Roi Baudouin base. The Dutch Ministry of Foreign Affairs then again tried to convince the KNAW again to do research in the Antarctic. The Ministry of Foreign Affairs asked the support of the Ministry of Education, Arts and Sciences and the Ministry of Traffic and Water Management. It said that

[99] The purposes of these expeditions were not only scientific, but also commercial and / or recreational. The (commercial) whale hunting, in which the Netherlands were particularly active, was famous. In 1946, the Dutch Whaling Society (Nederlandsche Maatschappij voor Walvischvaart) was founded. In the early post-war period, whales were especially wanted for their oil, as oil by then was a scarce product (Verlinden, 2009, pp. 252-255).

[100] A milestone in the history of the Antarctic expeditions was the Antarctic Treaty that was signed by twelve countries – amongst which Belgium - in December 1959 and that came into force in June 1961. The goal of this treaty was to regulate international relations with respect to Antarctica. The continent should be free of military conflict and should be reserved exclusively for scientific research (Verlinden, 2009, p. 274). So far, 49 countries have signed the treaty. The Netherlands signed it in 1967. However, the Antarctic Treaty – and several other regulations - did not prevent the continuation of commercial whale hunting (Rothwell and Stephens, 2009).

maybe 'Russia would take over the base if Belgium and the Netherlands would withdraw'. This Cold War argument, however, failed to convince the KNAW (Verlinden, 2009, p. 279).

The year after, in 1961, Belgium asked whether it would be possible to organise a Belgian-Dutch cooperation, where both countries would go to the Antarctic and where each would pay their share. But no clear answer followed.

In 1962, Gaston de Gerlache made an ultimate attempt to convince the Dutch. He approached the Dutch minister of Foreign Affairs with the proposal that Belgium would bear two thirds of the costs if the Netherlands would agree to cooperate in the Antarctic. The Dutch minister reacted quite enthusiastically and thought it was about time the Dutch should also have a share in the activities on the Antarctic. The KNAW finally agreed. The Netherlands Committee for Antarctic Research ('Nederlandse Commissie voor Antarctisch Onderzoek') – a committee of the Netherlands Marine Research Foundation - was founded to coordinate the cooperation with the Belgians. It got a sum of 650 000 Dfl of ZWO to enable the start of research on the Antarctic (Verlinden, 2009, p. 280). A special role in this commission was reserved for the KNMI, as the Belgians had asked the Dutch to focus on meteorological research.

In Belgium, a Committee for the Management of the Belgian-Dutch Antarctic Expeditions (Comité voor het Beheer van de Belgisch-Nederlandse Zuidpoolexpedities) – under the leadership of Gaston de Gerlache - was founded to coordinate things.

On 8 December 1963, a Belgian-Dutch crew left the port of Antwerp on board of the Danish ice breaker the *Magga Dan.* When this expedition arrived in January 1964, the first thing it had to do was to rebuild the Roi Baudoin base, which was covered in an 8 metres thick ice layer and had collapsed in several places. This expedition - which went smoothly (Kersten, 1996, p. 300) - lasted until February 1965. In the meantime, a second Belgian-Dutch crew had arrived in December 1964. They stayed until March 1966. A third expedition took place from December 1965 until March 1967. This was also the last Belgian-Dutch expedition. During its preparations, a disagreement had arisen in the Netherlands Committee for Antarctic Research about the continuation of the expeditions. The data that were gathered during these expeditions were useful in itself, but they were merely routine observations that were published in annual reports. Some committee members saw the ad-hoc character of these expeditions as a serious shortcoming. Only if the research would be continued for a long time, could it yield interesting results. But ZWO, which provided the Dutch budget, could not give any long-term guarantees. Therefore, after the third expedition, the Netherlands decided to withdraw. The Belgians did not want to continue alone and as a consequence, the Roi Bauduoin base was definitely closed on 9 February 1967 (Verlinden, 2009, p. 282).

Kersten emphasises several other reasons for the withdrawal of the Dutch: the inefficiency and rather negative attitude of C.J. Warners, president of the Netherlands Committee for Antarctic Research (and successor of Vening Meinesz as head of the KNMI); the poor communication between the Ministry of Foreign Affairs on the one hand and ZWO and the Ministry of Education, Arts and Sciences on the other hand and last but not least: budgetary reasons. Because of the difficult financial situation of ZWO in the late 1960s, only in the best-case scenario would there be a budget for a fourth expedition. Later expeditions would be impossible at all (Kersten, 1996, pp. 300-301).

The withdrawal of the Dutch was for the Belgians the immediate cause to withdraw from the cross antenna project. Indeed, in the minds of the Belgians, the Antarctic expeditions and BCAP were inextricably linked to each other. This means that they considered the Dutch participation in the Antarctic expeditions to be a necessary condition for the Belgian participation in the cross antenna project, although in reality, the two projects had nothing to do with each other. We read about this supposed 'link' for the first time in a letter of Bourgeois to Bannier. In this letter, Bourgeois talks about a meeting of Belgian and Dutch government officials (it is not clear which meeting this was or when it took place exactly) and he says:

> During this meeting the Belgian delegation had announced that a participation of Belgium in the cross antenna project could only be considered if the Netherlands participated in the Belgian-Dutch Antarctic expedition. I am told that this statement, written down in the minutes of the meeting, did not provoke any reaction of the Dutch delegation.[101]

The Dutch, however, made clear that for them the two projects were definitely *not* linked to each other: '(…) if the Belgians believe that the Dutch consider the Telescope Project as being linked to the joint Antarctic expedition, this view rests on a misunderstanding.'[102] Nevertheless, during the discussions it had become clear that several Dutch representatives were also strongly in favour of linking the two projects, as – in their eyes - this would enhance the chance that both projects would be realised. Among them were Bannier and the responsible official of the Ministry of Foreign Affairs, S. Meyer (Kersten, 1996, p. 301).

When discussing the radio telescope project, the Dutch sometimes stressed the fact the Belgians took the lead in these expeditions, which seemed to imply that Belgium should accept the Dutch preponderance in the radio telescope project. When in April 1964 Bannier wrote a letter to Massart (president of the National Council for Science Policy) about the telescope, he also said: 'I am now writing to you chiefly about another project of Belgian-Dutch scientific cooperation, one in which the Belgian share is bigger than the Dutch. I mean the expedition to the Roi Baudoin base in the Antarctic.'[103]

Moreover, J. Otker – at the same time head of the administration of ZWO and administrative officer for the radio telescope project - found himself in a 'difficult position', in his own words, as he was in a certain way responsible for both the Dutch contributions to the Antarctic expeditions and the Belgian contributions to BCAP. A complicating factor was that the Belgians were always late with their payments (we will explain this further in Chapter IV):

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[101] 'Au cours de cette réunion la délégation belge aurait fait connaître qu'une participation de la Belgique à l'antenne dite en croix ne pouvait se concevoir que comme la participation de la Hollande à l'expédition antarctique belgo-hollandaise. On m'affirme que cette déclaration, notée au procès-verbal de la réunion, n'avait attiré aucune remarque de la part de la délégation hollandaise.' Bourgeois to Bannier, 2 November 1965, SA, NWO.

[102] '(…) indien de Belgen van oordeel mochten zijn dat van Nederlandse kant het Telescoop Project zou worden gezien als gekoppeld aan de gezamenlijke Zuidpool expeditie, deze opvatting op een misverstand berust.' Minutes of an internal Dutch meeting about the Synthesis Radio Telescope Project, held on the Ministry of Education, Arts and Sciences, 6 December 1965, SA, NWO.

[103] 'Ik schrijf U thans in hoofdzaak over een ander project van Belgisch-Nederlandse wetenschappelijke samenwerking, thans een waarin het Belgische aandeel groter is dan het Nederlandse. Ik bedoel de expeditie naar de Koning Boudewijnbasis in het Zuidpoolgebied.' Bannier to Massart, 16 April 1964, SA, NWO. The letter was about the funding of the Antarctic expedition for the year 1965.

> You will understand that I am in a difficult position when on the one hand, in my job at ZWO I have to ensure that the funds for the other Belgian-Dutch project, the Antarctic expeditions, always have to be transferred to Brussels strictly on time and in advance, while on the other hand, acting as "administrative officer for B.C.A.P." I have to ask Z.W.O. time and again, year after year, for advances for B.C.A.P., since the Belgian contributions are in arrears.[104]

Anyway, two months after Otker's letter, the cooperation between the two countries was definitively abandoned: on 29 June 1966, a Dutch delegation announced in Brussels that the Dutch government had decided not to provide funding for an Antarctic expedition in the year 1967. Subsequently, on 25 July 1966, the Belgian ambassador in The Hague had a meeting with the Dutch Prime Minister and the Minister of Foreign Affairs, during which he communicated the withdrawal of the Belgians from BCAP:

> During this meeting the ambassador has confirmed that the Belgian Government, much to its regret, has been compelled to delete the provisions of the budget of 1967, that concern two scientific initiatives in which the Benelux-cooperation has been or was to be implemented, namely: the Antarctic expedition and the Cross Antenna. This decision, taken in the context of the indispensable reorganisation measures, is the direct consequence of the announcement the Dutch delegation has made in Brussels on 29 June 1966 that the Dutch government has decided to provide no funding in 1967 for the Antarctic Expedition. The Belgian delegation has then immediately stressed that the abandonment of one of the projects would ipso facto entail the end of the other project. Both projects should indeed be considered as a whole with respect to Belgian science policy in a European and, especially, in a Benelux context.[105]

It is not clear whether the people involved in the radio telescope project received this message immediately, but in any case they did not consider the cooperation (officially) ended. Bannier, for example, kept sending letters to the Belgians concerning the cooperation and was astonished to get no reactions. It seems as if Bannier was not aware of the withdrawal of the Belgians, as he wrote to Spaey:

> We still have not been notified of the termination of the cooperation. (...) Now that

[104] 'U begrijpt dat ik mij in een lastige positie bevind, wanneer ik er enerzijds in mijn functie bij Z.W.O. nauwlettend op moet toezien dat de gelden voor die andere Belgisch-Nederlandse onderneming, de Zuidpoolexpedities, steeds zeer tijdig en vooruit naar Brussel worden overgemaakt, terwijl ik anderzijds optredende als "administrative officer for B.C.A.P." steeds weer, en dat jaren achtereen, bij Z.W.O. moet aankloppen om voorschotten voor B.C.A.P. daar de Belgische bijdragen achterstallig zijn.' Otker to Deloz, 29 March 1966, SA, NWO.

[105] 'Tijdens dit onderhoud heeft de Ambassadeur bevestigd dat de Belgische Regering zich, zeer tot haar spijt, genoodzaakt heeft gezien de kredieten van de begroting van 1967 te schrappen, welke betrekking hebben op twee verschillende wetenschappelijke initiatieven waarbij de Benelux-samenwerking gestalte had gekregen c.q. zou krijgen, te weten: de Zuidpool Expeditie en de Kruis Antenne. Deze beslissing, genomen in het kader van de onmisbare saneringsmaatregelen, is het directe gevolg van de door de Nederlandse delegatie op 29 juni 1966 te Brussel gedane mededeling dat de Nederlandse regering heeft besloten voor 1967 geen kredieten te voorzien voor de financiering van de Zuidpool Expeditie. De Belgische delegatie heeft toen terstond onderstreept, dat het opgeven van één der projekten ipso facto ook het einde van het andere projekt tot gevolg zou hebben. Beide projekten dienen inderdaad als één geheel te worden beschouwd ten aanzien van het door België gevoerde wetenschapsbeleid in Europees- en, in het bijzonder, in Benelux-verband.' Memorandum of the Belgian embassy in The Hague, 28 July 1966, SA, NWO.

> diplomatic notes have not yield any result either, I am beginning to be a bit worried. Therefore, I would appreciate to hear from you what the state of affairs is in Belgium concerning the cooperation in the field of radio astronomy.[106]

A month later, Spaey wrote a short note to Bannier in which he confirmed the withdrawal of the Belgians:

> Your letter of 23 January 1967 (...) has retained our attention. The Belgian government decided on 28 July 1966 that it did not wish to participate in this project any longer. The decision was taken by the Ministerial Committee for Science Policy and was shortly afterwards confirmed by the Cabinet. We should therefore regard it as final. Moreover, there is no allocation for this project in the national budget.[107]

Although it might be clear that the Belgians had definitely ended the cooperation, Bannier still did not want to accept this decision, until he got a 'more official' confirmation of it:

> The provisions of the memorandum of 28 July 1966 are considered final neither by the Ministry of Foreign Affairs, nor by Your Ministry [the Ministry of Education, Arts, and Sciences]. (...) ZWO did not consider the cancellation of the cooperation in the field of radio astronomy as final either. (...) As it does not seem a good idea merely to rely on a letter of Dr. Spaey to me, more formal clarification should now be requested.[108]

On 14 July 1967, a second memorandum of the Belgian Embassy in The Hague was sent to the Dutch Ministry of Foreign Affairs and to Oort.[109] Its message was clear:

> On the (...) question whether the memorandum of the Embassy of 28 July 1966 (...) has to be understood in the sense that the Belgian Government considers the cooperation in the SRT-project as terminated, the Belgian Embassy has the honour to respond affirmatively.[110]

Summarising, we can say that this whole episode of the radio telescope project and the Antarctic expeditions is characterised by unequal involvement in the projects and different priorities in

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[106] 'Ook nu is ons immers nog geen bericht van beëindiging van samenwerking gezonden. (…) Nu ook de diplomatieke nota's tot nu toe geen resultaat hebben opgeleverd begin ik mij echter wel een beetje ongerust te maken. Daarom zal ik het op hoge prijs stellen van U te mogen vernemen wat de stand van zaken in België is ten aanzien van de samenwerking op radioastronomisch gebied.' Bannier to Spaey, 23 January 1967, SA, NWO.
[107] 'Uw brief van 23 januari 1967 (…) heeft onze aandacht gaande gehouden. De Belgische regering heeft op 28 juli 1966 aan de Nederlandse regering laten weten dat zij aan dit project niet verder wenst deel te nemen. Deze beslissing werd genomen door het Ministerieel Comité voor Wetenschapsbeleid, en werd kort daarna bevestigd door de Ministerraad. Wij moeten ze dus als definitief aanzien. Er staat trouwens geen enkele toelage hiervoor op de rijksbegroting.' Spaey to Bannier, 24 February 1967, SA, NWO.
[108] 'Noch door het Ministerie van Buitenlandse Zaken, noch door Uw Ministerie is het gestelde in de nota van 28 juli 1966 als definitief beschouwd. (…) Ook Z.W.O. heeft de opzegging van de samenwerking op radioastronomisch gebied niet als definitief opgevat. (…) Aangezien het niet goed mogelijk lijkt ons hieromtrent alleen te baseren op een brief van Dr. Spaey aan mij zal het gewenst zijn dat thans langs officiëlere weg opheldering gevraagd wordt.' Bannier to the Minister of Education, Arts and Sciences, 6 March 1967, SA, NWO.
[109] Oort to the Members of the Council of BCAP, 4 July 1967, SA, NWO.
[110] Memorandum of the Belgian Embassy in The Hague, 14 June 1967, SA, NWO.

Belgium and the Netherlands: the Belgians were passionate about their Antarctic expeditions, the Dutch were passionate about their radio telescope, but neither succeeded in kindling the same enthusiastic ardour in the other. Added – and to a certain extent linked – was the matter of lacking the necessary influential scientific pressure groups. The Dutch lacked a scientific lobby to enforce Dutch participation in the Antarctic expeditions. In the same way, the Belgians lacked a scientific lobby to enforce Belgian participation in the radio telescope project (Kersten, 1996, p. 302).

3.10 CONCLUSION

When the Dutch contacted the Belgians in 1958 for the joint building of a large radio telescope, this proposal marked a continuity in the history of Belgian-Dutch relations. Since the interwar period, there had been a quite intensive cultural and economic cooperation between the two countries. In astronomy too, Belgium and the Netherlands exchanged scientific staff and shared several fields of interest. What seemed to be the beginning of a successful common project, however, was in fact the start of several years of frustration, tensions and ultimately the decision of Belgium to withdraw from the project in June 1966. To explain this failure is a complex matter. Several reasons are responsible for this.

Firstly, despite the quite close cooperation between Belgian and Dutch astronomers in the interwar period, there had also been divergent astronomical traditions since the beginning of the twentieth century. In the interwar period, Belgium and the Netherlands were both strong in optical astronomy. Handicapped by an unfavourable climate for observations, however, astronomers in both countries were forced to travel abroad or to migrate, mostly to the USA. After the Second World War, this bad climate was for Dutch astronomers also an incentive to shift their focus to radio astronomy, a choice that Belgium did not make. We can probably explain this because of the fact that Milky Way structure and stellar dynamics were in Belgium negligible research topics, while in the Netherlands, unravelling the structure of the Milky Way had been one of the main objectives of astronomical research since the beginning of the twentieth century. And it was exactly there that radio astronomy could contribute greatly. In Belgium, astrophysics remained the favourite topic. Why did the Belgians not shift their attention towards Milky Way structure and stellar dynamics? One explanation may be that it is exactly this strong position in astrophysics that made the Belgians a little ‘blind’ to other possible options. A reinforcing fact was that during their frequent stays abroad, strong friendships were forged between Belgian and foreign astronomers, which can explain that the young scholars after the war just followed the same path.

Secondly, a great stumbling block was the internationalisation of the project. For Belgium, further internationalisation of the radio telescope project was a *conditio sine qua non*. The Dutch, however, were very much against this. The reasons they gave were that further internationalisation would delay the construction of the telescope and that the observing time of this instrument was limited. (The latter argument had only been used since 1964.) This difference in attitude became especially clear in the cooperation with OEEC / OECD. This funding organisation – which wanted to stimulate European cooperation – aimed at a further internationalisation of the project, certainly after its reorganisation of 1961. While the Belgians welcomed this opportunity, the Dutch, on the other hand, thought OECD overstepped its bounds.

This difference in attitude can partly be explained by the head of the Special Scientific Activities Division of OECD being Armand H. Delsemme, an influential Belgian astronomer. Delsemme therefore was a strong link between Belgian astronomy and the OECD. But there was more at stake. As mentioned above, the reform of Belgian science policy in the late 1950s brought about a very strong international orientation of Belgian science. It was said that Belgian science policy should – almost by definition – be an 'international science policy'. Moreover, this international orientation of Belgian science had a long tradition: when we take a look at student mobility, for example, since the late nineteenth century, Belgium had been one of the most internationalised European countries. Dutch science, on the other hand, was remarkably little internationalised in the period concerned. And although Dutch astronomy is an exception to this general picture, also in this field the international orientation had a different character of that of the Belgians. In the Netherlands, it was much more pragmatic: each project was individually studied to determine whether it would benefit from international cooperation or not. 'Internationalisation just because science had to be international' – an attitude that prevailed in Belgium - was not the attitude of Dutch astronomers, neither was it of Dutch science managers.

Thirdly, at the end of the 1950s Dutch science policy placed a strong emphasis on 'pure science'. In Belgium, however, this pure science rhetoric was a typical product of the interwar period and was outdated in the 1950s. To get a project funded, it was by then no longer sufficient to refer to its purely scientific value: in the first place, applications and industrial benefits had to be emphasised. Although in the proposals for the radio telescope project some vague promises were made concerning technological implications, these were absolutely insufficient to convince the technology working party of the National Council for Science Policy. The emphasis on industrial benefits also explains why the Belgians were much more eager to cooperate in space research, as this offered their industry several beneficial contracts.

Fourthly - this may partly be related to the previous reason – around 1960, (Earth-based) astronomy was no longer a government priority. With the reform of Belgian science policy, the Belgian government wanted special attention to be paid to molecular biology, space research and human genetics, which it considered at the time to be 'privileged sectors' that were important and still underdeveloped in Belgium. The field that absorbed by far the biggest share of government funding, however, was – as in the Netherlands – nuclear research. The fact that astronomy was no longer a priority in Belgian science policy, can to a certain extent explain why the handling of the project was slow and negligent. However, Belgian science policy – unlike in the Netherlands – around 1960 was highly bureaucratised, which made an expeditious handling of the matter – such as in the Netherlands - impossible.

Fifthly, the final breakpoint was the withdrawal of the Dutch from the Antarctic expeditions. After Belgium had officially confirmed its cooperation in February 1965, on 25 July 1966 the Belgian Ambassador in The Hague suddenly announced the termination of the cooperation to the Dutch Prime Minister and the Minister of Foreign Affairs. This was the direct consequence of the fact that on 29 June 1966 a Dutch delegation had announced in Brussels that no funding would be provided for the Antarctic expedition in 1967.

In the next chapter, the successive different designs for the telescope and the total cost of the project will be described. As will be explained, the troubled relation with the Belgians was one of the reasons why the Dutch had to choose a cheaper option.

CHAPTER IV: DESIGNING, CONSTRUCTING, AND USING THE NEW LARGE RADIO TELESCOPE

The first elaborate design of the new large radio telescope was presented in 1961. Later, at least four other designs followed. The telescope that was inaugurated in 1970 was indeed completely different from the design of 1961. In this chapter, we explore the reasons *why* the Dutch changed the design several times. As we will see, these reasons were sometimes scientific, but often they were also practical, political, and / or economic. Although on a much smaller scale, this radio telescope project was to a certain extent comparable to the making of the Hubble Space Telescope (launched on 24 April 1990). As the American historian of science Robert Smith said about the latter: design choices were not outside the political process of winning approval (Smith, 1992, p. 191). In our story, special attention will be paid to the developments abroad and to the hiring of foreigners for the project, as these factors truly 'shaped' the eventual design as well as the observational programme of the telescope.

In the mid-1960s, when the final design was put out to tender, a suitable location had to be found for the telescope. We explore why, after years of site surveys, a region close to the village of Westerbork (Drenthe) was finally chosen. Before this area was ready for use, some very serious obstacles had to be removed. For example, a military shooting range had to be closed and a number of Ambonese families had to be moved. How did Oort succeed in overcoming these obstacles and what does this reveal about his influence and the prestige of radio astronomy in general?

The construction of the telescope cost millions of Dutch guilders and hence, it was one of the most expensive Dutch scientific projects. (Other fields that consumed a great deal of money were nuclear physics and – since the mid-1960s – also space research.) First of all, we take a closer look at the rhetoric Oort used to get this expensive project accepted by the Belgian and Dutch governments. Then we consider two problems: first, the Belgians paid their share only after years of delays, and second, from the mid-1960s, Dutch government budgets were tightening. Then the question arises: *how* did ZWO – especially its director, Bannier - and the radio astronomers – especially Oort - deal with these problems?

Finally, we take a closer look at the development of the observational programme. The plans for the radio telescope were made at a time when cosmology and 'source counts' were hot topics in radio astronomy. Initially, the main research goal of the Dutch was to use radio source counts and radio source sizes to study cosmology. Indeed, this was even one of the justifications for building the new radio telescope. In the end, however, the telescope would be used for very different purposes. Why?

4.1 THE FIRST DESIGN: A LARGE CROSS ANTENNA FOR OBSERVATIONS AT 75 CM

As shown in the previous chapter, shortly after the commissioning of the radio telescope in Dwingeloo, ideas arose to build a larger and better instrument. In one of the early reports on the 'cross antenna project', we read *why* it was judged necessary to build this new telescope:

> The purpose of the project is to provide a radiotelescope of which the resolving power is of the order of one minute of arc, i.e. about 30 times better than what has so far been reached for metre waves, while at the same time the sensitivity (the smallest signal that it can clearly measure) is a factor 1000 greater than that of a conventional large telescope like the 25-metre paraboloid in Dwingeloo.[1]

At that time, radio astronomers all over the world were trying to build instruments with a higher sensitivity and, especially, a higher resolution (i.e. the power to distinguish details). Indeed, in the summer of 1958, Oort said that the 25-metre telescope in Dwingeloo 'works marvellously and produces very beautiful results. But in a few years' time it will no longer be able to compete with much larger instruments which are being built elsewhere.'[2] So if the Dutch aimed to stay at the forefront, no time should be wasted.

The first conceptual proposal for a large cross-shaped radio telescope, as we saw, was written in 1958 by the American engineer and radio amateur Charles L. Seeger. The idea was to construct a large array of small moveable antennas mounted on a horizontal plane and covering two perpendicular strips about 3 km long and about 30 metres wide. No definite suggestion of operating wavelength was made (Raimond, 1996, p. 17). However, it was said that the antenna should probably be designed to work at a wavelength of between 50 and 100 cm. More specific, 75 cm was a reasonable possibility. We assume that the choice for 75 cm had something to do with the following considerations. First of all, from a technical point of view, a low frequency (such as 75 cm), requires simpler receivers and has more relaxed constraints on dish accuracy. Moreover, non-thermal radio emission (as emitted by cosmic sources) is much stronger at low frequencies than at high frequencies. (Because the number of cosmic (point) sources increases rapidly with limiting flux density, this has an important effect.) And very important: 75 cm (or 408 MHz) was a protected frequency.[3]

We also assume that the choice for this wavelength had probably something to do with Seeger's experience: as we saw, he had previously developed a receiver for the Dwingeloo telescope to do continuum observations at 75 cm. At 75 cm, eruptions of the Sun could be measured, it was also a useful wavelength for Galactic and extragalactic research and for polarisation measurements. A few years earlier, when the observational programme of the Dwingeloo telescope was discussed, Oort said the following about this wavelength:

> The plan is first of all in Dwingeloo to measure the Sun at this wavelength, especially the 'eruptions' that regularly occur in the region of the radio waves. (…) This work will be done

[1] Coutrez, R., BCAP: interim report and cost estimate, June 1961, SA, NWO.
[2] Oort to Swings, 10 September 1958, SA, NWO.
[3] Personal communication of Leiden astronomer Frank Israel to author, 3 June 2014.

> with one of the 7 ½ -m mirrors. With the same receiver, as well with the 7 ½-m mirror as with the 25-m mirror, both Galactic and extragalactic radiation will be measured at 75 cm.[4]

During the years 1958 – 1960, Seeger would develop several instruments to perform polarisation measurements at 75 cm in a large region of the sky.

As Seeger's proposal was positively received at the meeting of the board of SRZM on 21 October 1958, it was decided that this idea should be further elaborated.[5] This was indeed done by two foreign scientists that were hired: the engineer, physicist and pioneer of Australian radio astronomy W.N. Christiansen and the Swedish astronomer J.A. Högbom. The importance of the hiring of these two men can hardly be overestimated: as we will explain, it greatly strengthened the connection between Dutch radio astronomy and radio astronomy in Australia and the UK, two other countries that were at the forefront in this field.

Christiansen and Högbom presented the first detailed design for the radio telescope in early 1961.[6] It was in fact an advanced version of the 'Mills cross' (see previous chapter), as Mills was by then 'the only person who has had much experience in using a cross-antenna for galactic and extra-galactic radio observations'.[7] The cross antenna would consist of cylindrical parabolic reflectors, each 30 metres in size, the axes of which lie in an east-west direction in both arms of the cross. The reflectors would be arranged in parallel east-west rows. The size suggested for each of the two arms of the cross antenna was 5000 m x 60 m. An array of four parallel lines of antennas would be used for the east-west arm. For the north-south arm, several hundred of parabolic cylinders would be used.

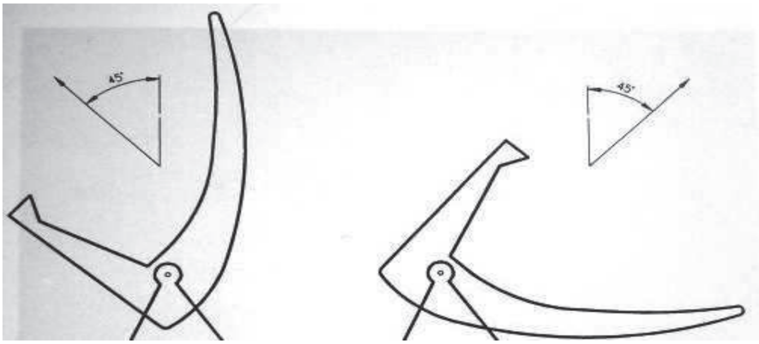

FIGURE 7. Cross-sections of the parabolic cylinders which were to be the basic elements of the Cross Antenna (Raimond, p. 1996, p. 21)

[4] 'Het plan is om op deze golflengte in Dwingeloo vooreerst de zon te gaan meten, en in 't bijzonder de "erupties" die de zon telkens vertoont in 't gebied der radiogolven. (…) Dit werk zal met een der 7 ½ –meter spiegels gedaan zorden. Met dezelfde ontvanger zal zowel in de 7 ½- meter als ook in de 25-meter spiegel de straling van de Melkweg bij 75 cm golglengte gemeten worden en tevens de straling die uit het heelal buiten het Melkwegstelsel komt.' Oort, J.H., Iets over de onderzoekingen die in Dwingeloo in het eeerste jaar gedaan zullen worden, OA, 256.

[5] Minutes of the executive committee meeting of SRZM of 21 October 1958, SA.

[6] Christiansen, W.N. and Högbom, J.A., Benelux Cross Antenna Project. BCAP Technical Report No. 3. 'A design for the Benelux Cross Antenna', 1961, SA, NWO.

[7] Christiansen, W.N. and Högbom, J.A., Benelux Cross Antenna Project. BCAP Technical Report No. 3. 'A design for the Benelux Cross Antenna', 1961, SA, NWO.

The chosen wavelength was again approximately 75 cm (406-410 MHz). It is not explained *why* this wavelength was preferred, but according to E. Raimond[8], this choice was relatively arbitrary - like in the conceptual proposal of Seeger - and probably based on the successful observations of others at 75 cm (Raimond, 1996, p. 19). However, we think the choice of 75 cm was not entirely arbitrary. During 1960, the Dutch group seems to have tackled the question of the frequency to be chosen for the Benelux Cross Antenna. Seeger had visited the radio astronomy groups in Bologna and Cambridge. The group in Bologna was led by Professor Marcello Ceccarelli, who had initiated radio astronomy in Italy (Perola, 2006, p. 174). During a meeting of the Council of the BCAP on 29 November 1960, Seeger explained that the Bologna radio astronomy group was going ahead with extensive plans for 327 MHz (approximately 91 cm). He thought that therefore the use of a similar frequency in the Netherlands was undesirable. In Manchester, the 606-614 MHz (about 50 cm) band was successfully used, although it was not assigned to radio astronomy. This frequency was the gap between a European civilian radar band and the official worldwide UHF (610-940 MHz) TV band, which was not yet occupied. Seeger's conclusion was that the 406-410 MHz band (75 cm) remained the best choice, 'most particularly because the cross will be a general-purpose instrument and because this is one band recognized in Europe for radio astronomy'.[9] The other members of the Council agreed with Seeger. Rinia remarked that, as Europe needed many more broadcast frequencies than did the USA, one could expect enormous opposition to giving up any TV frequencies to radio astronomy. Moreover, the broadcast interests had well-developed plans for expansion in the 400-940 MHz band. This led Oort to acknowledge again that choosing and obtaining protection for a frequency for radio astronomy was a 'very important and difficult problem' [10] and that the 'Inter Union Committee on Frequency Allocations for Radio Astronomy and Space Research', which had recently been established by the ICSU (International Council of Scientific Unions) , should be invited to consider the matter with urgency.

This design of Christiansen and Högbom was discussed at the meeting of the Council of the BCAP on 21 February 1961 and it was received very positively. Van de Hulst called it a 'fine piece of work, cutting down the great number of possibilities to one possible design.'[11] No estimate was mentioned of the cost of the project. Therefore, it was decided at the Council meeting that a firm of consulting engineers, viz. Dwars, Heederik, Verhey in Amersfoort would be contracted to make a more detailed design and a cost estimate of the steel frames and foundations for the radio telescope.[12] This was ready in May 1961.[13] After including all other elements (electronics, terrain etc.) the astronomers came to the conclusion that the total investment costs of the project would be about Dfl 25 000 000:[14]

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[8] Ernst Raimond himself belonged to the first generation of radio astronomers in the Netherlands. After he had obtained his PhD in Leiden in 1964, he spent two years at Caltech and then joined SRZM. He directed the online control system of the WSRT and participated in the programming. He became the first director of the WSRT in 1970, see: Noordam, J., Biographical Memoir – Ernst Raimond, 2011, at: http://rahist.nrao.edu/raimond_bio-memoir.shtml (Accessed on 29 August 2012).

[9] Minutes of the Council meeting of the BCAP of 29 November 1960, SA.

[10] Minutes of the Council meeting of the BCAP of 29 November 1960, SA.

[11] Minutes of the Council meeting of the BCAP of 21 February 1961, SA.

[12] Minutes of the Council meeting of the BCAP of 21 February 1961, SA.

[13] Dwars, Heederik & Verwey, 'Interim Report – May 1961. Preliminary design of steel frames and foundations for a very large Cross Aerial' SA, NWO.

[14] 'Preliminary budget'[1961], SA, NWO.

AERIALS Steel structure Foundations Electrical and mechanical drives	Dfl 18 500 000
ELECTRONICS Antennae, transmission lines Mixers Central apparatus	Dfl 4 000 000
ELECTRICITY Power Line **SUPPLY** Cables along aerials	Dfl 500 000
FACILITIES Laboratory and workshop buildings Roads for access and along aerials	Dfl 500 000
TERRAIN Including farms to be used as housing	Dfl 1 500 000
TOTAL	**Dfl 25 000 000**

Besides the investment costs, there was also annual operating costs, including the cost of the personnel. These were estimated at Dfl 400 000:[15]

PERSONNEL 5 staff positions 8 technical positions	Dfl 100 000 Dfl 100 000
APPARATUS Auxiliary instruments	Dfl 30 000
MAINTENANCE Structures and drives Electronic apparatus	Dfl 30 000 Dfl 100 000
UNFORESEEN Including insurance for storm damage	Dfl 40 000
TOTAL	**Dfl 400 000**

At the next meeting of the Council of the BCAP on 27 June 1961, Oort mentioned that, to avoid delays, it would be necessary to approach the governments of both Belgium and the Netherlands as soon as possible.[16] In July 1961, an 'Interim Report and Cost Estimate'[17] was sent to the Belgian

[15] 'Preliminary budget'[1961], SA, NWO.
[16] Minutes of the Council meeting of the BCAP, 27 June 1961, SA.
[17] 'Benelux Cross Antenna Project. Interim Report and Cost Estimate' [1961], SA, NWO.

and Dutch Ministries of Education.[18] The report explained what the telescope would look like and what research purposes it would serve. It emphasised that the resolving power of one minute of arc was absolutely necessary for an adequate investigation of radio sources within the Galactic System and the nearest other galaxies, and certainly for the study of the most distant parts of the universe. To make clear that the project was not just another megalomaniac idea, but that it was indeed feasible, the design of Christiansen and Högbom was enclosed as an appendix.

The report clearly appealed to a then existing sentiment of what we could call 'Benelux idealism'. When the Benelux was founded, many joint initiatives were taken to bring prosperity and progress into these countries. Scientific cooperation was one of these:

> The project would provide the Benelux countries with a piece of scientific equipment that is unique in the world. The acquisition of such an instrument would certainly become an important factor in stimulating scientific research in the countries concerned. Already in its preliminary stages it has attracted a number of top experts in electronics from other countries for the design work. There is no doubt that the completed telescope will greatly increase the number of foreign scientists who will want to spend some time in the Benelux; it can hardly be doubted that this will be to the advantage of our countries.[19]

There can be no doubt that Oort *used* this Benelux rhetoric as a vehicle to get his project accepted. As mentioned above, he was not interested in international cooperation in itself. As a real pragmatist, he just tried to find the ways to get his projects realised as quickly as possible.

Matters of 'pure science' were emphasised, for example where the report said: 'It may be hoped that a telescope of the size envisaged will provide some insight in the outer limits of the expanding universe, as well as in its origin.'[20] Of course, it was also important to mention applications. Remember that when funding was asked for the building of the radio telescope in Dwingeloo, the 'practical applications' of that project were also emphasised. Now, the situation was no different. The report said:

> In the past, scientific research, even in domains which at the time seemed to be of no practical importance, has always proved to pay, by discoveries that led to unexpected technical applications. There is every reason to expect that this will continue to be so, and that it is therefore economically justified to spend relatively large amounts on scientific projects that have no direct practical application. In the present case the research envisaged is so closely tied up with practical problems, such as the construction of stable, low-noise receivers that there will also be a direct stimulation of research in important growth areas of technical science.[21]

Note that these promises of applications remain – as usual - very vague. As we saw in the previous chapter, things were very different in Belgium. Around 1960, in Belgium there was a great

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[18] Coutrez and Oort to the Minister of Education, Arts, and Sciences, 4 July 1961; Coutrez and Oort to the Minister of Education, 4 July 1961, SA, NWO.
[19] 'Benelux Cross Antenna Project. Interim Report and Cost Estimate' [1961], p. 3, SA, NWO.
[20] 'Benelux Cross Antenna Project. Interim Report and Cost Estimate' [1961], p. 3, SA, NWO.
[21] 'Benelux Cross Antenna Project. Interim Report and Cost Estimate' [1961], p. 3, SA, NWO.

emphasis on industrialisation, and scientific projects had to make very explicit what industrial benefits could be expected, if they wanted to be eligible for funding.

In the letter to the Dutch Minister that accompanied the report, it was stressed that 'already in the budget of 1962, money should be reserved for the construction, because otherwise most of the activities that were now in full swing should be ended.'[22] In September 1961, the Dutch government took the decision to support the project.[23] In the same month, the budget for 1962 of SRZM was sent to ZWO. As in the previous estimate, it was said that the total construction cost of the telescope would be Dfl 25 000 000. The estimate of the annual cost, however, was reduced to Dfl 300 000. This amount had to be divided over the two countries (Belgium and the Netherlands).[24]

In the meantime, something had changed in the funding process of ZWO. Starting in 1962, the budget that the Dutch government provided for ZWO, was divided into an 'ordinary budget ('gewone dienst') and an 'extraordinary budget' ('buitengewone dienst'). The ordinary budget was meant for research and apparatus and the extraordinary budget for investment in apparatus and construction.[25] This division of the budget was in the first place due to the rising construction and apparatus costs of certain projects, especially those of FOM (the organisation for nuclear research, see Chapter II). Especially in the late 1950s, tensions between FOM and ZWO grew, as ZWO could no longer comply with FOM's growing demand for funding (Kersten, 1996, p. 136ff). Until 1962, FOM sometimes received additional funding for the building and construction of laboratories that came *directly* from the government instead of from ZWO. This meant, however, that not all scientific projects were treated the same way. In order to restore fair treatment, it was decided that all applicants had to follow the same procedure for all kinds of funding. Extraordinarily large budgets, for example for the construction of a laboratory or a telescope, should thence be funded out of the extraordinary budget of ZWO. Of course this had as a consequence that the total budget of ZWO increased considerably: from Dfl 9 911 137, 80 in 1961 to Dfl 17 364 651,28 (ordinary budget = Dfl 12 613 651,28 and extraordinary budget = Dfl 4 751 000) in 1962.[26]

For the radio astronomers, this meant that the annual costs had to be paid out of the ordinary budget, the investment costs out of the extraordinary budget. Not entirely surprising, the budget of SRZM for 1962 was approved by ZWO without any trouble. This meant that, for that year, the astronomers got Dfl 150 000 (half of Dfl 300 000, the other 150 000 had to be paid by Belgium) of the ordinary budget. At the same time, it was decided to earmark an amount of Dfl 1 000 000 from the extraordinary budget, to cover a first part of the investments cost for the new large radio telescope. This amount, however, would not be made available as long as the Belgian government had not made an official decision about participation.[27]

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[22] 'dat reeds op de begroting van 1962 gelden voor de bouw uitgetrokken worden, daar anders de meeste der thans op volle gang zijnde werkzaamheden stilgelegd zouden moeten worden.' Coutrez and Oort to the Minister of Education, Arts, and Sciences, 4 July 1961, SA, NWO.
[23] Minutes of the Council meeting of ZWO of 22 December 1961, SA, NWO.
[24] Blaauw to the director of ZWO, 5 September 1961, SA, NWO.
[25] Annual report ZWO 1960, pp. 18-19.
[26] Annual reports ZWO 1961 and 1962.
[27] Minutes of the board meeting of ZWO of 16 December 1961, SA, NWO.

4.1.1 THE COOPERATION WITH AUSTRALIA: LIVING APART TOGETHER

It is worthwhile to give some special attention to Christiansen, who made this first design together with Högbom. The hiring of Christiansen fits a tradition of intense Australian-Dutch cooperation which can be traced back to 1951, when in the Netherlands, Harvard and Australia attempts were made to detect the 21-cm hydrogen line (see Chapter II)**.** About these days, the Australian astronomer F.J. Kerr said: 'This whole episode was a fine example of international cooperation, which has always been the hallmark of most of the relationships in radio astronomy' (Kerr, 1984, p. 138).

Afterwards, Dutch radio astronomers stayed in touch with their Australian colleagues. In 1957, Kerr came to Leiden for several months and he and Gart Westerhout joined their respective maps to derive the first overall look at the hydrogen in the Galaxy. This map became known as the famous 'Leiden-Sydney map of the Milky Way' (Oort, Kerr and Westerhout, 1958) (see Chapter II).

Equally in the late 1950s, in Australia preparations were made for the construction of the Parkes radio telescope. As a matter of fact, since the late 1940s, E.G. Bowen, chief of the CSIRO Division of Radiophysics, and some of his colleagues had been thinking of building a large single-dish radio telescope. The reason for this may seem rather peculiar: it was not a specific research programme that lay at the base of the wish to build this instrument, but it was in the first place the conviction that radio astronomy would soon evolve in the same way as optical astronomy, where the best science and the important discoveries were carried out with the largest and most powerful optical telescopes (Robertson, 2011, p. 2). The crucial event that convinced Bowen that a large general-purpose telescope was the way of the future came in 1951, when Lovell's group at Jodrell Bank announced plans to build a giant parabolic dish. If Australia wanted to stay at the forefront in radio astronomy, it should build a giant dish too, according to Bowen (Robertson, 2011, p. 2). It is noteworthy that, notwithstanding the fact that the first radio astronomers were mostly not trained as astronomers, already in the early 1950s the idea prevailed to build 'ever larger and better radio telescopes' analogous to 'ever larger and better optical telescopes'.

What the Australians needed for their large radio telescope in the first place were good receivers. Since the start of radio astronomy at the CSIRO Division of Radiophysics, receivers had usually been improvised as the need arose. When the preparations for Parkes were made, Joseph Pawsey – assistant chief of the CSIRO division of Radiophysics until 1962 - decided this had to change. In august 1959 he established a specialist group to concentrate solely on receiver technology (Robertson, 1992, p. 170). It is in this context that the Australian Brian Robinson – a former research officer at CSIRO Division of Radiophysics – was sent to the Netherlands as a visiting scientist in 1958. The choice for Robinson was not arbitrary. Robinson – who was one of the pioneers of the hydrogen line – had just completed his PhD in Cambridge, entitled 'investigations of the e-layer of the ionosophere'. As a part of his thesis, he had designed and constructed an ionospheric sounder[28], which provided a power much higher than available with standard sounders (Sim and Whiteoak, 2006).

The choice for the Netherlands was not arbitrary either, given the good Australian-Dutch relations. More important, however, were the developments in receiver techniques in the

[28] An ionospheric sounder is a device that measures time delay and strength of the echo at various frequencies in the high frequency region by using basic radar techniques (Saverino et al., 2013, p. 100).

Netherlands. The role of C.A. Muller, engineer, can hardly be overestimated in this. Remember that when the 21-cm hydrogen line was detected with the Kootwijk telescope in 1951, this was done by a receiver that had been built by Muller (see chapter II). During the second half of the 1950s, the receivers of the Dwingeloo telescope underwent many modifications. Several receivers were developed to do observations at different wavelengths. In 1955-1956, there were two receivers available: one for the continuum at 408 MHz (75 cm) and one for the continuum at 1390 MHz (21 cm) and for line studies at 1420 MHz (also 21 cm). Later, receivers were installed for 242, 465, 610, 820 and 2700 MHz and for hydrogen line studies at 1612-1720 MHz (Van Woerden and Strom, 2007, p. 384). Both the design and construction of these receivers were the work of Muller in the first place.

About his departure to the Netherlands, Robinson said the following:

> I had just completed my doctorate at Cambridge and was back on the Radiophysics payroll. Pawsey asked me to go straight to the Netherlands and learn of the Dutch progress in receivers. I took up a position at the Kamerlingh Onnes Laboratory which had long been famous for its work on low-temperature physics. The radio astronomers at the nearby Leiden Observatory had been investigating maser receivers but the recent developments in parametric amplifiers[29] in the United States made them swing their effort in this direction. (...) Parametric amplifiers – or paramps as they were known for short – had the clear advantage of working at manageable temperatures, whereas masers had to be cooled down to just a few degrees above absolute zero with liquid helium (Robertson, 1992, p. 172).

The visit of Robinson was very fruitful for the Dutch: not only did Robinson learn of the progress of Dutch receivers, he also helped Muller develop a 21 cm parametric amplifier ('paramp') for the Dwingeloo telescope. Moreover, as Robinson's salary was paid by Australia, his achievements did not cost the Dutch a penny. In September 1959, Pawsey wanted Robinson back in Australia as soon as possible, as he was needed there. This was greatly to the regret of the Dutch. Finally, a deal was concluded: Robinson would stay in the Netherlands until the 21 cm parametric amplifier was ready. In return, he would construct an identical receiver for use in Sydney.[30] However, Oort started to irritate the Australians when he tried to get the most out of this deal. In December 1959, he wrote to Pawsey that Muller thought that he and his staff and Robinson would need two whole years to build the paramp when they would work fulltime on it. The cost of building this receiver – this included salaries, heating, material costs etc. – would be approximately Dfl 150 000. He continued: 'This is a very large sum and I was somewhat shocked when I first learned about it. (…) Would you find it reasonable to share the costs of development?'[31] Pawsey was rather upset about Oort's bold proposal. He felt the Australians had done their share by providing the free labour of Robinson: 'In making Robinson available to you for several years I felt we were indeed cooperating in the way you mention.'[32] Finally, a compromise was reached: Oort proposed that the Dutch would take on the full charge of the parametric development themselves and that the

[29] A parametric amplifier is a high-frequency, low-noise amplifier.
[30] Pawsey to Oort, 14 September 1959, SA, NWO.
[31] Oort to Pawsey, 30 December 1959, SA, NWO.
[32] Pawsey to Oort, 21 January 1960, SA, NWO.

Australians would only pay for those parts of the receiver which had to be bought elsewhere and the parts that had to be made in Dutch shops.[33] Pawsey agreed.[34]

Robinson returned to Australia in 1962. The new paramp was installed at Parkes and was used in a number of important observations of the hydrogen content of distant galaxies and clusters of galaxies. However, despite this major effort, the operation of the paramp in Australia was never entirely satisfactory. Very soon, the new receiver group at Radiophysics began to develop a whole range of other devices. One was the first Australian-made paramp (built by F. Gardner and D. Milne). It operated at 20 cm and was used in the first Parkes survey of radio sources (Robertson, 1992, p. 172).

In the meantime, W.N. Christiansen had arrived in the Netherlands in November 1960. Oort - who was delighted about the cooperation with Robinson - absolutely wanted to continue the cooperation with Australia after Robinson's departure. Therefore, in January 1960 he had already written to Bowen that he wanted another Australian co-worker, preferably W.N. Christiansen. Bowen had immediately agreed: 'We would be very happy for Christiansen to spend some time with you at Leiden in the manner you suggest. The collaboration between Leiden and the Radiophysics Laboratory has always been close and has had the happiest outcomes.'[35]

Being a close colleague of Bernard Mills (see Chapter III) Christiansen had built up a lot of experience in interferometry and cross antennas. In 1948 he was offered a position in the radio astronomy group - headed by J.L. Pawsey – of the Division of Radiophysics at CSIRO. Soon, he became the leader of the newly-established field station at Potts Hill (see below).

Shortly after it was decided to hire him, however, Christiansen was appointed to the Chair of Electrical Engineering at the University of Sydney. Oort sent him his congratulations, but was at the same time worried that this would prevent him from taking up his job in Leiden: 'I congratulate you with the appointment to the Chair of Electrical Engineering at the University of Sydney. I do hope that you will be able to organize your University duties in such a manner that you will keep enough time for your research in radio astronomy.'[36] Christiansen, eager to cooperate with the Dutch, did not take up his post immediately, but first spent fifteen months at Leiden (Frater, 2008, p. 86).[37]

The hiring of Christiansen caused a kind of 'snowball effect': several other Australians – often at the instigation of Christiansen - would follow. At the same time, the Dutch were not the Australians' exclusive partner in radio astronomy. As Munns pointed out, there was a nearly continuous trade in expertise among Australia, Great Britain, the Netherlands and the United States (Munns, 2013, p. 15). In the first decade after the Second World War, Australia had especially intensive contacts with the USA in the person of Bowen, who had been working in American war industry for three years (see Chapter I). The people with whom Bowen discussed the earliest proposals for what would ultimately become the steerable 64 m radio telescope in Parkes, were people with whom he had been involved in the days of microwave radar. Amongst

[33] Oort to Pawsey, 3 February 1960, SA, NWO.
[34] Pawsey to Oort, 24 March 1960, SA, NWO.
[35] Bowen to Oort, 6 January 1960, OA, 176.
[36] Oort to Christiansen, 20 April 1960, OA, 176.
[37] Unlike Robinson, Christiansen was paid by the Dutch.

them was Vannevar Bush (Bowen, 1984, p. 99). (In the end, it was the Carnegie Corporation and the Rockefeller Foundation that funded about half of the cost of the Parkes telescope.)

One of the senior lecturers in electronics in the Electrical Engineering Department at the University of Sydney – C. T. Murray – was planning a sabbatical leave in 1960-1961 and was looking around for a suitable place where he could work during his leave. Christiansen wrote to Oort: 'It occurred to me that you might possibly be interested in someone to help on the electronics part of the Benelux Cross.'[38] Oort reacted very positively and was eager to have 'a man of such erudition and experience' working with his group.[39] The 'Committee of Three' (see Chapter III) agreed to appoint Murray and he joined the cross antenna project on 1 May 1961.[40] Another example was the appointment of Christiansen's colleague, the experienced radio technician Watkinson, who joined the project in February 1962.[41]

Although the relations with the Australians were very good, Oort never wanted them to join the cross antenna project formally. Oort - who always wanted to realise his projects with the smallest number of parties involved – strongly opposed further internationalisation of the project, and he made no exception for the Australians. Indeed, when Pawsey indicated that - because of the successful cooperation with Robinson – he was willing to let the Australians join the cross antenna project and put forward the idea to erect a second 'Benelux' cross in Australia, Oort refused:

> I do not think that the Benelux organization which has now been set up for this plan and for which at least some official support by the governments has been obtained, would or could decide to change the entire set-up so drastically as to plan for erecting a Benelux cross antenna in Australia. We do not believe that an attempt in this direction would further the matter of obtaining a large cross. Rather, I believe it would be detrimental to it.[42]

4.2 THE SECOND DESIGN: A SMALLER CROSS ANTENNA FOR OBSERVATIONS AT 21 CM

Already during the year 1961, plans were made to change the design. One of the main reasons was that the research that was done by engineer Hooghoudt and by the firm of consulting engineers Dwars, Heederik, Verhey soon made it clear that the cost of the telescope would be much higher than originally estimated. Especially the steel structure would cost much more than was originally thought, and this could increase the total investment cost by several millions. It also seemed likely that considerable further increases in cost would be caused by difficulties encountered in the detailed structural development of the feeds and of the driving mechanism.[43] And there were also two further reasons why a change was considered:

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[38] Christiansen to Oort, 19 May 1960, OA, 176.
[39] Oort to Christiansen, 15 August 1960, OA, 176.
[40] Rapport intérimaire dur le projet Benelux pour l'antenne en croix - Benelux cross antenna project (BCAP), 22 February 1961, SA, NWO.
[41] Minutes of the Council meeting of the BCAP of 19 March 1962, SA.
[42] Oort to Pawsey, 26 October 1959, OA, 112 e.
[43] Minutes of the Council meeting of the BCAP of 11 December 1961, SA.

(a) no guarantee was forthcoming that a channel *near* 75 cm was to be allocated to radio astronomy

(b) the design had very little flexibility for changing to other wavelengths. Moreover, it would offer no possibility for observations of the 21-cm line of hydrogen, observations that were such a powerful means of investigating the structure and dynamics of galaxies.[44]

Therefore, Högbom had elaborated a new design. The telescope would consist of some 400 parabolic reflectors – each with a dish of about 25 metres - usable for wavelengths of 21 cm and longer – instead of 75 cm - and giving a beam width of 1 minute of arc at 21 cm. A disadvantage was however, that the total receiving surface would be three times less than for the first design. Moreover, most of the radiation is three times weaker at 21 cm than at 75 cm and so a longer integration time[45] was required. This meant that much less of the sky could be covered in a given time.[46] However, this effect could be compensated more or less by the fact that the design with the parabolic reflectors allowed tracking sources for a considerable time, albeit at the expense of telescope time.[47]

Högbom presented a comparison of the two designs at the OECD meeting on 'Large Radio-Telescopes' in December 1961 (see also Chapter III).

He explained there were four reasons to switch to 21 cm: Firstly, a wide band around 1420 MHz had been guaranteed to radio astronomy, while the future of the band around 408 MHz was very uncertain. Secondly, in a 21 cm array it was relatively easy to switch to other wavelengths, while that was a difficult thing to do with a 75 cm array. This way, it would be relatively easy to get information about the spectra of radio sources. Thirdly, 1420 MHz was much more suitable for polarisation measurements. Fourthly, at 1420 MHz, 21-cm hydrogen line observations could be made (Högbom, 1963, p. 132).

Roughly, the telescope would look as follows:

[44] Minutes of the Council meeting of the BCAP of 11 December 1961, SA.
[45] In radio astronomy this is the interval over which data are averaged to reduce background noise and increase the signal-to-noise ratio.
[46] Minutes of the Council meeting of the BCAP of 11 December 1961, SA.
[47] Telescope time is the time the user spends on the telescope.

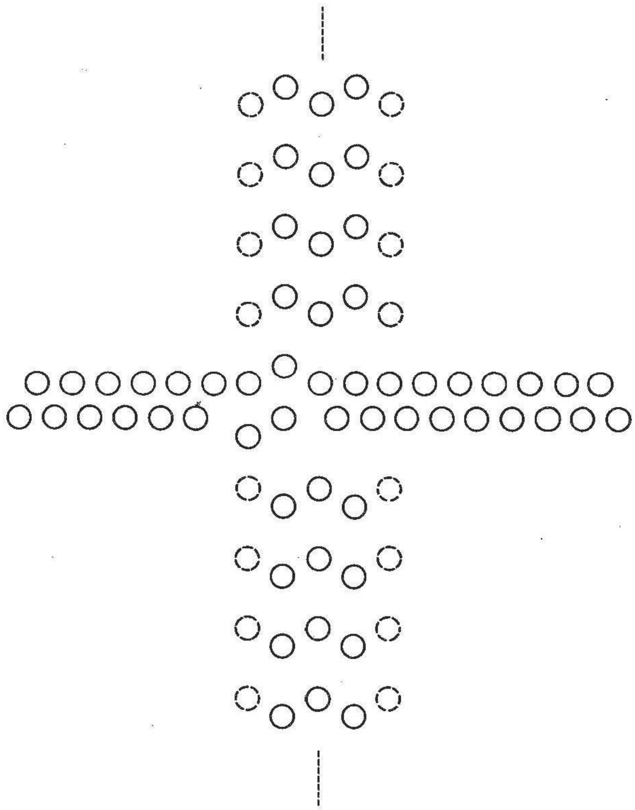

FIGURE 8. A possible basic pattern of 25 metre dishes (Högbom, 1963, p. 135)

The Council of the BCAP agreed that this design, consisting of individual paraboloids, had so many features that made it more attractive than the design of cylindrical paraboloids, that it should be adequately developed, before a final decision on the construction of the radio telescope was taken.[48]

Further research was done by the group and after several months, Högbom came to the conclusion that his initial idea of a 1420 MHz cross antenna consisting of 400 dishes of 25 m diameter, was unnecessarily complex. A smaller number of dishes – about 100 dishes of 35-40 m diameter was now considered.[49] For a brief period, it was also considered to give up the cross shape of the telescope. Indeed, in early 1962, Christiansen – just before he returned to Australia – had come up with the proposal of a 'matrix antenna' with the paraboloids arranged in a rectangle. Initially, it

[48] Minutes of the meeting of the Council of the BCAP of 11 December 1961, SA.
[49] Minutes of the Counil meeting of the BCAP of 19 March 1962, SA.

was thought that the simple structure of this matrix would offer some advantages concerning the electronics and the data processing. Högbom, however, studied this idea more thoroughly and soon realised that this was not entirely true. Moreover, the resolving power of the matrix cross would not be high enough. Therefore, the idea was quickly abandoned.[50]

When Christiansen returned to Australia, he was replaced by W.C. Erickson. Erickson had received his PhD at the University of Minnesota under the theoretical physicist Charles L. Critchfield in 1956 and had subsequently gained considerable experience in radio astronomy. First of all, he had accepted a Carnegie Fellowship at DTM the Department of Terrestrial Magnetism at the Carnegie Institution of Washington, where he carried out a 21 cm survey of neutral hydrogen at high Galactic latitudes (Erickson, 2005, p. 89).

Particularly useful for Erickson's later position in Leiden, however, was his next position at Convair Scientific Research Laboratory (CSRL) in San Diego, a small, company-funded research laboratory, founded by his former thesis advisor Critchfield, who had become Vice President and Director of Scientific Research for Convair, an aircraft and missile manufacturer. Erickson entered CSRL in late 1957. The staff was given complete freedom to choose its research projects, but the budget available was very limited. Erickson was the only radio astronomer. He wanted to undertake a research programme essentially on his own and on a low budget and therefore he made plans for the construction of a large array, with which he wanted to do some low frequency work. He found a suitable location at Clark Dry Lake, a desert plain about 100 km northeast of the city of San Diego. The first antenna Erickson and his colleagues built there was a 26.3 MHz array (Erickson, 2005, p. 90). Construction began in 1959 and the full array came into operation in 1961. It was a complex compound interferometer. The east-west array consisted of 8 banks of 19 dipoles on a 3.3 km baseline. The north-south array consisted of 4 banks of 19 dipoles placed along a 1.4 km baseline due south of the electrical centre of the east-west array (Polisensky and Kassim, 2005, p. 125).

By the time the full array came into operation (1961), however, Convair was in a deep financial crisis. Therefore the company decided no more money could be made available for a basic science laboratory. Almost all staff members left for academic or government positions and the CSRL disappeared (Erickson, 2005, p. 92). In 1963, the ownership of the 26.3 MHz array was transferred to the University of Maryland. It continued to operate until 1975 (Polisensky and Kassim, 2005, 125).

Thus, Erickson had accepted a faculty position at the University of Maryland, just before Oort asked him to come to Leiden for a year or two to work on the Benelux Cross Antenna Project. Erickson accepted Oort's offer, which he found very interesting. The Maryland administrators agreed to hold his position open in the meantime[51] (Erickson, 2005, p. 93).

In Leiden, Erickson together with Högbom worked out the alternative design for the Benelux cross antenna. By then, the Dutch had been cooperating with foreigners – especially with Australians – in designing this telescope for several years. Hence, the plans for the Dutch telescope resembled

[50] Minutes of the Counil meeting of the BCAP of 19 March 1962, SA.

[51] Remember that something quite similar happened to Christiansen, who was appointed to the Chair of Electrical Engineering at the University of Sydney, just before he went to Leiden.

other existing telescopes. However, it is noteworthy that Erickson later said that the concept of the Dutch telescope was clearly a product of optical astronomers:

> Because it [the instrument] had been conceived by astronomers, one of its requirements was that it should produce data like an optical telescope. An astronomer should be able to go to the telescope, take his “exposure”, and return to his home with a map of his specified area of sky. (Erickson, 2005, pp. 93-94)

The design of Erickson and Högbom was ready in September 1962.[52] Antenna structure, the design and mounting of the parabolic dishes, the amplifying and receiving system, the calibration system etc. were all worked out in detail. Erickson and Högbom emphasised that the main differences between this design and the previous one (of Christiansen and Högbom) were in its mechanical structure and its astronomical possibilities. The antenna system offered various options for future extensions to even higher resolutions in the form of interferometers, gratings, or *aperture synthesis.* This is the very first time that aperture synthesis is mentioned in this project. It is a specific type of interferometry that would ultimately be used in the large radio telescope, as we will see.

More specific, the telescope would consist of 65 30-metre parabolic dishes in the east-west arm and 38 in the north-south arm, which would give a total of 65 x 38 = 2470 possible combinations. However, some antenna combinations - which correspond to spacings smaller than the diameter of one dish - were missing in this system. Therefore, an extra parabolic dish with a diameter of about 70 m would be provided.[53]

An additional advantage of changing the wavelength from 75 to 21 cm was that the telescope could be much smaller.[54] While in the first design, each arm of the cross had to be 5 km, in the second design it only had to be 1.5 km for a resolution of one minute of arc. It was proposed to build the 1’ resolution device in two stages. First, a 3’ resolution portion with four arms extending from the centre would be built and operated. After experience had been gained operating this small 3’ instrument, it would be extended to 1’ resolution by extending the arms 750 m from the centre. The 70 m dish would be placed on one of the arms about 2.25 km from the centre.[55] The dimensions of the cross would be as follows:

[52] Erickson, W.C. and Högbom, J.A., BCAP-Memo 20 A, 13 September 1962: A design for a 1420 Mc/Sec Benelux Cross Antenna, SA, NWO.
[53] Erickson, W.C. and Högbom, J.A., BCAP-Memo 20 A, 13 September 1962: A design for a 1420 Mc/Sec Benelux Cross Antenna, pp. 2-3, SA, NWO.
[54] The resolving power of a telescope is inversely proportional to the wavelengths of radiation it receives.
[55] Erickson, W.C., BCAP-memo 19, Site requirements for the Benelux Cross-Antenna Project, 10 August 1962, SA, NWO.

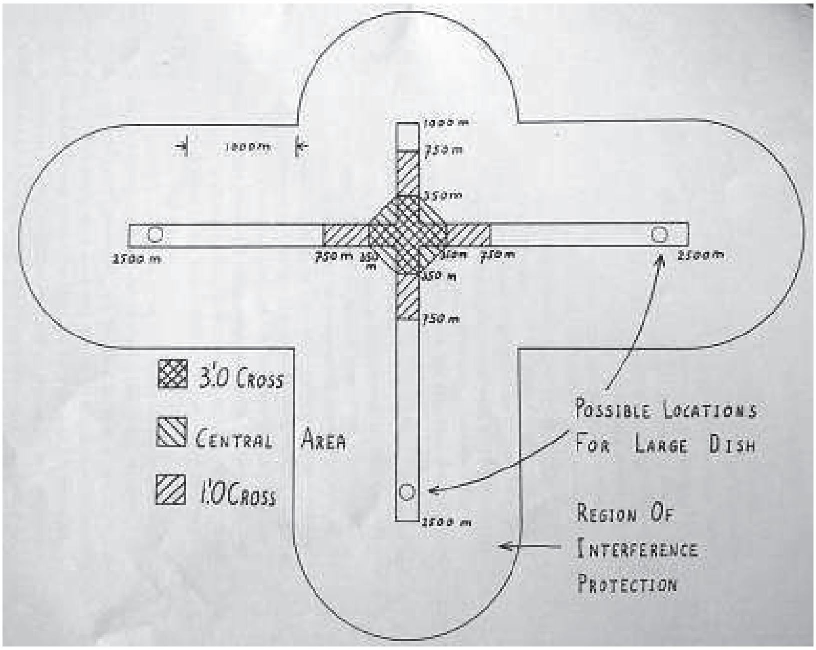

FIGURE 9. Site requirements for the Benelux Cross Antenna[56]

A cost estimate was made and in October 1962, this was sent to the members of the BCAP Council.[57]

The investment costs would roughly look as follows:

Cross antenna, 30-metre radio dishes (steerable)	16 million Dfl
70-metre radio dish	2 million Dfl
Electronic receiving installation	7 million Dfl
Buildings	1 million Dfl
General provisions (Electricity etc.)	2.5 million Dfl
TOTAL	**28.5 million Dfl**

Costs could increase by another 2.5 million Dfl for purchase of grounds and eventual damage claims, which could bring the total investment cost to about 30 million Dfl. According to Oort, this

[56] Erickson, W.C., BCAP-memo 19. Site requirements for the Benelux Cross-Antenna Project, 10 August 1962, SA, NWO.
[57] Oort to the Members of the BCAP Council, 15 October 1962, SA, NWO.

estimate was a ‘minimum estimate’, a choice he defended by saying that giving a higher estimate would automatically lead to spending more money.

Several parties had been involved in establishing this estimate: the cost of the 30-m radio dishes, for example, was estimated by the firm of consulting engineers N.V. Dwars, Heederik en Verhey and engineer Hooghoudt, and the estimate of the 70-m dish was derived from the price of an analogous dish of 90 m that was built in Green Bank (West Virginia, USA).

In addition, the operating cost was now estimated at around 2 million Dfl a year.

The construction of the antenna would start in 1963 and the whole was to be ready in 1967.

The report and cost estimate had to be sent to the governments of the two countries, but this was seriously delayed. On 26 October 1962, Oort had sent the report and cost estimate to Darimont, the president of the Committee of Three and Director of the Belgian Department of Higher Education of the Ministry of Public Education. Darimont in turn, had to send it to the Ministers of Education in Brussels and The Hague. It remains unclear what exactly happened, but in the council meeting of 21 January 1963, Deloz, an official at the Belgian Department of Higher Education, said that ‘some delay had occurred in transmitting the report to the Governments, but that he expected that this transmission should take place in the first week of February.’ [58] He also said that the Belgian Government wanted to consider the project together with more detailed data on the sites. Eventually, it was only at the end of February that the report was sent to the two ministries.[59]

It is not entirely clear whether the Dutch government had to approve this new design officially. Even in government circles, there seems to have been some confusion about it. In a letter of the Dutch Ministry of Finances of 7 December 1962 to Bannier, we read that, as the project had changed significantly and the cost would be several millions higher, it ‘seemed’ that a new decision of the government would be necessary.[60] In any case, no such a decision can be found in the archives. Furthermore, even after receiving the new plans, the Belgian government still did not make a decision about participation in the project.

For the year 1963, ZWO earmarked an amount of Dfl 3 000 000 of the extraordinary budget to cover part of the investment cost. Like the amount of Dfl 1 000 000 of the previous year, however, this amount would not be made available as long as the Belgian government had not made an official decision about participation.[61]

[58] Minutes of the Council meeting of the BCAP of 21 January 1963, SA.
[59] Minutes of the Council meeting of the BCAP of 27 February 1963, SA.
[60] Vos to Bannier, 7 December 1962, SA, NWO.
[61] Aantekening ZWO, Kruisantenne-project, August 1963, SA, NWO.

4.3 THE THIRD DESIGN: A LINEAR EARTH-ROTATION APERTURE SYNTHESIS ARRAY

A few months after the plans of the second design had been submitted to the Belgian and Dutch governments, a radical change in the arrangement of the telescope was again considered.

The reason this time was that the resolving power of one minute of arc did not seem high enough anymore. When the project began around 1958, the idea was to construct an antenna system with a very high resolution. In those days, it seemed that a resolution of one minute of arc was high enough. As time went by and radio astronomical research progressed, however, it soon became clear that a much higher resolution was required to keep up with the most recent developments in radio astronomy. The first time this matter was discussed was in the Council meeting of BCAP on 27 February 1963:

> Discussing the general progress of the project, the President said that considerable thinking and discussion had been done in recent months about ways in which the highest resolving power could be reached more rapidly than had originally been planned. Recent developments in radio astronomy have emphasised the essential importance of obtaining beams of 10'' or 20''.[62]

Indeed, for the investigation of point sources (a single identifiable localised source) a resolution of about 10'' was necessary. For several months, Högbom (together with Hooghoudt) had been studying the possible ways to obtain these higher resolutions in an earlier stage of the work. However, nothing had been said yet about the possibility of abandoning the cross shape. It was only in the summer of 1963 that Högbom proposed a linear east-west array of telescopes that would make use of the rotation of the Earth, instead of a cross antenna. The information which in the cross design would be provided by the combination of the reflectors in the north-south arm with those in the east-west arm, would in this set-up be provided by the rotation of the Earth.[63] Application of this 'Earth-rotation aperture synthesis' could offer a resolution between 10 and 20 seconds of arc, if about 30 25 m reflectors were set up in an east-west array.[64]

For this Earth-rotation aperture synthesis linear array, the Dutch had been inspired by important work that had been done in this respect by Martin Ryle and his group in Cambridge in the early 1960s, as Muller wrote:

> Meanwhile, RYLE at Cambridge had indicated a new possibility to achieve a higher resolution with a simpler alignment of a number of antennae in one array, i.e. a one-dimensional system, in which the necessary second dimension is obtained by rotation of the system with respect to the sky using the rotation of the Earth (...).[65]

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[62] Minutes of the Meeting of the BCAP Project of 27 February 1963, SA.
[63] Oort, J.H., 'Proposal for constructing the Benelux radiotelescope as a synthesis instrument', 25 March 1964, SA, NWO.
[64] Muller, C.A., 'Memorandum over de ontwikkeling van het radiosterrenkundig onderzoek in Nederland', 8 juli 1963, SA, NWO.
[65] 'Door RYLE te Cambridge was inmiddels een nieuwe mogelijkheid aangegeven voor het bereiken van een groot scheidend vermogen met een eenvoudiger opstelling van een aantal antennes in één rij, dus een één-dimensionaal systeem, waarbij echter de noodzakelijke tweeden (sic) dimensie werd verkregen door draaiing van het systeem ten opzichte van de sterrenhemel met behulp van de draaiing van de aarde (...).'

That the Dutch were inspired by the Cambridge group should come as no surprise. A strong connection between the two groups was established in the person of Högbom, who had worked towards a PhD from Cambridge under the direction of Martin Ryle from 1955 until 1959 (see also below).

The main problem of the new design, however, was that for each complete observation, twelve hours of observation time were required. This meant that at most 700 complete observations could be done in one year. So the telescope could not be used to contribute to a large number of research projects in a short amount of time. Therefore, it was unsuitable as 'main telescope' for the different institutes in Belgium and the Netherlands. However, despite these disadvantages - and despite the technical difficulties involved in its construction – given the high resolving power, this design was considered the best choice. Moreover, there was the additional advantage that a 21-cm hydrogen line receiver could easily be installed in this kind of telescope. In the cross antenna, this could only be used in the interior parts of the cross. If this type of receiver would be used in the entire cross, an enormous amount of apparatus would be needed. The installation of a multiple-channel receiver even seemed entirely impossible in the cross.

Roughly, the telescope would look as follows:

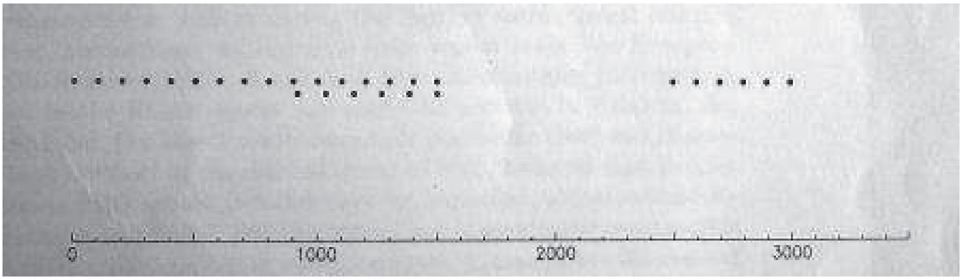

FIGURE 10. Schematic arrangement of the third conceptual design of the Benelux Radio Telescope: a cross antenna re-arranged to an east-west array. (Raimond, 1996, p. 24)

In addition to these dishes, like in the previous design, a steerable reflector telescope with a dish of about 65 m would be required.[66]

It is interesting that for a while this 65-m reflector was considered as a kind of 'transition instrument' between the 25 m radio telescope in Dwingeloo and the new radio telescope – in which this 65 m dish would only have a limited function.[67] As it would take several years before the entire radio telescope would be ready, it would be a good idea to construct this 65-m dish in

Muller, C.A., 'Memorandum over de ontwikkeling van het radiosterrenkundig onderzoek in Nederland', 8 July 1963, SA, NWO.

[66] Muller, C.A., 'Memorandum over de ontwikkeling van het radiosterrenkundig onderzoek in Nederland', 8 July 1963, SA, NWO.

[67] Muller, C.A., 'Memorandum over de ontwikkeling van het radiosterrenkundig onderzoek in Nederland', 8 July 1963, SA, NWO.

the first construction stage so that observations could begin before the whole instrument was ready. This instrument would have a higher resolution than the 25-m telescope in Dwingeloo. It could be used for the 21 cm investigation of the extragalactic nebulae and for short radio wave surveys of continuum radiation from the Galaxy. Remember that in this period the Dwingeloo telescope was nowhere near the largest telescope in the world any more: in Jodrell Bank in the UK, the 'Lovell' radio telescope of 76.2 m had been completed in 1957; in Australia at Parkes, the 64-m telescope had been completed in 1961; and in Greenbank in the USA, the 90 m radio telescope had started operating in 1962.

However, in the end these plans for a 'transition telescope' were never put into action.

After a further elaboration of the design later that year, an estimate of the price of this telescope could be made: the total investment cost of this project would be about the same as the previous design (30 million Dfl).[68]

The question was, of course, how Oort should communicate to the Governments that the design had – again – changed, and even in a very radical way this time. He chose to be very careful and made it appear that the change was no big deal. The document in which the design was described, was simply entitled *Note on a Possible Re-arrangement in the design of the Benelux Radio Telescope*. Moreover, Oort explained that the alteration in the original design was the result of a 'natural development', and that it did not affect the general type of instrument.[69]

4.3.1 THE DEVELOPMENT OF EARTH-ROTATION APERTURE SYNTHESIS

The change of a cross antenna into an Earth-rotation aperture synthesis linear array might have been the result of a 'natural development', yet, when we look at the history of Earth-rotation aperture synthesis, we might wonder why Oort did not come up earlier with the idea to use this technique for the new telescope.

Traditionally, the 'invention' of aperture synthesis is attributed to the Cambridge astronomer Martin Ryle. Graham Smith, former professor at Jodrell Bank Observatory, for example, said: 'Aperture synthesis, the simulation of a very large radio telescope by the use of multiple interferometers, was Ryle's supreme invention' (Smith, 1984, p. 18). And U.J. Schwarz of the Kapteyn Astronomical Institute in Groningen said about arrays of telescopes in one direction that use the rotation of the Earth: 'This (...) idea is called Earth-rotation synthesis, invented by the British radio astronomer Martin Ryle (...)'[70] (Schwarz, 1986, p. 247). Oort himself too, attributed aperture synthesis to Ryle:

> (...) in a synthesis telescope, like we have now in Westerbork, one needs to integrate over time. You cannot get an image immediately, but you have to observe for twelve hours – or at least for a certain amount of time – so that the one array you have in such a line-interferometer makes several position angles with respect to the sky; when you put these

[68] Minutes of the Council meeting of the BCAP of 17 October 1963, SA.
[69] Minutes of the Council meeting of the BCAP of 17 October 1963, SA.
[70] 'Dit (…) wordt de aardrotatie-synthese genoemd, uitgevonden door de Britse radioastronoom Martin Ryle (…).'

> together, you get a two-dimensional image. (...) This was invented by Martin Ryle several years ago.[71] (Oort, 1986, p. 252)

With regard to Ryle and aperture synthesis, one of his publications is especially famous, namely his 1962 article in *Nature* 'The new Cambridge radio telescope'.[72] In the 1960s, it was often referred to by the Dutch. When Oort explained why the new large radio telescope should make use of the rotation of the Earth, he referred to this publication: 'A radio telescope based on the synthesis principle, and giving a resolution of 25'', has recently been described by M. Ryle (Nature, 194, 517).'[73]

In 1974, Martin Ryle and his colleague, the British radio astronomer Antony Hewish, shared the Nobel Prize in Physics: Ryle for his 'observations and inventions, in particular of the aperture synthesis technique', and Hewish for his decisive role in the discovery of pulsars.'[74]

It can not be denied that in the early 1960s, Ryle made great contributions to imaging with aperture synthesis, but the principle itself existed long before. As Raimond put it:

> (...) Christiansen and Warburton (1955) produced a two-dimensional map of the quiet sun at a wavelength of 21 cm, using a combination of an east-west and a north-south array of parabolic reflectors. In fact, this could be called the first application of earth rotation aperture synthesis, although Ryle described the principle more explicitly in 1962[75]. (Raimond, 1996, p. 16)

Indeed, for the origins of Earth-rotation aperture synthesis, we have to go back to Australia in the early 1950s. And one of the pioneers was W.N. Christiansen, who later made the first design of the 'Benelux cross antenna'. As mentioned before, Christiansen was working in Potts Hill in the late 1940s. At that time, the main radio telescope there was a wartime experimental radar antenna that had been relocated to Potts Hill in 1948 for 'observation' of the partial solar eclipse of 1 November. Christiansen organised the observations of the partial solar eclipses of 1 November 1948 (together with Mills) and 1 April 1949. His experiences with the eclipses ultimately led him to the development of an east-west solar 'grating array' telescope at Potts Hill in 1951. This grating array, which consisted of 32 steerable paraboloids, allowed Christiansen to study the distribution of radio brightness across the Sun as the Sun drifted through the responses during the day. An important finding of this research was that enhanced emission at 21 cm came from regions in the lower corona of the Sun. Their dimensions and height above the photosphere could now be determined for the first time. (Frater, 2008, p. 86).

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[71] '(…) bij een synthese-telescoop zoals we nu in Westerbork hebben moet je over de tijd integreren. Je kunt niet onmiddellijk een beeld krijgen, maar je moet twaalf uur lang waarnemen – of althans een tijd lang – zodat die ene arm die je hebt in zo'n lijn interferometer verschillende positiehoeken ten opzichte van de hemel maakt ; als je die samenvoegt kun je het tweedimensionale beeld krijgen.'

[72] Ryle, M., The new Cambridge radio telescope, in : *Nature*, 194 (1962), pp. 517-518.

[73] Oort, J.H., 'Proposal for constructing the Benelux radiotelescope as a synthesis instrument', 25 March 1964, SA, NWO.

[74] "Press Release: The 1974 Nobel Prize in Physics". http://www.nobelprize.org/nobel_prizes/physics/laureates/1974/press.html (Accessed 10 July 2012).

[75] The article that is meant is: Ryle, M., The New Cambridge Radio Telescope, in: *Nature*, 194 (1962), pp. 517-518.

One of the limitations of Christiansen's east-west array, however, was that the Sun could only be scanned in one dimension. In order to calculate the distribution of radiation across the solar disk, it was therefore necessary to assume a symmetrical distribution. But visual observations had revealed that the Sun is an oblate spheroid. Moreover, the eclipse observations had also indicated that the solar corona was far from symmetrical. Therefore, Christiansen decided to construct a second array, consisting of 16 parabolic dishes and arranged in a north-south direction, so that the Sun could be scanned at a variety of angles (Wendt, Orchiston and Slee, 2008, p. 177).

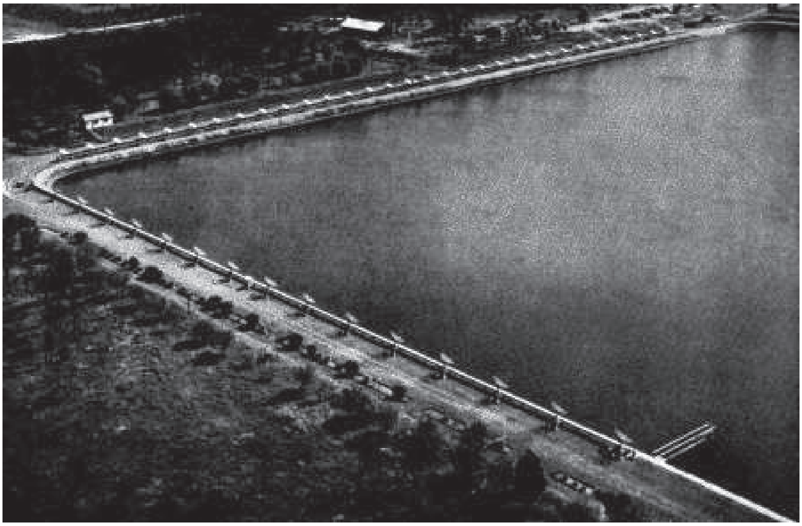

FIGURE 11. Aerial view of the 23-element east-west and the 16-element north-south arrays (Christiansen and Warburton, 1955a, p. 475)

With this telescope Christiansen made daily observations from September 1953 to April 1954, together with his colleague Joe Warburton. They published their findings in 1955 (Christiansen and Warburton, 1955a and 1955b). The observations allowed them to make a two-dimensional image of the radio brightness distribution of the Sun at 1420 MHz (21 cm):

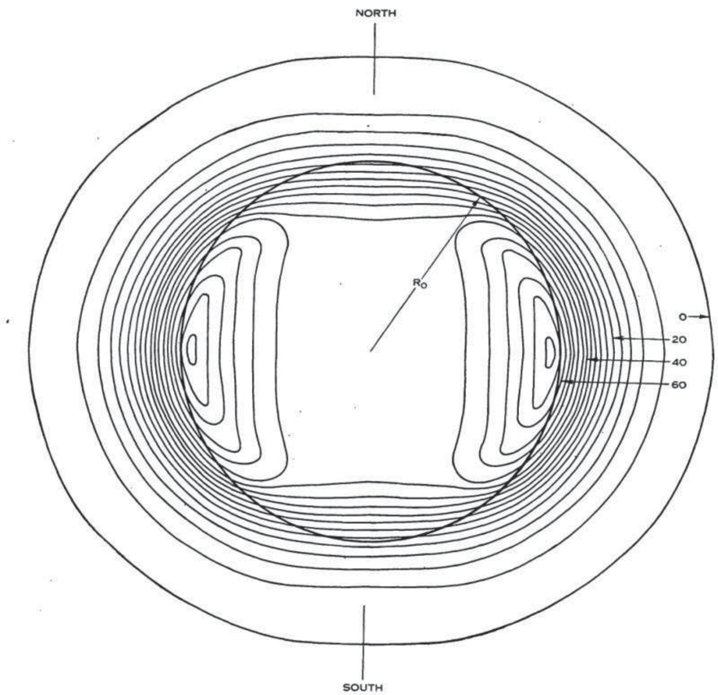

FIGURE 12. Derived two-dimensional radio brightness distribution (Christiansen and Warburton, 1955a, p. 482)

Wendt, Orchiston and Slee consider the above image the 'world's first application of Earth-rotational synthesis in radio astronomy' (Wendt, Orchiston and Slee, 2008, p. 178). Frater too acknowledges that their approach was 'an early application of Earth-rotational synthesis[76] to produce for the first time a radio map with a resolution as high as four minutes of arc' (Frater, 2008, p. 86).

However, the contribution of the Australians in this respect is not widely acknowledged.

Christiansen himself remained displeased with this lack of recognition for the rest of his life. In 1989, he wrote an article which carries the unambiguous title: *An omission in radio astronomy histories*. There, Christiansen explained that Earth rotation in synthesising a two-dimensional antenna aperture was used in Australia almost a decade before it appeared elsewhere:

[76] Aperture synthesis or synthesis is a type of interferometry that mixes signals from several telescopes to produce images that have the same angular resolution as an instrument that would have the size of the largest baseline of the array. Most interferometers use the rotation of the Earth to increase the number of baselines (the distance between two aerials) included in an observation. When data are taken at different times, measurements with different telescope separations and angles are provided, without the need for moving the telescope manually. The rotation of the Earth, namely, moves the telescopes automatically to new baselines.

> An essential element of this technique is the use of two or more antennas with accurately known positions and with accurately known electrical separations from a common receiver, these remaining known while the individual antennas turn to follow some fixed region of sky during many hours of observation. This prerequisite for the technique was developed first in Australia in 1952 (Christiansen 1953)[77] (...) Once this had been done, the development of earth-rotational synthesis was almost an obvious step to anyone aware of the geometry of the Solar System. Thus in Sydney we used the apparent change in the solar axis as the Earth rotated to synthesize a two-dimensional map of the Sun from one-dimensional observations. This work was (...) later published by Christiansen & Warburton (1955). (Christiansen, 1989, p. 357)

However, after the achievements of the early 1950s, developments in Earth-rotation aperture synthesis came to a halt for over a decade in Australia. According to Christiansen, the reason for this was that further developments required much faster methods than the hand-operated mechanical calculators then available in Sydney. The next decade, however, a necessary turning point took place at Cambridge, when the digital computer revolutionised the speed of computation.[78] From then on, powerful and very large radio telescopes were developed that make use of Earth-rotational synthesis (Christiansen, 1989, pp. 357-358).

So do we have to conclude that the Australians were the 'first' to develop Earth-rotation based aperture synthesis? It depends. P.A.G. Scheuer of the Mullard Radio Astronomy Observatory (and former student of Martin Ryle) in Cambridge found a notebook of Martin Ryle of 1954 in which this principle is already described. According to Scheuer, this is the first *written* mention of Earth-rotation synthesis. (Scheuer, 1984, p. 256). (The article of Christiansen and Warburton was indeed only published in 1955).

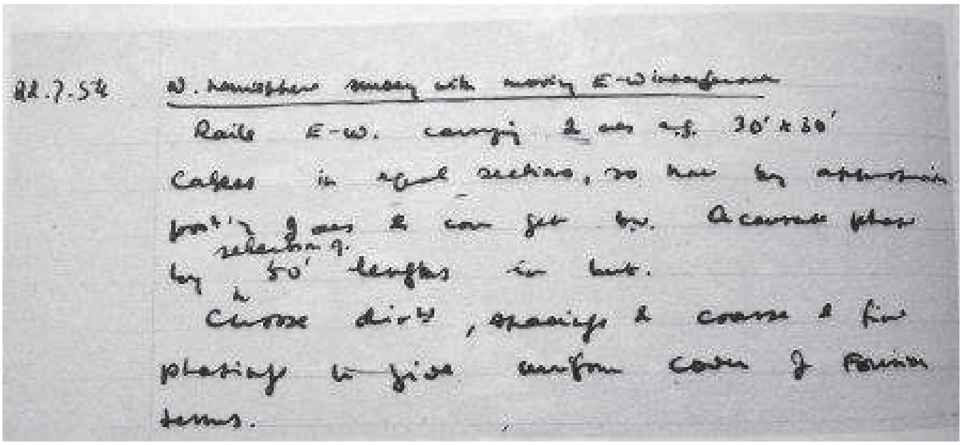

FIGURE 13. Entry in Ryle's laboratory notebook, 22nd July 1954 (Scheuer, 1984, p. 256)

[77] Christiansen, W.N., A high-resolution aerial for radio astronomy, in : *Nature*, 171 (1953), p. 831.
[78] Also in the Netherlands, computers have revolutionised the speed of computation in astronomy since the 1960s, see: Van Helvoort, 2012, pp. 62-76.

A transcription of the text in the notebook reads: "N hemisphere survey with moving E-W interferometer. Rails east-west carrying 2 aerials e.g. 30 ft x 30 ft. Cables in equal sections, so that by appropriate pos[itionin]g of ae[rial]s and can get b.[and] w.[idth]. Accurate phase by selection of 50 ft lengths in hut. Choose dir[ectio]ns, spacings and coarse and fine phasings to give uniform cover of Fourier terms." (Scheuer, 1984, p. 256)

Concerning the development of Earth-rotation based aperture synthesis, not only the role of the Australians, but also the role of Ryle's own PhD student, Högbom, is rather neglected in historiography.

As mentioned before, from 1955 to 1959 Högbom worked on a PhD in Cambridge under the supervision of Martin Ryle. His PhD dissertation - entitled *The Structure and Magnetic Field of the Solar Corona* - includes several chapters on aperture synthesis theory and earth-rotational synthesis. Ryle might have been the very first to write something down about Earth-rotation based aperture synthesis, but Högbom certainly *tested* Earth-rotation aperture synthesis before Ryle did. Kellerman and Moran acknowledge that Högbom previously used an array of simple dipole elements to test the principle of 'supersynthesis'[79], as part of his PhD dissertation work (Kellerman and Moran, 2001, p. 468).

It seems, however, that Ryle has deliberately neglected Högbom's contributions with respect to Earth-rotation based aperture synthesis. In a famous article he wrote in 1960, together with Hewish, *The synthesis of large radio telescopes*, no mention at all is made of Högbom. Scheuer says that, Ryle was 'apparently scarcely aware of the experiment and cannot recall it now' (Scheuer, 1984, p. 258). This, however, is very unlikely, as Högbom was Ryle's PhD student. Moreover, we have concrete proof that Ryle *was* at the time very well aware of Högbom's experiments in this respect, as he discussed them in a letter to Oort in 1961.[80]

Most likely, as a supervisor, Ryle was convinced he deserved the credits for this discovery. In these days, it was certainly not uncommon that supervisors were rewarded for the work their PhD students had done. Indeed, as noted above when in 1974, Ryle got the Nobel Prize in Physics for invention of aperture synthesis, he had to share this prize with Hewish, for 'his decisive role in the discovery of pulsars'. However, it was Hewish's PhD student Jocelyn Bell, who had actually done the research. Pulsars are remnants of massive stars that became supernovae. Jocelyn Bell - who in 1967 was a graduate student in radio astronomy at Cambridge – discovered the recurring signals given off by the rotation of these pulsars when she was analysing the data, gathered by a radio telescope she had helped to assemble. Jocelyn Bell's contributions, however, were – and in the astronomical community still are – widely known. Indeed, she got a 'wave of sympathy' after Hewish received the award. Bell not only had the 'disadvantage' of being a graduate student, but also of being a woman. In a very recent interview for *National Geographic* (May 2013), Bell – now a visiting astronomy professor at the University of Oxford - said:

> The picture people had at the time of the way that science was done was that there was a senior man – and it was always a man – who had under him a whole load of minions, junior staff, who weren't expected to think, who were only expected to do as he said. (Quoted in Lee, 2013)

[79] Earth-rotation based aperture synthesis was by often referred to as 'supersynthesis' in Britain.
[80] Ryle to Oort, 21 December 1961, OA, 114c.

The whole discussion about 'who had been the first' to develop Earth-rotation based aperture synthesis, might have in itself no great historical relevance. It might be just another example of Stigler's law, which says that no scientific discovery is named after its actual discoverer (Wilkins, 2011). However, the fact that in the 1950s, both Christiansen and Högbom were experimenting with it, is of great importance, as these very same persons were also key persons in the development of the radio telescope in Westerbork.

So the question arises why the Dutch did not come up sooner with the idea to use Earth-rotation based aperture synthesis. By the late 1950s, Oort must certainly have been aware of the principle: in a letter of Högbom to Oort, dated 11 August 1959, Högbom mentions it:

> I have been very interested in aerial theory, particularly interferometer technique, and I have made some preliminary tests with a new synthesis method which makes it possible to study point sources without using large aerials. In this the rotation of the earth is used to provide transport in one dimension. A simple interferometer with two small aerials spaced 60 λ on an NS axis has in this way given records equivalent to that of a 50 λ EW array.[81]

Although there was still a long way to go from studying point sources to making images of the sky, it is a bit odd that it took such a long time before it occurred to the Dutch that the new radio telescope could be based on Earth-rotation synthesis technique. According to Erickson, who made the second design together with Högbom, the reason was that they started with a much too complicated system in mind and they therefore overlooked all simpler options. Erickson says the main lesson he learned from his experience with the Benelux radio telescope was:

> BE CAREFUL NEVER TO OVER SPECIFY A SYSTEM – KEEP IT SIMPLE[82]. One must always be certain that all the specifications and requirements of a system are absolutely necessary. It is easy for features to creep into the specifications that are not vital even though they may contribute to the convenience of the system. They quickly are adopted and become so familiar that simpler alternatives are overlooked (Erickson, 2005**,** p. 98).

The question is then *when* Oort came upon the idea to use Earth-rotation based aperture synthesis. The various sources contradict one another in this respect.

Erickson's explanation is as follows. At a certain moment, Jan Högbom visited Cambridge to learn the details of the developments in Earth-rotation based synthesis over there.[83] He returned full of enthusiasm for the concept. Erickson and Hooghoudt, the mechanical engineer who designed the dishes and was responsible for the construction, embraced the idea immediately. Consequently, Hooghoudt, Högbom and Erickson convinced Oort to use it. Oort agreed with the design, but envisioned difficulties convincing other astronomers and funding agencies of the plans. The basic design was however more or less agreed upon by the time Erickson left Leiden at the beginning of March 1963 to take up his post at the University of Maryland (Erickson, 2005, p. 96).

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[81] Högbom to Oort, 11 August 1959, OA, 112c.
[82] Capital letters in original
[83] Erickson does not mention *when* Högbom visited Cambridge. Probably, this must have been somewhere at the end of 1962 or the beginning of 1963. However, we could not find any information in the archives about a journey of Högbom to Cambridge in this period.

Scheuer, on the other hand, comes up with a completely different explanation. In May 1960 and June 1961, a trial of Earth-rotation synthesis was made by Ryle and Ann Neville. It was a North Pole survey at 4'.5 angular resolution that was published in 1962 (Ryle and Neville, 1962).

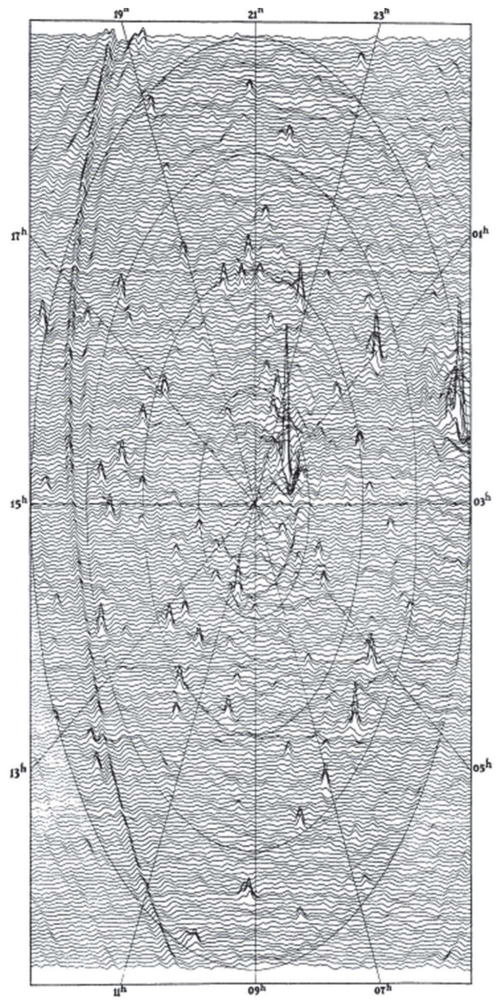

FIGURE 14. North Pole survey (Ryle and Neville, 1962, p. 46)

Scheuer called this survey the 'first earth rotation synthesis map' (Scheuer, 1984, p. 259). Particularly interesting is that Scheuer said that it can have been exactly *this* map that made Oort think of using Earth-rotation aperture synthesis for the radio telescope in Westerbork:

> The map (…) was exhibited at a Herstmonceux conference[84] and some of those who were there reported that Prof. Oort had looked at it thoughtfully for a very long time. Whether or not that was the moment of decision, the Benelux Cross Project soon metamorphosed into plans for the Westerbork Synthesis Radio Telescope. (Scheuer, 1984, p. 259)

The Herstmonceux conference Scheuer mentions here is probably the conference of 7-8 January 1963, devoted to 'the coordination of optical and radio astronomy' (Clube and Sargent, 1963, pp. 150-162). Ryle, Neville and Oort were present at this conference. Ryle gave a talk on 'Radio galaxies and cosmology' and discussed the aforementioned survey, made by the 'aperture synthesis interferometer' at Cambridge (Clube and Sargent, 1963, p 161).

Who is right: Scheuer or Erickson? Or was it perhaps a combination of the two events that convinced Oort? Or was it even something completely different? We will probably never know. The fact remains, however, that in the summer of 1963, the Dutch had firmly decided that the technique used in the new large radio telescope would be Earth-rotation aperture synthesis. (Note that the Belgians did not take part in these discussions on the techniques to be used.)

4.4 THE FOURTH AND FINAL DESIGN: A SIMPLICIFATION OF THE LINEAR ARRAY

When the year 1963 came to a close, the relations with Belgium were so troubled that the Dutch started thinking about continuing alone. However, in that case the project would have to be of a much more modest nature. In January 1964, Piekaar, head of the Division of Higher Education at the Ministry of Education, wrote the following to the Belgian Prime Minister Lefèvre: 'Under these circumstances they [the Dutch astronomers] wonder whether it might not be preferable to realise a more modest design without Belgian participation, possibly in connection to Dwingelo (...).'[85]

This 'more modest' design was prepared by Muller. In January 1964, he proposed a 'drastic simplification' of the plans, to which everybody agreed.[86] This simplification made it possible to reduce the previously estimated cost of 30 million Dfl to half that, 15 million Dfl. Moreover, it had the advantage that it could be built relatively quickly. This was important, as the Dutch were eager to start construction as soon as possible. The simplification was not at the expense of resolution and sensitivity, but rather at the expense of the speed of the observations.

The telescope would consist of 10 reflectors of 25 metres. 9 of them would be placed with a distance of 150 metres in between – which made an array of 1200 metres - and the 10th telescope would be a movable one on a rail-track of 300 metres length.[87]

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[84] The annual Herstmonceux conferences (which took place at the Royal Greenwich Observatory at Herstmonceux in East Sussex, UK) were organised by the British Astronomer Royal Sir Richard Woolley in 1957 (Parker, 2000, p. 287).

[85] 'Onder deze omstandigheden vragen zij zich af, of het niet verkieslijker zou zijn dan maar een meer bescheiden opzet te verwezenlijken zonder Belgische deelname, zo mogelijk in aansluiting op Dwingelo (…)' : Piekaar to Lefèvre, 13 January 1964, SA, NWO.

[86] Oort, J.H., 'Memorandum over de te bouwen grote radiotelescoop', Leiden, 13 January 1964, SA, NWO.

[87] Ferrier, 'Notitie met betrekking tot de Vergadering van de Raad voor het Benelux-Kruisantenneproject, gehouden te Leiden op 17 maart 1964', SA, NWO.

Why did Muller make this new design? Was he not fully taken up with his work in Dwingeloo? Or could nobody else be found? Indeed, the main problem had always been to find someone to lead the electronic design of the new radio telescope.[88] This had to be someone with a very specific and long experience. Muller met these criteria, but when the cross antenna project took off, he was very busy in Dwingeloo. So initially, he was no option. For several years Oort had searched for another leader for the design and construction period, but neither in Belgium, nor in the Netherlands could a suitable person be found. Of course, some very experienced researchers from abroad had been recruited, such as Christiansen and Erickson, but neither of them could stay long enough to start the execution of the project.

Not only was it difficult to find a project leader, it was hard to find competent engineers for the project in general. First of all, the work was highly specialised, but there were some additional problems. Recruiting engineers in Belgium, for example, was particularly difficult, as the salaries of engineers were considerably higher in Belgium than in the Netherlands. In order not to lose the possibility of attracting Belgian engineers, the executive committee of SRZM decided that this difference had to be taken into account when setting the salaries of the Belgian engineers. However, it should also be taken into account that they were working in a Dutch environment and therefore too big a difference in remuneration had to be avoided.[89] In the early 1960s, two outstanding young Belgian engineers of the Institut Montefiore, the Department of Electrical Engineering of the University of Liège, were attracted: G. Cantraine and O. Barbalat. Barbalat, however, never joined the project as 'he had been engaged abroad'.[90] Cantraine was appointed in July 1960, but he stayed for only about one year. Only one Belgian engineer, J.L. Casse, appointed by Belgium at the end of 1961, stayed until the opening of the telescope and beyond. He was a key person in the development of the electronic system of the telescope (Raimond, 1996, p. 29).

As it seemed a 'mission impossible' to recruit a sufficient number of engineers from Belgium and the Netherlands, the Dutch started looking overseas. Sometimes, this quest was successful (see the appointment of Robinson, Christiansen, Erickson etc.), sometimes it was not. Working in Holland did not always please people coming from more exotic places in the world. In the beginning of 1963, for example, an engineer from San Diego (California, USA), D.A. Williams, was hired. He was highly appreciated, as he had ten years of experience in engineering, experience in radio astronomy, in dealing with contractors etc.[91] However, in October 1963, Williams made it clear that he wanted to leave at the end of 1964, because he was not happy. At a council meeting of BCAP, Oort explained:

> (…) Williams had been somewhat disappointed by the character of the work on the project, which he had expected to be in a more advanced, production stage. Moreover his wife did not feel happy in Holland, and had decided to go back to the U.S.[92]

In early 1964, the construction of instruments in Dwingeloo did no longer require Muller full time, so he had considerable spare time to lead the electronic design of the new radio telescope.

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[88] Oort, J.H., 'Memorandum over de te bouwen grote radiotelescoop', Leiden, 13 January 1964, SA, NWO.
[89] Minutes of the executive committee meeting of SRZM of 19 October 1959, SA.
[90] Minutes of the Council meeting of the BCAP of 21 February 1961, SA.
[91] Minutes of the Council meeting of the BCAP of 20 September 1962; Minutes of the Council meeting of the BCAP of 21 January 1963, SA.
[92] Minutes of the Council meeting of the BCAP, held on 17 October 1963, SA.

Initially, it was planned that the telescope was to consist of 10 reflectors of 25 metres, 9 of them to be placed with a distance of 150 metres in between – which made an array of 1200 metres - and the 10th telescope would be a movable one on a rail-track of 300 metres length. However, later it was decided – it is not certain when exactly – that there were to be 11 reflectors, 10 of which would be placed with 150 metres in between and the 11th on a rail-track.[93]

It was this design that was finally put out to tender on 30 December 1964. Several companies – amongst which Werkspoor that had built the telescope in Dwingeloo – showed interest.[94] Although Belgium was still a partner, Belgian companies did not participate. They were contacted several times, but without result.[95] 3 May 1965 was the closing day of the tender. The contract for the construction of the telescopes was awarded to Wilton-Fijenoord, a shipbuilding and repair company in Rotterdam, which had made the lowest bid and could offer the eleven reflectors for Dfl 6 711 000.[96]

At that time, it had not been decided yet whether a second movable telescope would be added to the system. At the end of 1965, however, that decision was taken and a twelfth reflector was ordered.[97]

4.5 IN SEARCH OF A LOCATION AND A NAME

'Is het in de buurt van het vroegere doorgangskamp?'
'Het is op het terrein van het kamp,' zei Max, terwijl hij voelde dat zich iets verstrakte in zijn wangen.
Harry Mulisch, *De ontdekking van de hemel*

The question was now *where* the telescope should be built. To enable Muller to lead both projects – Dwingeloo and the new radio telescope – the new telescope had to be built close to Dwingeloo. This meant that most locations that had been considered previously had become irrelevant.

The quest for a suitable location for the new radio telescope had begun in 1960. Initially, the possibility was left open to look for a location outside the Benelux:

> It appeared to the Council that possibilities have to be carefully investigated, and that it is prematurate [sic] to define now a precise region for the location of this large cross. Possibilities in the Benelux have to be analysed first, before seeking a site in the neightbouring [sic] countries.[98]

[93] Bannier to the [Dutch] Minister of Education, 27 May 1965, SA, NWO.
[94] Werkspoor Utrecht to Stichting Radiostraling van Zon en Melkweg, 15 January 1965 ; Wilton Feijenoord to Oort, 13 January 1965, SA.
[95] Bannier to Ferrier, 21 August 1964, SA, NWO.
[96] Bannier to the [Dutch] Minister of Education, 27 May 1965, SA, NWO.
[97] Note added on 20 December 1965 on the minutes of the meeting of 11 October 1965, SA.
[98] Minutes of the meeting of the BCAP, held on 4 July 1960, SA.

As early as 1961, the first site surveys were done. Soon it became clear that finding a location was a very complicated matter. Dr. G. Westerhout wrote a first report on the Dutch site survey.[99] The most important requirement was that the region should be free of interference, five kilometres east, south and west and one kilometre north. Moreover, solid ground over two five-kilometre strips – where the antennas were constructed - was required. Several sites were investigated, but ultimately judged unsuitable:

(a) Drenthe: the telescope could be placed near the Dwingeloo telescope. However, a local road passed at 1500 metres and the nature reserve 'Kralose Veld'[100] would be ruined
(b) Overijssel: the only place available was in the lakes area, where the telescope could only be built at great cost
(c) Gelderland: the wooded area on the Veluwe had been considered, but there were three disadvantages: intensively used recreation area, military training grounds and hills up to fifty metres
(d) Zeeland: this was too near the coast and too intensively cultivated
(e) Southern part of Limburg: there were too many hills and mining industry

Some further research was done, and ultimately it was judged that some regions of North Brabant and North Limburg were far the most suitable, especially the regions that were situated along the Belgian-Dutch border, as these were the most 'empty', but also because it was politically and practically interesting to build the telescope on the border of the two countries participating in the project. However, when it was decided that Muller would lead both telescope projects, only regions close to Dwingeloo were considered in the site surveys.[101] Soon the Dutch had their eye on a region east of the village of Hooghalen, namely the 'Boswachterij Hooghalen', the forestry of Hooghalen – property of the Forestry Commission - in the province Drenthe.[102] The forestry of Hooghalen was located about twenty kilometres from Dwingeloo. There were some 'minor problems' in this area that had to be overcome before the construction of the telescope could begin: a road had to be closed, a farm and a military shooting range had to be removed, and several Ambonese families had to be moved. The relative ease with which Oort had all these things done is illustrative of his influence on Dutch politics. At the same time, it made clear that by the mid-1960s, radio astronomy had become a mature and prestigious field of which the importance was no longer doubted. In the Netherlands, people were eagerly looking forward to the construction of the prestigious instrument. As early as 1965, Dutch newspapers proudly announced on a regular basis the construction of the 'Giant telescope' in Westerbork.[103] On the other hand, however, the construction of the radio telescope was also a welcome opportunity for the Dutch government.

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[99] Westerhout, G., 'Report on the preliminary site survey in the Netherlands' (Appendix at Minutes of the Council meeting of the BCAP of 21 February, 1961), SA.
[100] I.e. the 'Kraloërheide'.
[101] Minutes of the Council meeting of the BCAP of 17 March 1964, SA.
[102] Raimond, E., 'Possible sites for the Benelux Antenna in Drente' [sic: DrentHe was by then often written Drente], 30 April 1964, SA, NWO.
[103] Reuzen-telescoop komt in Westerbork, in : *De waarheid*, 1 July 1965. Some other examples: Grootste ter wereld. Telescoop in Westerbork tast naar « grenzen » in het heelal, in : *Friese Koerier*, 27 May 1968 ; Bij Westerbork verrijst enorme radiotelescoop. Waarschijnlijk volgend jaar in gebruik, in : *Friese Koerier*, 16 July 1968.

Let us first consider the Ambonese. In the forestry of Hooghalen, there were still remains of the camp ‘Schattenberg’, where some Ambonese families were living. Camp Schattenberg had a long history. At the dawn of the Second World War, Camp Westerbork – ten kilometres to the north of the village of Westerbork - was built as a refugee camp for (German) Jews that had fled Nazi Germany. When the Germans occupied the Netherlands, they made use of the existing structure to change the refugee camp into a transit camp for Jews, Gypsies, homosexuals etc. From Westerbork, they were transported to the death camps of Auschwitz, Sobibor, Theresienstadt and Bergen-Belsen (Mulder, 2003, p. 469).

After the war, the camp was used as an internment camp for members of the Dutch National Socialist Movement, who had collaborated with the Germans. This was not unusual. Also other Dutch camps – for example Camp Amersfoort , Camp Vught, Camp Schoorl and Camp Erika – were used as internment camps for Dutch people who had collaborated with the Germans (Hijink, 2009, p. 135). When, in 1948, the internment period came to an end, it was uncertain for a while what would happen to the camp. Several options were considered, even changing it into a pig farm. The former camp then served several short-time purposes (Mulder, 2003, p. 469).

However, this indecisiveness, did not last long. In December 1949, Indonesia became independent. The Ambonese or South Moluccans - inhabitants of the Ambon Island in Maluku – who had fought in the Royal Dutch-Indian Army against the Indonesian nationalists, were of course very unpopular in Indonesia after the independence. Therefore, the Dutch government decided to offer transport to the Netherlands, and to house them together with their families in the former Dutch camps. In hindsight, the way the Dutch dealt with the camp heritage is rather upsetting: the remaining objects of the camps were not preserved or made into memorials, although many former prisoners tried to achieve this. At the end of the 1940s, the camp inventories of Camp Vught and Camp Westerbork were even auctioned. It was only in the 1980s that the former camp possessions were considered to have museum value and exhibitions with these objects were organised within the structures of existing museums (Hijink, 2009, p. 136).

On 22 March 1952, the first Ambonese entered the former camp Westerbork, which was in the meantime renamed to ‘Schattenberg’, after a neighbouring hill. In the end, 3000 Ambonese would live in Schattenberg. It was a closed community that had little contact with the outside world. The intention was to house the Ambonese only temporarily in Schattenberg, but in the end, they would stay for almost twenty years (Mulder, 2003, p. 470).

Since the end of the 1950s, the Dutch government had tried to integrate the Ambonese people into the Dutch society.[104] It enforced this by no longer carrying out the necessary maintenance on their barracks. As a consequence, one barrack after the other became uninhabitable, so that the people living there had to leave. The question was what would happen to the area when the Ambonese had left. The plans for the huge radio telescope offered an excellent solution (Mulder, 2003, p. 470). At the same time, it was a welcome occasion to hasten the eviction of the remaining Ambonese families. In June 1967, there were still 1300 Ambonese people in Schattenberg. Oort had had a meeting with the Provincial Executive, during which the latter had assured him that the

[104] See also the report it issued in 1957 : *Ambonezen in Nederland: rapport van de commissie ingesteld bij besluit van de Minister van Maatschappelijk Werk*, d.d. 24 Sept. 1957 nr. U 2598.

camp would be empty no later than 1 September 1968.[105] It was decided that the Ambonese would be rehoused in Bovensmilde, a small village to the west of Assen.

Although the evacuation of the Ambonese camp was already taking place at the time the construction of the radio telescope began, in the Dutch newspapers it was presented as if the arrival of the telescope was the one and only reason the camp had to be removed. At the end of October 1967, the newspaper *Nieuwsblad van het Noorden* reported:

> Mayor P. de Noord of Smilde announced yesterday evening at the beginning of the meeting of the city council that the Ambonese that are still staying in camp "Schattenberg" near Westerbork will be rehoused in Bovensmilde. (...) The discussions about the rehousing of these Ambonese, that will have to leave "Schattenberg" because of the construction of a radio telescope over there, went very well, said the mayor.[106]

However, the evacuation was delayed.[107] This was due to strong resistance of some of the remaining Ambonese. Despite the forceful intervention of the authorities, it took until February 1971 before the last Ambonese family was moved (Mulder, 2003, p. 470). In the end, the delay did not cause the Dutch astronomers too much trouble, as they just adapted their construction plans to this situation.[108]

Also the Forestry Commission showed itself a loyal partner in this prestigious project in Westerbork. In the area where the telescope would be located, there was a road leading to the Ambonese camp. As the area had to be free of interference, however, this road needed to be closed to all motorised vehicles. As it belonged to the Forestry Commission, it 'could be closed without any difficulties'.[109] Furthermore, the Forestry Commission bought some neighbouring grounds where they subsequently banned all motorised traffic etc., to make sure that an interference-free zone could be guaranteed for the astronomers.[110] After the inauguration of the telescope, the Forestry Commission was very proud of having facilitated the arrival of this prestigious instrument. It published a special booklet *Boswachterij en Sterrenwacht* (Forestry and Observatory), in which it said: 'Nature and technology have found each other in the 1200 hectares forestry of 'Hooghalen'.[111] (Van Wageningen, 1970, p. 1)

The Dutch Ministry of Education and Sciences too, was very supportive. The farm in the area that needed to be removed was bought by the Ministry on 5 September 1967. The farmer was rehoused

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[105] Minutes of the board meeting of SRZM of 30 June 1967, SA.

[106] 'Burgemeester P. de Noord van Smilde heeft gisteravond aan het begin van de gemeenteraadsvergadering meegedeeld, dat de thans nog in het kamp « Schattenberg » bij Westerbork verblijvende Ambonezen in Bovensmilde zullen wrden gehuisvest. (…) De besprekingen over de verhuizing van deze Ambonezen, die « Schattenberg » zullen moeten verlaten in verband met de bouw van een radiotelescoop aldaar, zijn zeer gunstig verlopen, aldus de burgemeester.' *Nieuwsblad van het Noorden*, 27 October 1967.

[107] Toelichting bij de begroting 1968, SA, NWO.

[108] Toelichting bij de begroting 1968, SA, NWO.

[109] Raimond, E., 'Possible sites for the Benelux Antenna in Drente' [sic: DrentHe was by then often written Drente], 30 April 1964, SA, NWO.

[110] Minutes of the board meeting of SRZM of 19 August 1964, SA; Minutes of the board meeting of SRZM of 14 May 1965, SA.

[111] 'Natuur en techniek hebben elkaar gevonden in de 1200 hectare grote boswachterij 'Hooghalen'.

in the polder of East Flevoland. Moreover, the Ministry even decided to remodel the former farm as housing for the telescope observers.[112] Most striking, however, was that Oort got the military shooting range removed relatively easily. To his initial request to *close* the shooting range, the Ministry of Defence answered that it was impossible, as it was very intensively used. At the same time, however, it recognised the scientific importance of the radio telescope and therefore it was willing to *relocate* the range: 'Given the great scientific interest that is served by the construction of a radio telescope, there are in principle no objections from the side of the ministry against a relocation (…).'[113] The idea was to incorporate the shooting range into another shooting range nearby, the one in Witten (near Assen). However, the Ministry of Defence did not want to pay for the costs of this relocation.[114] The total cost of the expansion of the shooting range in Witten was estimated at Dfl 500 000. There were five battalions that would make use of the range. Two of them had previously used the range near Westerbork. Consequently, the reasoning of the Ministry of Defence was that 2/5 of this amount of Dfl 500 000, namely Dfl 200 000 should not be paid by this Ministry. Therefore, Oort asked Piekaar whether the Ministry of Education could pay this amount.[115] The Ministry immediately agreed.[116]

When the design was put out to tender, the telescope had no name yet. Oort, Rinia, Blaauw and Muller discussed this, and they agreed that 'Cross antenna' was no longer relevant as the final shape would definitely not be a cross. Moreover, 'Benelux' should no longer be used in the name, as Luxemburg had never participated. Because Belgian participation had also become highly uncertain, it was agreed that any reference to the participating countries in the name of the telescope should be avoided. Several names were then proposed: 'Earth-rotation Antenna Synthesizer', which could then be abbreviated to the acronym 'ERAS'. This name was Rinia's favourite. He preferred not to use the word 'Westerbork' in the name of the telescope, as this word 'sounded unpleasant' to many people.[117] Indeed, the name of the village of Westerbork was inextricably linked to the Second World War 'Camp Westerbork'. Therefore, if a reference to the place would be made, Rinia would prefer 'Schattenberg'. The others, however, were not keen on the name 'Schattenberg', because this name did not figure on any map[118] and because it was unpronounceable for foreigners.[119] Muller for his part wanted to make a distinction between the name of the project, which he would call 'Westerbork Synthesis Telescope Project' (WSTP) and the name of the observatory, which he would call 'Radio Observatory Westerbork'. In the latter, he preferred to speak of an *observatory* instead of of a *telescope* as he expected that later on several other telescopes would figure on this terrain[120] Blaauw especially warned that the word 'large'

[112] Oort to the Ministry of Education and Sciences, 12 July 1967, SA, NWO.
[113] 'Gezien het grote wetenschappelijke belang dat met de stichting van de radio-telescoop wordt gediend, bestaan van defensiezijde tegen een verplaatsing naar elders in beginsel geen bezwaren (…).' Taks, A.M.J., Colonel of the Army, to the Director of the State Office for the National Plan, 24 August 1964, SA, NWO.
[114] Taks, A.M.J., Colonel of the Army, to the Director of the State Office for the National Plan, 24 August 1964, SA, NWO.
[115] Oort to Piekaar, 25 March 1965, SA, NWO.
[116] Minutes of the board meeting of SRZM of 14 May 1965, SA.
[117] Rinia to Oort, 18 March 1965, SA, NWO.
[118] Muller to Oort, 5 April 1965, SA, NWO.
[119] Blaauw to Oort, 23 March 1965, SA, NWO.
[120] Muller to Oort, 5 April 1965, SA, NWO.

should absolutely be avoided, as it was to be expected that in the near future much larger instruments would be built.[121]

The name ultimately chosen was the Westerbork Synthesis Radio Telescope (Westerbork Synthese Radio Telescoop) or WSRT. The village of Westerbork, of course, was very happy – after its dark past - to see its name now connected with a new prestigious scientific facility (Raimond, 1996, p. 26).

4.6 CONSTRUCTING AND INAUGURATING THE WESTERBORK SYNTHESIS RADIO TELESCOPE

The construction of the WSRT began in the winter of 1965-1966. The start was problematic, because manufacturing defects in the supporting structures of the reflectors delayed the assembly of the reflectors until June 1967.[122]

The electronics were developed partly by a group at Leiden Observatory under the leadership of the Belgian engineer Casse and partly by the staff of the laboratory in Dwingeloo under the direction of Muller (Raimond, 1996, p. 29). To this end, the laboratory in Dwingeloo was expanded.[123] During 1967, the production of the receiver system – which consisted of about 20 interferometer receivers – began. Muller was responsible for the development of the digital part. He worked closely together with Philips, the Dutch electronics company, which was contracted to deliver the hardware and software for controlling the positioning of the telescopes. [124]

The mechanical part of the twelve radio telescopes was finished in the fall of 1968.[125] Although the plan was to have all the aspects of the telescope ready at the same time, in virtually all areas except the mechanical – electronics, computer control etc. - problems arose. To give an example, it was agreed that Philips would deliver the numerical control on 1 November 1968. In the summer of 1968, however, it became clear that this was impossible and that delivery would take place no earlier than the end of March 1969. This delay caused some friction between Philips and the board of SRZM. Philips put the blame for the delays on staff changeover in the company, on the May 1968 strikes in France and on the ever changing demands of the astronomers. The astronomers themselves, however, thought that Philips just started the work too late. Oort was in

[121] Blaauw to Oort, 23 March 1965, SA, NWO. In hindsight, this was a very smart suggestion of Blaauw : in 2011, for example, a prize contest was organised to rename New Mexico's 'Very Large Array', a giant radio telescope that was commissioned in 1980. According to the USA consumer magazine *Popular Science,* the Very Large Array was 'named in a fine tradition of utilitarian monikers like the European Extremely Large Telescope and the ultimately impractical Overwhelmingly Large Telescope.' (Adams, 2011). The 'European Extremely Large Telescope' is an ESO-telescope that will be the largest ground based optical/near-infrared telescope in the world and will be built in Cerro Armazones (Chile). The 'Overwhelmingly Large Telescope' was a conceptual design of ESO that was ultimately given up because of the high cost and the complexity. The simpler European Extremely Large Telescope was chosen instead. The Very Large Array got its new name in January 2012 : it is now called the 'Karl G. Jansky Very Large Array'.

[122] Stichting Radiostraling van Zon en Melkweg. Annual report 1967, p. 25.

[123] Minutes of the board meeting of SRZM of 30 June 1967, SA.

[124] Stichting Radiostraling van Zon en Melkweg. Annual report 1967, p. 26. Remember that Philips had been involved in radio astronomy since its very beginnings.

[125] Stichting Radiostraling van Zon en Melkweg. Annual report 1968, p. 23.

despair about the delays that were caused by Philips and said it was ‘disastrous that, while the steel structures in Westerbork will be ready on 1 November, the telescope will only be ready for use several months later’.[126] Moreover, the estimate that the telescope would be ready for use ‘several months later’ would prove to be far too optimistic. Several other problems were encountered. The computer programs, for example, could not cope with the enormous amount of data to be reduced.[127] Another major problem was to get the pressurized coaxial cable system free of gas leaks.

And last but not least, there was a major problem that again shows how highly this project was valued and illustrates Oort’s influential position: a severe source of interference was visible in all data and horizon scans revealed that the interference originated from a military base about ten kilometres to the south-west of the observatory. The culprit was a transmitter that was part of a NATO communications network in Western Europe. Its frequency coincided with one of the ‘harmonics’ of the WSRT’s observing frequency, a frequency band in which interfering signals were rejected to a slightly lesser extent than elsewhere in the spectrum. Although transmitting in this band did not violate any frequency protection rules, the military authorities were willing to change the transmission frequency. After the necessary administrative procedures, the interference was removed in the fall of 1970 (Raimond, 1996, p. 31).

The numerous problems that arose in the construction of the WSRT made it clear that the astronomers had underestimated the whole project. At the end of 1968, Muller admitted: ‘We must say that across the board, the work was partly underestimated, partly it was also delayed by external factors’.[128]

With the delays accumulating, the estimated date on which the entire telescope should be ready for use changed several times: from the fall of 1968 to the beginning of 1969 to the first of September 1969 etc. The inauguration date was also moved forward several times. At the meeting of the board of SRZM on 13 December 1968, two possible inauguration dates were proposed: September 1969 and April 1970. It was agreed upon that September 1969 was the best choice. This was because by then, it was still estimated that the first observations would be made in September. Publicity was expected and so it was considered a good idea to have the inauguration shortly after the first observations.[129]

The first test observations were made with a single interferometer in the spring of 1969.[130] However, not until February 1970 could observations be made under computer control and with digital recording of the data on magnetic tape (Raimond, 1996, p. 31). Contrary to what was initially expected, no media coverage followed. It remains unclear whether there was no interest of the media in the observations or whether the astronomers just did not write any press releases.

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[126] ‘Het is rampzalig dat, terwijl de staalconstructies te Westerbork op 1 november klaar zullen zijn, de telescoop pas verscheidene maanden later zal kunnen worden gebruikt.’ Minutes of the board meeting of SRZM of 24 June 1968, SA.
[127] Minutes of the board meeting of SRZM of 13 December 1968, SA.
[128] ‘Over de gehele linie moet men zeggen dat het werk ten dele onderschat is, ten dele ook vertraagd door externe factoren.’ Minutes of the board meeting of SRZM of 13 December 1968, SA.
[129] Minutes of the board meeting of SRZM of 13 December 1968, SA.
[130] Stichting Radiostraling van Zon en Melkweg. Annual report 1969, p. 24

Probably the latter. This in turn, was most likely due to the fact that the astronomers wanted to ensure plenty of media coverage when the inauguration took place.

The radio telescope was inaugurated on 24 June 1970 by the Dutch Queen Juliana. It was the second time – after the inauguration of the radio telescope in Dwingeloo - that she opened a prestigious Dutch radio telescope.[131] The inauguration was front-page news in several Dutch newspapers. As at the time of the inauguration of the radio telescope in Dwingeloo, the Dutch were again very proud of this prestigious scientific instrument.

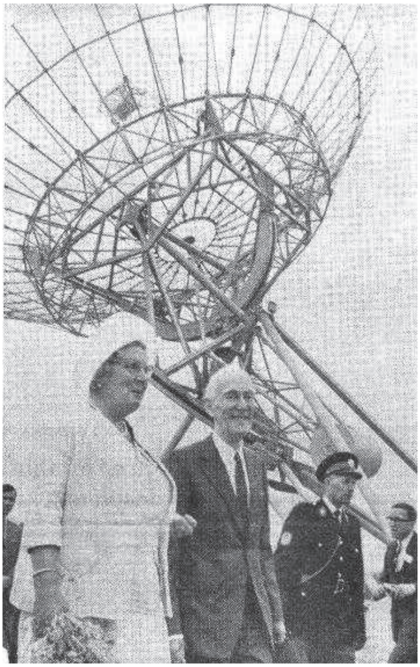

FIGURE 14. The Dutch Queen Juliana and Oort at the inauguration of the radio telescope in Westerbork (*Leeuwarder Courant*, 25 June 1970)

[131] 'H.M. Koningin Juliana opent radiosterrenwacht Westerbork', s.d., SA, NWO.

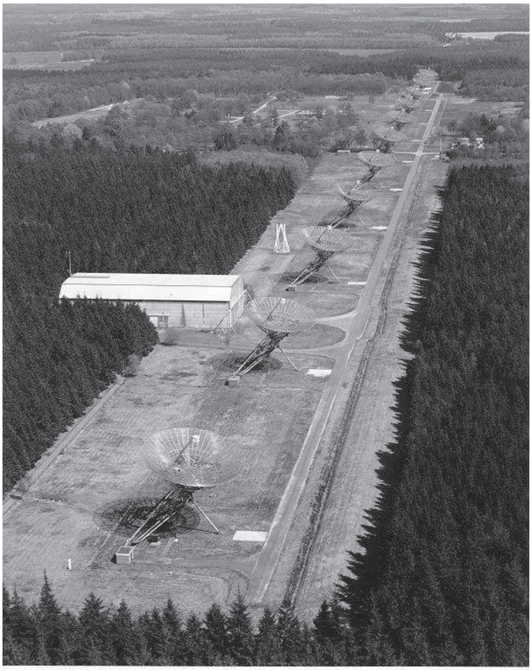

FIGURE 15. The radio telescope at Westerbork (http://www.astronomie.nl/#!/onderzoek/observatoria/_detail/gli/westerbork-telescoop/**)**

Even a company such as Philips, which had never showed itself a very enthusiast partner, in hindsight was very proud that it had participated in the development of this prestigious instrument. In 1970, it published a booklet, entitled *Billions of years and split seconds* in which it emphasised its contribution:

> The development and the realisation of the radio telescope was a joint venture of a number of highly specialised Dutch industries and of the staff of the foundation. Philips, being experts in scientific and industrial instrumentation and process control, contributed a computer and numerical control system. (Philips, 1970, p.1)

4.7 PAYING FOR AN EXPENSIVE INSTRUMENT OUT OF A TIGHTENING BUDGET

Until now, we have only briefly addressed the financial side of the story. However, it is worth dwelling on. First of all, it gives an idea on how the Dutch dealt with the delays in the Belgian contributions and what influence the Belgian arrears had on the course of the project. Moreover, it gives an excellent view of the changing Dutch science policy and tightening budgets during the 1960s. It also shows how Oort was struggling with this changing situation. Oort had been at the height of his career in the early post-war period, a time in which money for science was generously provided and prestigious university professors obtained extensive funding almost automatically. By the mid-1960s, however, these comfortable times were over.

In the total cost of the telescope, a distinction was made between the 'preparatory costs', the 'investment costs' and the 'operating costs' (or 'annual costs') of the project. In practice, however, these costs were not covered in sequence, starting with the preparatory costs and ending with the operating costs, nor were these different kinds of costs clearly separable. In 1960, ZWO provided a starting budget of Dfl 50 000 for the cross antenna project. Starting in 1962, an annual budget was provided to cover the investment costs. It was paid out of the 'extraordinary budget' of ZWO. The provision of money for the 'preparation of the cross antenna', however, continued through 1964. Beginning in 1965, ZWO used the term 'operating costs' instead of 'preparatory costs', although the telescope was far from being operational at that time. As a matter of fact, the distinction between preparatory costs, investment costs and operating costs was rather arbitrary. A sharp distinction could not be drawn, as Blaauw wrote to Oort in 1965: 'The transition of construction phase into operating phase will be a gradual one.'[132]

It is noteworthy that the Dutch share of the WSRT was *entirely* paid for by ZWO. This was in sharp contrast to what happened in most other countries. There, most often industry and/or the military were also involved. In Britain, for example, the Mullard Radio Astronomy Observatory (MRAO) in Cambridge, built in 1957, was partly funded by a grant from the Department of Scientific and Industrial Research (DSIR, see Chapter II) and partly by Mullard Limited, a British manufacturer of electronic components (Ryle, 1957, p. 110). The 'Lovell Telescope' (1957) in Jodrell Bank (see Chapter II) was funded by the British government as well as industry. Initially, it received money from DSIR and from the University Grants Committee (UGC). When the costs of the telescope spiralled, however, the private Nuffield Foundation and other government and military bodies, such as the Air Ministry and Ministry of Supply, were mobilised (Agar, 1998, p. xvii). Another example is the Effelsberg 100-m radio telescope (1972) of the Max Planck Institute for Radio Astronomy in Germany that was funded by the Volkswagen Foundation (Wielebinski, 1971, p. 115).

The fact that in the construction of the WSRT no military, industrial or private money was involved also meant that the radio telescope was not bound to perform any other than academic research. This was different for some of the other telescopes, the 'Lovell Telescope' in particular (see also Chapter II). Sven Grahn, involved in Swedish space research since the 1970s, has written an article on Jodrell Bank's role in early space tracking activities. He emphasised that the immense size and capability of this telescope was recognised as an invaluable asset when the USA decided to initiate a crash programme to send a probe to the Moon: the Able I project. Indeed, the USA ground tracking installations for this were inadequate. Able – and also some other American projects – definitely *needed* Jodrell Bank. The US Air Force and its contractor Space Technology Laboratories put trailers with equipment at Jodrell Bank and paid for the use of the telescope. At the same time, the success of the telescope in tracking US and Soviet space probes led to a donation from Lord Nuffield to pay off the telescope's remaining debt (Grahn, 2008).

[132] Blaauw to Oort, 23 March 1965, SA, NWO.

4.7.1 DEALING WITH THE BELGIAN ARREARS

The vague distinction between preparatory costs, investment costs and operating costs, however, caused some – further – trouble in the relation between the Belgians and the Dutch. As mentioned in the previous chapter, the Belgians only wanted to spend a maximum of 7 million Bfr - about Dfl 500 000 - annually on this project, initially for a period of 25 years. By then, they would have paid half of the total cost (preparatory costs/ investment costs / and exploitation costs) of the telescope. To the Dutch, however, this seemed an unrealistic scenario. According to them, it was a much more viable option to let the Belgians contribute for a period of 10 years. Taking the maximum of 7 million Bfr annually into account, the Dutch would then pay all of the investment costs, and the Belgians and the Dutch would each contribute 50% of the preparatory and operating costs,[133] which was agreed to by the Belgians.

So each year when the budget for the radio telescope project was prepared, the Dutch counted on an equal share of the Belgians in the preparation or operating costs. The amount due from each country from 1960 through 1963 was as follows:[134]

1960	Dfl 50 000
1961	Dfl 63 750
1962	Dfl 150 000
1963	Dfl 250 000

However, from the very beginning, the Belgian payments only arrived after long delays. Below, a list is shown of which amounts were sent on which date to secretary-treasurer Coutrez on a special BCAP account in the Belgian 'Banque Degroof & Cie' to cover the amount due from 1960 up to and including 1963:[135]

31 March 1961	Bfr 332 000
29 March 1962	Bfr 700 000
19 March 1963	Bfr 2 251 746
2 March 1964	Bfr 3 806 040

While in the Netherlands, each contribution for the operating year concerned was paid in December of the previous year (the contribution for 1964, for example, was paid in December 1963), in Belgium it was only paid in March of the year *after* the operating year concerned.

[133] 'Verslag van het interne Nederlands overleg over de Nederlands-Belgische samenwerking inzake het Synthese Radiotelescoop Project', held on 6 December 1965, SA, NWO.

[134] Bannier, J.H., 'Nota over de Belgische achterstand in de betaling voor de radioastronomische samenwerking', 26 July 1966, SA, NWO.

[135] Bannier, J.H., 'Nota over de Belgische achterstand in de betaling voor de radioastronomische samenwerking', 26 July 1966, SA, NWO.

Moreover, the Dutch did not actually receive the money on these dates in March. It often took several more months before these sums were deposited into the Dutch account at 'N.V. Slavenburg's Bank'.[136] In addition, no exact amounts were paid. For example, for 1960 Dfl 50 000 had to be paid, but the Belgians only paid Bfr 332 000, which is only about Dfl 23 000. They compensated this by paying more during 1963 and 1964. So in the end, they had paid a total amount of Bfr 7 089 786 or Dfl 513 750, which was the exact amount due.

After 1964 the situation worsened.

The table shows the amount of money both countries had to pay from 1964 through 1967:[137]

1964	Dfl 340 000
1965	Dfl 250 000
1966	Dfl 320 000
1967	Dfl 340.000

Without a clear reason, however, the Belgians did not pay their contribution for 1964. In February 1966, Coutrez offered a vague explanation for this state of affairs: '(…) I have received the instruction of the Minister of Public Education to provisionally end the transfer to the BCAP account in the Netherlands, while awaiting the outcome of the discussions between the parties involved.'[138] Otker - head of the administration of ZWO and administrative officer for the radio telescope project - was utterly astonished by this letter and wrote to Darimont of the Belgian Ministry of Public Education that he would '(…) very much appreciate it if you were able to use your high influence in order to arrange a quick settlement of the overdue payments.'[139] Unfortunately, Darimont died in a car accident on 27 February 1966 (Fraiture, 2006, p. 32). So an answer to this letter never came. A few months later, however, Deloz, an official of the Department of Higher Education and Scientific Research of the Belgian Ministry of Public Education, seems to have – verbally - communicated to Bannier that the Belgian contributions had come to an end because Belgium was only bound to participate in the 'preparatory stage' of the project.[140] The Dutch, however, found this an unacceptable explanation. They stressed that in practice, it was impossible to make a distinction between the 'preparatory stage' and the 'construction stage'.[141]

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[136] Bannier, J.H., 'Nota over de Belgische achterstand in de betaling voor de radioastronomische samenwerking', 26 July 1966, SA, NWO.

[137] Bannier, J.H., 'Nota over de Belgische achterstand in de betaling voor de radioastronomische samenwerking', 26 July 1966, SA, NWO; Bannier to the Minister of Education and Sciences, 6 March 1967, SA, NWO

[138] '(…) j'ai reçu instruction du Ministère de l'Education Nationale d'arrêter provisoirement tout transfert au compte BCAP aux Pays-Bas en attendant les résultats des discussions entre parties intéressées.' Coutrez to Otker, 9 February 1966, SA, NWO.

[139] '(…) bijzonder op prijs stellen als U Uw hoge invloed wilde aanwenden om een snelle afdoening van de achterstallige betalingen te regelen.' Otker to Darimont, 22 February 1966.

[140] Bannier, J.H., 'Nota over de Belgische achterstand in de betaling voor de radioastronomische samenwerking', 26 July 1966, SA, NWO.

[141] Bannier, J.H., 'Nota over de Belgische achterstand in de betaling voor de radioastronomische samenwerking', 26 July 1966, SA, NWO. Bannier also mentions that the OEEC was also bound to give support in the 'preparatory stage'. However, as the 'preparatory stage' did not come 'officially' to an end, the contract with OEEC was also never officially ended. OEEC ended the support after 1962, as the organisation had no money available to support this project further.

Eventually, the Belgians continued their payments – it is not clear why they decided to do so - but not until early 1968 (!) was the contribution of 1964 paid.[142] By this time, the contributions for 1965 and 1966 had been deposited in the Banque Degroof & Cie, but could not yet be sent to the Netherlands. Apparently, a new complication had arisen. The Belgian Inspectorate of Finance – responsible for administrative and budgetary control tasks - first wanted to have copies of the reports of the Central Accounting Service of the Dutch Ministry of Finances (Centrale Accountantsdienst van het Nederlandse Ministerie van Financiën) of the radio telescope project of the years 1965 and 1966.[143] Unfortunately, the reports of 1965 and 1966 were not ready yet.[144] A report of the years 1965-1967 was issued on 30 August 1968 and on 17 September Bannier sent a copy to Deloz.[145] However, after the receipt of this document, the Belgians remained silent. Several reminders of the Dutch followed during 1969.[146] In the beginning of December 1969, Deloz asked Coutrez to deposit the contributions for 1965 and 1966 into Slavenburg's Bank.[147] The final payment was received by the Dutch on 9 January 1970.[148]

So the Belgians paid their share of the preparation and/ or operation costs of the telescope from 1960 up to and including 1966. There was disagreement about whether or not Belgium had to pay the contribution for 1967: according to the Dutch, they should, according to the Belgians, they should not. On 25 July 1966, the Belgian ambassador in The Hague had had a meeting with the Dutch Prime Minister and the Minister of Foreign Affairs, during which he communicated the withdrawal of the Belgians from the radio telescope project (see previous chapter). The Dutch, however, did not consider this as an 'official' withdrawal. As we saw, they only considered the memorandum that was sent from the Belgian Embassy in The Hague to the Dutch Ministry of Foreign Affairs and to Oort on 14 July 1967 as final. Therefore, the Dutch thought that the Belgians still should pay the contribution for 1967. However, as the Belgians absolutely disagreed and the Dutch became aware that they would never be able to persuade them to pay, they considered the case closed.[149]

To deal with the Belgian delays, each year ZWO paid an advance to the Dutch astronomers to make up for the lacking Belgian amounts. When the amount due was finally received by the Dutch, it was paid back to ZWO.[150] This arrangement prevented serious delays in the project. So the complaints of the Dutch about the delays the Belgians caused – as you could read in the previous chapter – must be taken with a pinch of salt. Jean Casse - the Belgian engineer for the project – has confirmed that the 'financial problems in Belgium did not delay the project very much'.[151] The difficult relation with Belgium eventually forced the Dutch to simplify the design, but - as Casse emphasises – this happened very quickly (within a few months).[152] Although it is difficult to judge how the radio telescope project would have proceeded if we counterfactually assume that there

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142 Deloz to Bannier, 26 March 1968, SA, NWO.
143 Deloz to Bannier, 26 March 1968, SA, NWO.
144 Bannier to Deloz, 9 April 1968, SA, NWO.
145 Bannier to Deloz, 17 September 1968, SA, NWO.
146 Bannier to Deloz, 1 May 1969: Bannier to Deloz, 17 September 1969; Bannier to Deloz, 27 October 1969, SA, NWO.
147 Deloz to Coutrez, 5 December 1969, SA, NWO.
148 Bannier to Deloz, 28 May 1970, SA, NWO.
149 Minutes of the board meeting SRZM of 4 February 1971, SA, NWO.
150 See for example: Bannier, J.H., 'Nota over de Belgische achterstand in de betaling voor de radioastronomische samenwerking', 26 July 1966, SA, NWO.
151 Personal communication of Jean Casse to author, 8 February 2012.
152 Personal communication of Jean Casse to author, 8 February 2012.

had been no cooperation with Belgium, it is quite obvious that this cooperation was far from detrimental for the project. The Belgians had paid half of the preparation and operation costs of the telescope from 1960 until 1966, without having benefitted from any returns: Belgian industry was hardly involved in the construction of the telescope[153] and as they did not use the telescope, the Belgians did not claim any of the (limited) observation time.

To have an idea of the total amount the Dutch paid for the radio telescope in Westerbork, the following table gives an overview of the funding ZWO provided for the radio telescope project from 1960 up to and including 1970. Remember that since 1962, a division had been made between the 'Ordinary budget' and the 'Extraordinary budget' of ZWO. The investment costs of the telescope were covered out of the 'Extraordinary budget' of ZWO.[154]

1960	Dfl 50 000	
1961	Dfl 63 750	
	Ordinary budget	**Extraordinary budget**
1962	Dfl 150 000	Dfl 1 000 000
1963	Dfl 250 000	Dfl 3 000 000
1964	Dfl 340 000	/ *
1965	Dfl 250 000	Dfl 1 000 000
1966	Dfl 320 000	Dfl 3 000 000
1967	Dfl 340 000	Dfl 4 000 000
1968	/	Dfl 3 750 000
1969	/	Dfl 3 395 000
1970	/	Dfl 2 257 767

*For the year 1964, no lump sum for capital expenses was put on the budget, because it was thought unlikely that a sum exceeding two times four million Dfl – by then it was still the idea that Belgium would also pay half of the investment costs – would be needed before the end of 1964.[155]

As mentioned above, the budget that had been earmarked since 1962 to cover the investment costs was not made available while the Belgian government had not made an official decision about participation. When the preparations were made to start the construction in the fall of 1965, a first part of the amount was made available. Indeed, in February 1965, the Belgian Ministerial Committee had decided that Belgium would participate in the radio telescope project for a

[153] The largest Belgian company of light bulbs and electronic components, the Manufacture Belge de Lampes et Matériel Electronique (MBLE) was the only Belgian company that was involved in the BCAP. It developed a parametric amplifier for 408 MHz. In the end, this amplifier was not used, as the operating wavelength was changed to 1420 MHz. MBLE did not wish to be reimbursed for the amount of Bfr 267 500 which had been allotted for this work, but in return, it wanted to keep the rights on the results for itself. The Council of the BCAP agreed. See: Minutes of the Council meeting of the BCAP of 11 December 1961; Minutes of the Council meeting of the BCAP of 17 March 1964, SA.

[154] The amounts in the table come from the Annual Reports of ZWO of 1960 up to and including 1970.
[155] Minutes of the Council meeting of the BCAP of 18 July 1963, SA.

maximum of 7 million Bfr annually.[156] The procedure was that, each time an amount was needed, ZWO had to be asked for its release.[157]

4.7.2 TIGHTENING BUDGETS, STRICTER APPLICATION PROCEDURES AND OORT'S INABILITY TO DEAL WITH IT

As we saw, the Dutch economy flourished during the 1950s. In 1960, the economy was still growing, but tensions surfaced. A major problem was that, as a result of the tightening labour market, wages and prices were continuously rising. Therefore, since mid-1963, there had been a high inflation. This inflation problem existed also in other Western countries. However, it was most severe in the Netherlands, followed by France and Britain and it was much less serious in countries such as Belgium and the United States. Government spending had also greatly risen in the 1950s, because of entirely new investments, like the exploitation of natural gas. Furthermore, several industries had become much more capital-intensive. Other traditionally capital-intensive industries – such as the chemical industry and metallurgy – had grown considerably (Miljoennennota 1967, pp. 7-9).

Therefore, in the mid-1960s, the restoration of economic equilibrium became a priority of the Dutch government. Government spending had to be limited. Measures that were taken were a hiring freeze that was imposed on 1 June 1966 and lasted until the end of 1966, the deferment of new investments, and a general restraint on government spending (Miljoenennota 1967, p. 24).

Not surprisingly, this government austerity was also experienced by ZWO and Dutch science. A letter of Bannier to the board of SRZM could hardly be more explicit:

> As you probably know, in the context of the wage and price policy the government has decided to reduce public spending by introducing a hiring freeze, by postponing new investments and by exercising the necessary caution when making other outlays. These measures apply primarily to the departments and government agencies, as well as to other government administrations. Formally, these provisions do not strictly apply to bodies that do not belong to the above, but that are financed chiefly from public funds. However, the government has urged them to join the austerity measures as much as possible and they will not be able to avoid doing so. Such an appeal has also been made to Z.W.O., and we in turn have to appeal to your Foundation.[158]

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[156] 'Naar aanleiding van de jongste vergadering van het Ministerieel Comité heb ik het genoegen U thans zonder verwijl mede te delen dat het Ministerieel Comité beslist heeft dat België zou deelnemen in de werkingskosten van de radiotelescoop (…). De deelneming van België zou evenwel het bedrag van de 7 miljoen F per jaar niet overschrijden.' Spaey to Oort, 19 February 1965, SA, NWO.

[157] Minutes of the board meeting of SRZM of 23 November 1965, SA.

[158] 'Zoals U bekend zal zijn heeft de Regering in het kader van het loon-en prijsbeleid besloten tot een beperking van de overheidsuitgaven door invoering van een personeelsstop, door temporisering van de investeringen en door het betrachten van de nodige terughoudendheid bij het doen van andere uitgaven. Deze maatregelen gelden in eerste instantie voor de departementen en rijksdiensten, alsmede voor de verdere overheidsdiensten. Voor lichamen die hiertoe niet behoren maar die wel voor het grootste deel uit rijksgelden worden gefinancierd gelden de bepalingen formeel niet in strikte zin, maar de Regering heeft op hen een zeer duidelijk beroep gedaan zich zoveel mogelijk bij de bezuinigingsmaatregelen aan te sluiten

In practice, this meant that the hiring of new personnel had to be supported by strong arguments and the explanatory notes to the annual budgets had to be very detailed. Cars, business trips, new machinery and the like would become more difficult to obtain. Concerning the investment costs of the telescope, not many problems were expected, as these had been approved by the government several years before.[159]

The austerity measures were not, however, entirely new in 1966. They had gradually come into force years earlier. Although in absolute terms the government budgets for scientific education and research kept rising[160] (Kersten, p. 166), the explosive growth of the student population and the increasing number of research projects necessitated thrift. Bannier himself had had to get used to the situation that money for scientific research was not as abundantly available anymore. For the year 1963, for example, the astronomers asked for Dfl 75 000 to cover the costs of apparatus. Bannier was inclined to give them Dfl 100 0O0, as this sum was available. But this was not to the liking of the Dutch Ministry of Finances:

> It seems to me that, despite the appeal for thrift, it is putting the fox in the henhouse if Z.W.O. would announce that there is Dfl 100 000 available, while the board of the foundation itself believes that Dfl 75 000 is sufficient.[161]

In the 1950s, SRZM submitted its annual budgets to ZWO with very brief explanatory notes and often too late. Nevertheless, the budgets were always approved. This changed during the 1960s. When in September 1963, SRZM submitted the budget for 1964 Bannier wrote to Oort that the explanatory note accompanying the budget was much too brief. To decide about such an amount of money, the advisory committee and the board of ZWO needed a much more detailed explanation,[162] which the astronomers then wrote and the budget was approved.

Oort – who had been used to getting what he wanted, without following the procedures rigorously – found it difficult to cope with the new restrictions. He had a habit of always submitting his grant applications much too late, a habit that now started to irritate Bannier. Since 1963 Bannier had regularly reminded Oort or the then secretary of SRZM, A. Blaauw, of the deadlines for the applications.[163]

However, the situation did not improve. Although Oort and Bannier had always been on good terms, after a few years Bannier started to lose his patience:

> I should point out to you once more that I have serious objections to the way in which you continuously submit requests to me for approval on (and even *after*) the date on which the decision has to be made. In future, I will no longer take such requests into consideration, unless valid reasons for the late submission are given.[164]

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en zij zullen zich daaraan niet kunnen onttrekken. Zulk een beroep is ook gedaan op Z.W.O. en wij moeten dat onzerzijds weer doen op Uw Stichting.' Bannier to the Board of SRZM, 22 July 1966, SA, NWO.

159 Bannier to the Board of SRZM, 22 July 1966, SA, NWO.

160 Specificly for the budgets of ZWO, see: Annual reports ZWO, 1960-1965.

161 Vos to Bannier, 7 December 1962, SA, NWO.

162 Bannier to Oort, 9 September 1963, SA, NWO.

163 For example : Oort to Blaauw, 9 January 1963, SA, NWO.

164 'Ik wijs U er nogmaals op dat ik ernstig bezwaar heb tegen de wijze waarop U bij voortduring stukken ter goedkeuring aan mij voorlegt op (en zelfs ná) de datum waarop de beslissing moet worden genomen.

Oort was very offended by Bannier's criticism and wrote a furious reply:

> The last paragraph of your letter has surprised me. I fully realise that our requests to your organisation for decisions at short notice may be difficult for you. However, I believe that we agree that the fastest possible construction of the radio telescope is an essential factor for the value of the project, the more so because of the plans that exist in the USA for the construction of composite radio telescopes. Therefore, when designs are ready, we should be able to sign contracts for the production on short notice, while sometimes decisions on incidental needs also have to be made quickly. Moreover, we should not lose sight of the fact that, because of the coherence of the different components of the project, a delay in one area very often entails a delay in other areas. (...) But even if you do not find these reasons convincing, I have serious objections against the tenor of the last paragraph of your letter. By now I find it hard to be corrected like a school boy.[165]

This reply offered Bannier an opportunity to get off his chest all the things that were bothering him about Oort. In particular, he had a problem with the way Oort was leading SRZM. In an attempt to deal with government austerity and stricter procedures, Oort's attitude as president of SRZM became more and more authoritarian, as Bannier said: 'the regime has changed from democratic into authoritarian'.[166]

The examples Bannier gave, were indeed typical for Oort's personality. At the meeting of the board of SRZM on 23 November 1965, some things had happened that had terribly irritated Bannier. First of all, Oort had invited an engineer to the meeting (L.H. Sondaar) without discussing this previously with the other members of the board. Furthermore, Oort wanted to have a journey to America of M.M. Davis reimbursed. Davis was an American who had been working in Leiden for several years and who had made a survey of radio sources at 21 cm in Dwingeloo. He planned to finish a PhD on this topic in the fall of 1966. But to this end he needed to make some additional observations with the 300-feet telescope in Green Bank.[167] Oort had previously arranged that Davis's trip would be partly funded out of the Kerkhoven-Bosscha Fund, a fund that was established in Leiden in 1954 to stimulate Dutch and Indonesian astronomical research. At the meeting of the board, Oort presented this to the other members of the board and asked for additional funding for the trip from ZWO. Bannier refused.[168] In his letter he wrote: 'You had the

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Dergelijke stukken neem ik in het vervolg niet meer in behandeling, tenzij plausibele redenen voor de late indiening worden aangevoerd.' Bannier to Oort, 8 December 1965, SA, NWO.

[165] 'De laatste alinea van Uw schrijven heeft mij verwonderd. Ik besef volkomen dat onze verzoeken aan Uw Organisatie om beslissingen op korte termijn voor U bezwaarlijk kunnen zijn. Ik geloof echter dat wij het erover eens zijn dat, mede in verband met in de Verenigde Staten bestaande plannen voor de bouw van samengestelde radiotelescopen, een zo snel mogelijke bouw van de radiotelescoop een essentiële factor is voor de waarde van het project. Het is daarom nodig dat wij, wanneer ontwerpen gereed zijn, op korte termijn de contracten voor de fabricage kunnen afsluiten, terwijl ook tot meer incidentele voorzieningen af en toe snel besloten zal moeten kunnen worden. Bovendien mag niet uit het oog verloren worden dat door de samenhang van de onderdelen van het werk vertraging van één deel dikwijls ernstige vertraging van andere werkzaamheden meebrengt. (…) Maar zelfs indien deze redenen niet afdoende geweest zouden zijn, moet ik ernstige bezwaren maken tegen de strekking van de laatste alinea van Uw brief. Ik kan moeilijk meer accepteren als een schooljongen terechtgewezen te worden.' Oort to Bannier, 15 December 1965, SA, NWO.

[166] 'het regime is veranderd van democratisch in autoritair.' Bannier to Oort, 4 January 1966, SA, NWO.

[167] Minutes of the board meeting of SRZM, of 23 November 1965, SA, NWO.

[168] Minutes of the board meeting of SRZM of 23 November 1965, SA, NWO.

matter with (...) the Kerkhoven Fund in the bag and you presented it (...) to the board in such a way that it had hardly any option but to agree.'[169]

However, a far bigger problem, according to Bannier, was that Oort did not treat the different projects the same way. Things he himself found of prime importance – such as the expansion of the laboratory in Dwingeloo, where the electronics for the new radio telescope were developed – were discussed very thoroughly. Other plans – such as of the construction of antennas for solar research in Westerbork – were hardly discussed at the board meetings.[170] This is not surprising. Oort was, as we saw, hardly interested in solar research. On the other hand, it *is* remarkable that Oort's dominant position and his ability to determine the research programme more or less on his own, was still going on in the later 1960s. Over time, however, Oort's idiosyncratic way of arranging things started to annoy his colleagues more and more.

Not only was Bannier irritated by the authoritarian way Oort led SRZM, but he also disapproved Oort's habit of contacting the government *directly* instead of going through ZWO. Remember that in 1945, Oort contacted Prime Minister Schermerhorn directly to discuss his plans for the building of a large radio telescope (see Chapter I). And it was not only in matters of radio astronomy that Oort acted like this. A memorable event was also his 1956 initiative to write a letter to the then Prime Minister Drees to protest against the announced hiring freeze at the Dutch state universities. Oort was at that time the dean of the Faculty of Mathematics and Sciences at Leiden University. The curators of Leiden University had already had contacts with Dutch members of parliament and a parliamentary debate about the budget was planned. However, Oort did not want to wait for this. He proposed to address a letter to the prime minister in the name of the deans of the science faculties of the state universities. Several other deans supported his initiative. Hence, on 7 December 1956 a letter was sent to Prime Minister Drees. With this action – on the initiative of Oort - the deans ignored their own faculties, the university senates and curators. This was a very unusual proceeding, but according to Oort, the only thing that mattered was that it was the fastest way to get things done. Moreover, it was inappropriate to address the letter to the prime minister and not to Minister Cals, the Dutch Minister of Education, Arts and Sciences, whom it concerned. Oort, however, was convinced that Cals did not have sufficient influence in the Dutch government (Baneke, 2012, pp. 114-115). Oort's action would finally lead to the installation of the 'Commissie Ontwikkeling Natuurwetenschappelijk Onderzoek' (the 'Commissie-Casimir') in December 1957 (see Chapter III).

Indirectly, Bannier had heard that Oort had once said that he would have been very happy to arrange everything directly with the Ministries of Education and Finances, without the mediation of ZWO. This remark had seriously hurt Bannier. According to the latter, ZWO had made every effort to speed up the whole radio telescope project. If ZWO had not existed, things would have gone much slower:

> (...) you still do not understand (...) how hopeless the situation would have looked if Z.W.O. had not energetically involved itself and if the project had been treated by the Department

[169] 'Je had de zaak met (...) het Kerkhoven-fonds al geheel in kannen en kruiken en stelde deze (...) aan het bestuur zó voor dat dit bijna niet meer anders kon doen dan akkoord gaan.' Bannier to Oort, 4 January 1966, SA, NWO.
[170] Oort to Bannier, 15 December 1965, SA, NWO.

> according to the prescribed channels. In such a case, even the public tendering of the paraboloids might not have taken place yet.[171]

Not only was Bannier personally insulted by the way Oort time and again ignored ZWO, he was also convinced that this was a very risky way of doing business. His colleagues at ZWO were becoming irritated by Oort's idiosyncratic way of arranging things. It might not take much longer before they would lose their interest in the whole radio telescope project, said Bannier. Not only for his own project, but also more in general, Oort's attitude was detrimental to Dutch science: ZWO had always been a very successful mediator between the scientists and the Dutch government and Oort's attitude was seriously undermining this position of ZWO.

After this open conflict between Oort and Bannier, the relation between the two old friends seemed to have calmed down somewhat, but the funding procedures never again went as smoothly as in the previous period.

When the budget for 1966 was submitted at the end of 1965, problems arose again. For the first time, the budget was *not* approved. The total sum the astronomers had asked for 'research on radio emission of the Sun and the universe' (this did *not* include the cross antenna project) was Dfl 771 400. Bannier wrote that ZWO would only contribute a maximum of Dfl 700 000. To this end, the astronomers had to submit a new budget that did not exceed this amount.[172]

The next year, in October 1966, the Ministry of Education and Science asked SRZM whether it was possible to substantially decrease the operational costs of the large telescope. But for the board of SRZM, this was really a bridge too far: 'The board believes that a further significant lowering of the annual costs is not possible without an essential violation of the entire project of the synthesis telescope.'[173]

4.8 THE OBSERVATIONAL PROGRAMME: SOURCE COUNTS RULE

Like the radio telescope in Dwingeloo, the radio telescope in Westerbork would ultimately not be used for the research it was originally intended for, or at least not entirely,.

In itself, this is not so strange. As Raimond and Genée write in their introductory chapter in the volume they edited on the history of the WSRT: in order to discuss and fix the requirements for so expensive an instrument as the WSRT, at least some consideration of astronomical aims was unavoidable in the first place. But in the second place:

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[171] '(…) begrijp je dus nog steeds niet(…) hoe hopeloos de situatie er op het ogenblik ongetwijfeld zou hebben uitgezien indien Z.W.O. er zich niet energiek mee bemoeid had maar de zaak volgens de voorgeschreven ambtelijke wegen behandeld zou zijn door het Departement. Zelfs de aanbesteding van de parabolen zou dan wellicht nog niet hebben plaatsgehad.' Oort to Bannier, 15 December 1965, SA, NWO.
[172] Bannier to the Board of SRZM, 30 December 1965, SA, NWO.
[173] 'Het bestuur is van mening dat een verdergaande aanzienlijke verlaging van de jaarlijkse kosten niet mogelijk is zonder een wezenlijke aantasting van het gehele project van de synthese telescoop.' Oort to the Ministry of Education and Sciences, 17 February 1967, SA, NWO.

> (…) as has been so regularly the case in research with new types of instruments and new methods, it may well be that the instrument will lead into new, at present unpredictable, types of research; and these might become the most important. (Raimond and Genée, 1996, p. 3)

The plans for the construction of the large Dutch radio telescope arose at a time when radio 'source counts'[174] were a major issue in radio astronomy.

In the early 1950s the idea arose that radio source counts could be used to study the structure of the universe. In 1951, the British astronomer Graham Smith measured the positions of the two brightest radio sources in the northern sky, Cygnus A and Cassiopeia A. Smith's measurement, which had an accuracy of about 1 minute of arc, led to the optical identification of Cygnus A and Cassiopeia A by W. Baade and R. Minkowski, using the Palomar 200-inch telescope. Cassiopeia A was associated with a young supernova remnant in our own Galaxy, Cygnus A was associated with a faint, distant galaxy. The latter observation was very important, as it showed that radio sources could be used in cosmological studies. Fainter radio sources would lie at a significantly greater cosmological distance, and hence probe the Universe at earlier epochs (Longair, 2005, p. 107).

The subsequent study of source counts was dominated by Cambridge, more specifically by – again – Martin Ryle. Initially Ryle had supported the view that discrete radio sources were 'radio stars' in our own Galaxy. But the optical identification of radio sources, especially the identification of Cygnus A, made him change his mind. From then on, he adopted the view – which later turned out to be correct - that most of the radio sources observed in directions away from the Galactic plane (the densest part of the Galaxy) are distant extragalactic objects (Longair, 2005, p. 107).

To carry out a deep survey of the radio sky, Ryle and Hewish constructed a large four-element interferometer, operating at 81.5 MHz. In 1954, it was used for the second Cambridge survey of radio sources and the results were published the year after (Shakeshaft et al., 1955). Ryle and his colleagues found that the small-diameter radio sources were uniformly distributed over the sky and that the numbers of sources increased enormously as the survey extended to fainter and fainter flux densities (brightness). The only reasonable interpretation of these data, Ryle concluded, was that the sources were extragalactic, that they were objects similar in luminosity to Cygnus A, and that there was a much greater number density of sources at large distances than nearby (Longair, 2005, pp. 107-108). The source counts were considered to be strong evidence against the Steady-State theory, which claimed that the absolute luminosity and spatial density of radio sources were constant (Ryle, 1955, p. 146). The Steady-State theory had originated in England shortly after the Second World War as a counterpart of the Big-Bang theory. Almost all discussions and attempts to develop this theory further also took place in England (Kragh, 1999, p. 204). Outside England, responses to the Steady-State theory were fewer and less appreciative (Kragh, 1999, p. 223). It was not taken all too seriously outside England – except by Soviet astronomers.[175] In England, however, its advocates were the 'loud and articulate' trio Fred Hoyle,

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[174] 'Source counts' are the increase in the number of radio sources as one observes fainter sources (Van der Kruit, 2011, p. 21). It is the statistical relation between numbers and flux density of radio sources. The predicted relation differs for the various models of the structure and evolution of the universe.

[175] Steady state fitted into the world view of the Soviets, see: Elbers, A., De relaties tussen Nederlandse astronomen en hun Sovjetcollega's tijdens de Koude Oorlog: tussen pragmatisme en idealisme, in: *Studium. Tijdschrift Voor Wetenschaps- En Universiteits-Geschiedenis* - *Revue D'Histoire Des Sciences Et Des Universités*, 5 (2012), pp. 21.

Thomas Gold, and Hermann Bondi, which made the theory quite influential in the country.[176] But according to Ryle, the source counts made it clear that the Steady State theory should be dismissed and evolutionary theories embraced (e.g. the Big Bang):

> This is a most remarkable and important result, but if we accept the conclusion that most of the radio stars are external to the galaxy, and this conclusion seems hard to avoid, then there seems no way in which the observations can be explained in terms of a Steady-State theory. According to evolutionary theories, on the other hand, both the luminosity and the spatial density of the radio sources are likely to change with time (…) (Ryle, 1955, p. 146).

That such profound conclusions could be drawn from the counts of radio sources, however, was met with some scepticism, especially because in those days the physical nature of radio sources was not understood yet and only the brightest twenty or so objects had been associated with relatively nearby galaxies (Longair, 2005, p. 108). Moreover, further research revealed that the second Cambridge survey was severely flawed. At about the same time, the radio astronomy group in Sydney performed a survey of the southern sky with the Mills cross. This catalogue revealed no obvious cosmological effects at all. Moreover, the discrepancy between the two catalogues was so immense, that one of them had to be completely wrong (Mitton, 2011, p. 185).

In May 1957, Mills and Slee published an article, the summary of which must have made grim reading in Cambridge:

> A preliminary catalogue has been prepared of radio sources observed in a sample area of about one steradian[177] near the celestial equator (…) The catalogue is compared in detail with a recent Cambridge catalogue which includes the sample area; it is found that they are almost completely discordant. A theory is developed which explains this discordance in terms of instrumental effects and it is concluded that a major part of the Cambridge catalogue is affected by the low resolution of their radio interferometer. (Mills and Slee, 1957, p. 162)

Indeed, the Cambridge survey was corrupted, because the resolution of its interferometer was too low. This had the effect that several of its radio sources were in fact blends of two or more weaker sources (Mitton, 2011, p. 185). And of course, as the Cambridge catalogue itself was corrupted, the Australians concluded that 'accordingly deductions of cosmological interest derived from its analysis are without foundation' (Mills and Slee, 1957, p. 181).

Years of confusion followed. A bitter conflict was raging between the two Cambridge astronomers Hoyle – a strong advocate of the Steady-State theory – and Martin Ryle – a proponent of the Big Bang,[178] a conflict Mitton aptly describes as a 'clash of Titans' (Mitton, 2011, p. 167). Between 1955 and 1963, research on source counts was undertaken. By the mid-1960s, the situation had calmed

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[176] Interview of Martin Rees by Alan Lightman on 30 March 1988, Niels Bohr Library & Archives, American Institute of Physics, College Park, MD USA, http://www.aip.org/history/ohilist/34300.html (Accessed on 6 September 2012).

[177] The steradian is the unit to measure a solid angle.

[178] Ironically, the name 'Big Bang' was invented by Fred Hoyle. In 1949, Hoyle appeared on the BBC radio programme *The Nature of Things*, in which he defended the Steady-State theory. When his opinion was asked on the idea that the universe had started at a definite moment and point in time in the past – an idea that was first suggested by Georges Lemaître in 1927 – Hoyle responded that he could not conceive of the universe as having been born in what he contemptuously referred to as 'Big Bang' (Kidger, 2007, p. 157).

down. Although the radio source counts did not decisively settle the conflict between the Steady-State theory and evolutionary cosmological models[179], the majority of scientists by then accepted Ryle's cosmological interpretation (Sierotowitcz, 1991, p. 80).

It was at the height of the radio source counts controversy that in the Netherlands the plans arose to build the cross antenna. From the very beginnings, ideas – although not elaborated yet – were formulated about what should be investigated with this telescope. Not surprisingly, using radio source counts and radio source sizes to study the structure of the universe was one of the justifications for building the WSRT. This clearly indicates that - although HI research was still dominant in the Netherlands in those days - the Dutch were not operating in a void and their research programme was influenced by international developments.

In the beginning of November 1958, Bourgeois and Oort let the OEEC Governing Committee on Scientific and Technical Personnel know what they wanted to do with the instrument. At this time, the description of the research goals was still rather vague:

> The principal aims for which the instrument is intended are the investigation of the large-scale properties of the universe, the detailed investigation of the regions of ionized hydrogen and of their distribution throughout the Galactic System and near-by external galaxies, the study of the sources of the non-thermal (so-called "synchrotron") radiation in these same systems; in addition detailed studies of sun and moon may also be considered.[180]

Over the next ten years, the aims were repeated several times. In the meantime, Oort regularly discussed source counts with Ryle. They exchanged ideas on recent publications on source counts - for example on publications by the British astronomer P.F. Scott - and Oort also showed a great interest in Ryle's own research in this field. In February 1963, for example, Oort wrote to Ryle:

> Dear Ryle, Thank you very much for your information concerning the new source counts. I was most interested to see how nicely these fit in with the counts that Scott and you published earlier. They seem to give a fine confirmation of the excess of faint sources.[181]

In the 1964 proposal for constructing the telescope as a synthesis instrument, Oort explicitly emphasised that he and his colleagues were primarily interested in the investigation of the *structure* and *evolution* of the universe, something for which the source counts were particularly useful. It was said that the fundamental problems the telescope should solve 'concern in the first place the structure and origin of the very powerful radio sources and their relation with the structure and the evolution of the universe.'[182]

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[179] The whole issue was superseded by the discovery of cosmic microwave background radiation by the American radio astronomers Arno Penzias and Robert Wilson in 1964. Cosmic microwave background radiation is a kind of 'left over' radiation from an early stage in the development of the universe. Its discovery secured the Big Bang as the best theory of the origin and evolution of the cosmos (Schiller, J., 2010, p. 27).

[180] Bourgeois and Oort to the Governing Committee on Scientific and Technical Personnel, 3 November 1958, SA, NWO.

[181] Oort to Ryle, 12 February 1963, OA, 33.

[182] Oort, J.H., Proposal for constructing the Benelux radiotelescope as a synthesis instrument, 25 March 1964, SA, NWO.

Over time, the descriptions of the observational programme became more detailed. Although at the end of the 1960s, source counts had lost their relevance in the Steady-State versus Big-Bang discussion, it was still believed that radio sources were important for cosmology. For example, in the SRZM activity programme for 1969, we read:

> It is obvious that the first programmes will be chosen amongst issues for which the synthesis telescope is particularly suited: detailed structure (…) of bright radio sources; discovery, and determination of the general characteristics (angular size, flux, polarisation) of weaker radio sources; statistics of the characteristics of radio sources – to determine their distribution in space and their significance for cosmology; spatial distribution, intensity and polarisation of continuum radio radiation in nearby galaxies.[183]

Around the middle of the 1960s, 'quasars' had been discovered by Oort's former student, Maarten Schmidt. Quasars are astronomical objects of very high luminosity, found in the centres of some galaxies.[184] Together with the source counts, it was believed that quasars could reveal important cosmological information. They too, became a 'hot topic' of research.

So it happened that the main interest of Irish astronomer George Miley – whom Oort gave a full position in Leiden to work with the WSRT in 1970 – was using the radio size of quasars as a means of measuring the geometry of the universe. Oort immediately approached Miley to discuss the angular size-redshift relation and the possibility of using the WSRT in this area (Miley, 1996, p. 156). However, in the end the WSRT would only be used to a small extent for this kind of research. Miley says about this:

> Several years later I found out that using radio source size to study cosmology was one of the justifications for building the Westerbork Telescope. Although the preparation of a detailed scientific justification is a necessary evil when seeking funding for new instrumentation, subsequent important discoveries are often unrelated to this justification. This was the case with the angular size-redshift relation and Westerbork. (Miley, 1996, p. 156)

The reason why the angular size-redshift relation research was abandoned was – according to Miley – because the angular resolution of the WSRT was insufficient to make fundamental contributions to the research (Miley, 1996, p. 156). However, there was more at stake. Around 1970, it had become clear that in general, the relevance of the investigation of extragalactic radio sources for cosmology was disappointing (Kellerman, 1972, p. 531).

So in the end, little work was done on radio source size, because the resolution was insufficient. Radio source counts were actually carried out, but they soon turned out to be useless for determinations of the structure of the universe. But then, what topics *were* investigated with the WSRT during its early days? For the first time, the largest known radio sources, the giant radio

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[183] 'Het ligt voor de hand dat deze eerste programma's zullen worden gekozen uit die onderwerpen waarvoor de synthese-telescoop bijzonder geschikt is: gedetailleerde structuur (…) van heldere radiobronnen; ontdekking, en bepaling van de globale eigenschappen (hoekafmeting, flux, polarisatie), van zwakkere radiobronnen; statistiek van de eigenschappen van radiobronnen – ter bepaling van hun verdeling in de ruimte en hun betekenis voor de kosmologie; ruimtelijke verdeling, intensiteit en polarisatie van de continue radiostraling in nabije sterrenstelsels.' Stichting Radiostraling van Zon en Melkweg, Programma van werkzaamheden voor het jaar 1969, 29 August 1968, SA, NWO.

[184] As they have a 'starlike' appearance, quasars were initially called 'quasi-stellar radio source', which was in 1964 shortened to 'quasar'.

galaxies, were mapped with the WSRT. Research was done on neutron stars (a type of stellar remnant), on the continuum radiation of spiral galaxies, spectral lines – neutral hydrogen, ionised hydrogen etc. – were measured, detailed investigations were made of stars, ionised regions, molecular clouds, supernova remnants in galaxies etc. One of the great discoveries that were made with the WSRT, was the presence of a radio spiral structure in several galaxies.[185]

In other words, although the observational programme differed greatly from what was originally envisaged, we cannot deny that the diversity of the research topics was enormous, as one author said: 'The discoveries are as varied as the differences between the tropical wealth of the Moluccas and the bare mountain sides of Terra del Fuego.'[186]

4.9 CONCLUSION

The reason why the Dutch started thinking about building another radio telescope as soon as observations with the radio telescope in Dwingeloo were made was because they needed higher resolving power to keep up with the recent developments in radio astronomy. They chose a cross-shaped interferometer. Cross interferometers were being constructed in several countries, which indicates that the new Dutch telescope was to a certain extent 'shaped' by its international counterparts. Indeed, by means of the hiring of foreigners, Oort brought the worldwide expertise in radio telescopes into Holland. The first elaborate design, for example, was made by the Australian Christiansen together with Högbom, a former PhD student of Ryle. Notwithstanding these strong international influences and the initial cooperation with Belgium, Oort wanted to keep the new telescope a Dutch matter as much as possible: despite the fruitful relations with the Australians, he never agreed with a formal cooperation. It is also noteworthy that despite the international influences, the peculiar start of Dutch radio astronomy remained visible in the conception of the Westerbork telescope. Indeed, the American Erickson – who elaborated the second design together with Högbom – characterised the Dutch plans as 'clearly developed by *optical* astronomers'.

When we take a closer look at the motivations that drove the Dutch astronomers, it is clear that these were not only scientific. The decision as to which operating wavelength would initially be chosen - 75 cm - , for example, was motivated by the wavelengths that were used elsewhere, by technical and scientific advantages, by Seeger's personal experience and last but not least: by the fact that in Europe this band was recognised for radio astronomy. That the design was changed several times was also often motivated by other than scientific considerations. During 1961, it became clear that the telescope would cost much more than originally estimated. Moreover, there were no guarantees that a channel *near* 75 cm was also going to be allocated to radio astronomy. And last but not least, the design had little flexibility for changing to other wavelengths. Therefore, a second design was developed.

[185] S.n. 'Vijftien jaar ontdekkingen met de Westerbork Telescoop' [1986], SA, NWO.
[186] 'De ontdekkingen zijn even gevarieerd als de verschillen tussen de tropische rijkdom van de Molukken en de kale berghellingen van Vuurland.' S.n. 'Vijftien jaar ontdekkingen met de Westerbork Telescoop' [1986], SA, NWO.

However, a few months after the plans of the second design had been submitted to the Belgian and the Dutch governments, the design of the telescope was *again* radically changed. The reason was now that the resolving power of one minute of arc did not seem high enough anymore. At the end of the 1950s, when the first ideas for the telescope arose, a resolution of 1' was considered to be very high. By the beginning of 1963, however, this resolution was already outdated. Therefore, in the summer of 1963, Högbom proposed an instrument that would make use of *Earth-rotation aperture synthesis*. It would be a linear east-west array of telescopes, which could offer a resolution between 10'' and 20'' (when operating at 1420 MHz).

When the year 1963 came to a close, the plans changed again, due to financial reasons this time. The relations with the Belgians were so troubled that the Dutch started thinking about continuing alone. However, the project would have to be of a 'much more modest nature' then. In other words: it should be cheaper. In January 1964, Muller therefore proposed a new design, which was a 'drastic simplification' of the previous one. It enabled them to construct the telescope for about 15 million Dfl, about half of what the previous design would have cost.

At the location that was ultimately chosen – the forestry of Hooghalen – some obstacles needed to be overcome before the construction of the telescope could begin: a road had to be closed, a farm and a military shooting range had to be removed, and several Ambonese families had to be moved. The ease with which Oort got this all done, testifies to his prestige and to the fact he had a great influence on decision making in the Dutch government, as well as - more in general - to the prestige radio astronomy had gained by the mid-1960s and. At the same time, we should not forget that the construction of the telescope was a welcome opportunity for the Dutch government to hasten the relocation of the Ambonese. Thus, there was a certain 'convergence of interests'.

Notwithstanding the radical simplification of the eventual design, the telescope remained one of the most expensive Dutch scientific projects. At the same time, there were two financial problems. First, the Belgians were always late with their payments. To deal with this, each year ZWO paid an advance to the Dutch astronomers to make up for the lacking Belgian amounts. When the amount due was finally received by the Dutch, it was paid back to ZWO. So this problem was in fact easily solved. Therefore, the complaints of the Dutch about the delays the Belgians caused must be taken with a pinch of salt.

A second problem was that Dutch government budgets had been tightening since the mid-1960s. Government austerity was also felt by ZWO. As a result, grant application procedures became more and more strict. Oort – who had been used to getting what he wanted, without rigorously following the procedures – had great difficulty adapting to this. After some minor incidents, this situation led to a serious conflict between Oort and Bannier. The latter blamed Oort for being authoritarian, for not respecting procedures and for undermining ZWO's position as a mediator between the scientists and the Dutch government.

Last but not least, there was a striking difference between the eventual – very diverse - observational programme of the telescope and what was originally envisaged. However, this is not entirely surprising. The entire process of planning, designing and constructing the telescope, took almost twelve years. In the meantime, scientific research progressed. Although using radio source size to study cosmology was one of the justifications for building the Westerbork Telescope, around 1970 it had become clear that the relevance of the investigation of extragalactic radio sources for cosmology was disappointing. Moreover, the resolution of the WSRT proved to be insufficient for studying topics like the angular size-redshift relation. Hence, we may conclude that funding a scientific project almost inevitably entails a huge amount of uncertainty about exactly *what* is funded.

CONCLUSION

Since the early twentieth century, Dutch astronomy has been preoccupied with one simple question: What is the structure of the Milky Way? Answering this question, however, was a different story. Firstly, the Dutch cloudy climate severely hindered (optical) astronomical observations. And secondly, the largest part of the Milky Way was inaccessible for observations at optical wavelengths because of the extinction of the light by interstellar dust. Astronomers had already resigned themselves to the fact that their question might never be answered.

And this is where radio astronomy entered the picture. Throughout this book, you could read the answers to the questions we asked in the beginning: How can we explain the quick and remarkable success of Dutch radio astronomy? How did the astronomers manage to raise the necessary funds for these expensive projects? Which strategic alliances did they forge in order to safeguard their projects? How did they deal with the new and unfamiliar kind of instrumentation? To what extent did they collaborate or interact with other groups abroad? Why did the Dutch focus on *Galactic* radio astronomy, whereas in most other countries the focus was on *solar* radio astronomy?

A decisive moment in the history of Dutch radio astronomy was when at the end of 1940, the Leiden astronomer Jan Hendrik Oort read an article by Grote Reber, an electronic engineer from Chicago, in the *Astrophysical Journal*. Reber had been able to detect radio radiation from the Galaxy with a self-made telescope and he had studied how the intensity of radio emission changed with position in the sky and wavelength. Oort immediately realised that radio radiation could be vital for astronomical research: as radio waves were not hindered by earthly clouds and by interstellar dust, it was an ideal means to answer the question of the structure of the Milky Way.

Although Reber's work was of crucial importance for early Dutch radio astronomy, it was hardly known outside the Netherlands. Much more important were wartime developments in military radio and radar electronics. As the technologies of radar installations and radio telescopes were closely linked, this is not surprising. During the war, radar workers – mostly engineers and physicists – were confronted with interference, in the first place mostly from radio radiation from the Sun. Some of them wanted to explore this further after the war. Hence, the first radio astronomy groups consisted mainly of engineers and physicists with a background in wartime radar research. The Dutch group was anomalous in this respect.

This anomalous beginning of Dutch radio astronomy had several profound consequences. First of all, Dutch (radio) astronomers were not familiar with the new kind of instrumentation: they lacked the technical background to build radio telescopes, a disadvantage that would prove to be an advantage in the end. It forced them to conclude strategic alliances with industrial partners such as Philips, the PTT and the KNMI. These partners were willing to cooperate for several reasons: in Philips, several people of NatLab had a personal interest in (radio) astronomy (although the company as a whole showed little interest), the PTT was interested in possible spin-offs in telecommunication and the KNMI hoped the research would give them a better insight in weather conditions. In the end, these relations yielded the astronomers much more than the necessary technical know-how. First of all, in the beginning of 1948, the PTT made one of the Würzburgs at their transmitting station in Kootwijk available to the Dutch astronomers for studies of Galactic radiation. So the first radio telescope in the Netherlands was actually a 'present' from the PTT.

And there was more. In the context of Dutch post-war politics, science – and especially 'pure science' - came to be seen as a key factor in rebuilding the country, as its applications would stimulate the economy. Of course, industrial partnerships entailed promises of possible applications and hence they made it easier to obtain government funding.

However, when Oort and his colleagues tried to get the large radio telescope in Dwingeloo funded, it became clear that more was needed than industrial partners and promises of possible spin-offs. When in 1949 the plan for 'a large radio telescope with a dish of 25 m' was presented to the national funding organisation ZWO for the first time, it was not approved. The main reason was that in Kootwijk, no significant observations had yet been made, so why should another expensive instrument be built? It was only after the Dutch detection of the 21-cm hydrogen line in May 1951 that the definitive plan for the large radio telescope was approved. Apparently, only then was ZWO really convinced that the Dutch could indeed play a vital role in this new discipline.

Nevertheless, despite the industrial partnerships, the favourable post-war context and the breakthrough of the detection of the 21-cm hydrogen line, it remains remarkable that such an expensive project as the large radio telescope was approved rather easily. Two additional reasons can be mentioned here. First of all, in the whole radio astronomical project, only a handful of people were involved and also ZWO was still in an embryonic stage. Hence, in the application procedures people were often judge and party at the same time. Moreover, the fact that in the Netherlands radio astronomy was initiated by optical astronomers also assured that there was no 'gap' that needed to be bridged between the communities of optical and radio astronomers. Unlike in other countries, Dutch radio astronomers were no astronomical novices, prone to astronomical blunders. Hence, they were immediately taken seriously by optical astronomers. Even more: the astronomical community in the Netherlands was so small that radio astronomers and optical astronomers were to a large extent the same persons and not each other's competitors.

The anomalous beginning of Dutch radio astronomy also influenced the early radio astronomical research itself. Worldwide, the vast majority of radio astronomical research during or immediately after the war was radio astronomy of the *Sun*. That was because during the war radar workers had often been confronted with interference by radio radiation from the Sun. Dutch astronomers, on the other hand, focused on Galactic radio astronomical research, which was a continuation of their pre-war research by means of a new technology.

Over time, international influences and international collaboration strongly diminished the influence of the Dutch peculiar start. However, the American radio astronomer Erickson once described the conception of the Westerbork telescope in the 1960s, as 'clearly developed by *optical* astronomers'.

The above illustrates that in the beginning of the 1950s, Dutch academics, people from industry and government officials were clearly convinced of the importance of radio astronomy and of the vital role their country could play in it. However, this did not mean that this new field already enjoyed the acceptance of the broader public. Although the astronomers had put in a lot of 'popularisation' efforts and regularly dealt with the press, they met with a lot of resistance when they chose the village of Dwingeloo (Drenthe) as the location for their telescope. Nevertheless, construction started in 1954 and the 25-m telescope was inaugurated in April 1956.

As soon as the first observations with the telescope in Dwingeloo were made, ideas came up to build an even larger and better instrument. This was to become the radio telescope in Westerbork, inaugurated on 24 June 1970. The reason for the new plans was that higher resolving power was needed to keep up with the recent developments in radio astronomy. The Dutch chose a cross shaped interferometer, a choice that was to a certain extent 'shaped' by its international counterparts, as cross interferometers were constructed in several countries those days. By means of the hiring of foreigners - such as the Australian Christiansen, the Swedish Högbom and the American Erickson - Oort brought the worldwide expertise in radio telescopes into Holland.

From the beginning, it was estimated that this cross-shaped interferometer would be so expensive that the Dutch government would not provide funding. To share the costs, an international partner was needed. Therefore, in 1958, the Dutch chose the Belgians as their partner, a choice that marked a continuity with the history of Belgian-Dutch relations. However, what seemed to be the beginning of a successful common project, was in fact the start of several years of frustration, tensions and ultimately the decision of Belgium to withdraw from the project in June 1966. There are several reasons for this.

First of all, in Belgium and the Netherlands astronomical traditions had diverged since the beginning of the twentieth century. In the Netherlands, since the days of Kapteyn Milky Way structure and stellar dynamics – in which radio astronomy would later make great contributions - had become the main objectives of astronomical research. In Belgium, these research topics were negligible.

Another great stumbling block between the two countries was the different way in which they dealt with 'internationalisation'. Since the late nineteenth century, Belgium had been one of the most internationalised European countries. Dutch science, on the other hand, was remarkably little internationalised in the period concerned. And although Dutch astronomy can to a certain extent be considered an exception in this general picture - Dutch astronomers *did* collaborate and interact with groups abroad - also in this field the international orientation differed very much from that of the Belgians. In the Netherlands, it had a much more pragmatic character: each project was individually studied to determine whether it would benefit from international cooperation or not. 'Internationalisation just because science had to be international' – an attitude that prevailed in Belgium - was not the attitude of the Dutch. Hence, for the Belgians, further internationalisation of the radio telescope project was a *conditio sine qua non*, while this was definitely not the case for the Dutch.

Another problem was that the radio astronomical project was too much of a 'pure science' project for the Belgians. This rhetoric of pure science had at the end of the 1950s been long outdated in Belgium. In Belgium, applications and industrial benefits came first. In the proposals for the radio telescope project, the promises about technological implications were much too vague. This is also the reason why the Belgians were much more eager to cooperate in space research, as this offered their industry several beneficial contracts. Besides, (Earth-based) astronomy in general was no longer a government priority in Belgium. This can partly be explained by the absence of technological opportunities, but also by the fact that with the reform of Belgian science policy around 1960, the Belgian government wanted special attention to be paid to other fields such as molecular biology, space research and human genetics. The field that absorbed by far the biggest share of government funding, however, was – as in the Netherlands – nuclear research. The fact that astronomy was no longer a priority in Belgian science policy, is also one of the reasons why the handling of the project was sometimes slow and negligent. And last but not least: around 1960, Belgian science policy was – unlike in the Netherlands – already highly bureaucratised, which made an expeditious handling of the matter impossible.

In 1965, a breakthrough seemed to have been reached, as the Belgian government had officially decided to participate. However, the next year the Belgians suddenly withdrew because of the developments in a completely different Belgian-Dutch project that was running at the time: the Antarctic expeditions. At the end of June 1966, a Dutch delegation announced in Brussels that the Dutch government had decided not to provide funding for an Antarctic expedition in 1967. As both projects were inextricably linked in the eyes of the Belgians - although in reality they had nothing to do with each other – the Belgians announced their withdrawal from the radio telescope project the month after.

The withdrawal of the Belgians forced the Dutch to simplify the design of the radio telescope. However, as this was already the fourth design in a row, this was nothing exceptional. These decisions were often motivated by other than scientific considerations. The reasons to modify the first design were the disappointingly high cost, the fact that there were no guarantees that a channel near 75 cm was going to be allocated to radio astronomy and the fact that the design had little flexibility for changing to other wavelengths. Therefore, a second design was developed. In the beginning of 1963, however, the resolving power of one minute of arc did not seem high enough anymore. At the end of the 1950s - when the first ideas for the telescope arose - a resolution of 1' was considered to be very high, but in 1963 this resolution was outdated. Hence, an entirely new design was proposed by Högbom in the summer of 1963. The telescope would no longer be cross-shaped, but it would be a linear east-west array of telescopes that would make use of *Earth-rotation aperture synthesis*. This telescope could offer a resolution between 10'' and 20''. Soon, however, new complications arose. Because of the troubled relations with the Belgians, the Dutch started thinking about continuing alone. This meant of course that the project should be much cheaper. In January 1964, Muller therefore proposed a new design, a simplification of the previous one.

When it came to choosing a location for the telescope, the difference with the Dwingeloo period is striking. In Dwingeloo, the astronomers met with resistance. In the location where the Westerbork radio telescope was built– the forestry of Hooghalen – some serious obstacles needed to be overcome before the construction of the telescope could take off: a road had to be closed, a farm and a military shooting range had to be removed, and several Ambonese families had to be moved. The ease with which Oort got this all done, testifies to his prestige and to the fact he had a great influence on decision making in the Dutch government, as well as - more in general - to the prestige radio astronomy had gained by the mid-1960s.

Nevertheless, not everything went smoothly. Notwithstanding the radical simplification of the eventual design, the telescope remained one of the most expensive Dutch scientific projects. And there were two financial problems. First of all, the Belgians were always late with their payments. This problem, however, was easily overcome by yearly advance payments of ZWO. The second problem was more difficult to handle. Dutch government budgets had been tightening since the mid-1960s. Government austerity was also felt by ZWO. As a result, grant application procedures became more and more strict.

The plans for the Westerbork radio telescope were made at a time when cosmology and 'source counts' were hot topics in radio astronomy. Hence, it is not surprising that the main research goal was to use radio source sizes and radio source counts to study cosmology. However, although this was even one of the justifications for building the radio telescope in Westerbork, in the end, this observational programme would be curtailed. Reasons were that around 1970 it had become clear that the relevance of the investigation of extragalactic radio sources for cosmology was disappointing. Moreover, the resolution of the WSRT proved to be rather insufficient to study topics like the angular size-redshift relation. This big difference between what was originally envisaged and what was actually carried out is not so unusual: the entire process of planning, designing and constructing the telescope, took almost twelve years. In the meantime, scientific research progressed. Nevertheless, this did not prevent the observational programme from being enormously diverse: giant radio galaxies were mapped, research was done on neutron stars, on the continuum radiation of spiral galaxies, on clusters of galaxies etc.

The period 1940 – 1970 may well be called the 'Oort period' in Dutch radio astronomy. The radio telescopes in Kootwijk, Dwingeloo and Westerbork are inextricably linked to the name of Oort. However, we should not forget that Dutch radio astronomy would never have been so successful without engineers such as Muller and Hooghoudt. This 'public effacement' of the engineer is a general feature of the historiography of early radio astronomy. In the case of the Netherlands, this is not too surprising. Unlike in other countries, in the Netherlands the research programme was entirely developed by astronomers and it was a purely *astronomical* one. The telescope was not used for other, e.g. defence related, purposes in which the engineers could have a say. So in the Netherlands, engineers had a subordinate role, although a crucial one. Oort remained the driving force behind everything. It is not exaggerated to say that it was especially thanks to Oort that the Dutch radio astronomical group was one of the five major groups in the post-war decade.

If we should summarise Oort's character in one word, we can say his was a very *dominant* personality. He knew very well how to exploit the peculiar post-war situation in which large budgets were made available for science. At the same time, Dutch science policy was not well developed yet, which left ample opportunity for talented and ambitious scientists such as Oort. Without any engineering background, Oort and his colleagues succeeded in invading the unknown territory of radio astronomy and in turning their efforts very quickly into a success story. In this the small but influential network they had established with people from industry, politics and government was crucial.

The smaller the field, the more influence dominant personalities such as Oort and small networks can have. And Dutch radio *was* a small field in the period 1940-1970. That it began as a small field, was not exceptional however. Everywhere radio astronomy started as 'Little Science'. Even in countries where its first practitioners had a background in the big-science setting of war laboratories, the first radio astronomy groups were small groups working with modest resources and using adapted war equipment.

What was special in the Netherlands, however, was that radio astronomy remained small for quite a long time. In the making and, afterwards, the using of the radio telescope in Dwingeloo, only a handful of people were involved. Moreover, Dwingeloo was an exclusively Dutch affair: it was a matter of Dutch astronomers, engineers and construction companies. Besides the fact that this telescope was an expensive instrument, the organisational structure around it can certainly not be called Big Science. At first sight, the setup of the huge and extremely expensive radio telescope in Westerbork seems completely different. However, a closer look reveals that the similarities with the previous period are striking: although the number of people involved in the making of the radio telescope in Westerbork was much larger than in the Dwingeloo case, the organisational structure was initially about the same. Westerbork, too, was a truly Dutch project: although for a few years there was a cooperation with Belgium, the project again became a national Dutch project after the failure of this cooperation. This had something to do with the Dutch mentality (a pragmatic attitude towards internationalisation), but even more with Oort's personality: Oort always wanted to work alone. Despite very fruitful relations with the Australians on the Westerbork telescope, he never agreed to a formal cooperation. Summarising, we can say that in 1970 Dutch radio astronomy had still many little-science characteristics.

It was not only Dutch radio astronomy that was very small, Dutch national science policy too was still a small-scale undertaking in the 1950s and the beginning of the 1960s. ZWO was only founded in 1950, while in most other countries these organisations were a typical interwar product. Moreover, the reforms in the national science policies that had taken place in several European countries since the early 1960s at the instigation of the OEEC/OECD only took place about a decade later in the Netherlands. Hence, while in other countries – the Belgian example is illustrative - science policy had already evolved into a huge bureaucratic undertaking, this was anything but the case in the Netherlands. This in turn meant that in the Netherlands, things could still be arranged in the typically Dutch style: it was sufficient to have a chat with the right person to get something done. Very often, people were also judge and party at the same time. This meant of course that arrangements could be made very quickly, while in many other countries, things were slowed down by bureaucracy.

Around 1970, however, the Dutch radio astronomical scene underwent a complete metamorphosis.[1] Oort retired. His disappearance from the scene created a power vacuum that could not be filled immediately. Several potential successors were proposed, but none of them was available at the moment: Oort saw Adriaan Blaauw as the most suitable candidate, but Blaauw became the general director of ESO in the same year 1970. Henk van de Hulst and Kees de Jager, two other potential successors, were too busy in space research. Then there were Lodewijk Woltjer and Maarten Schmidt, but these had good positions in the USA, at Columbia University (New York) and Caltech (Pasadena, CA) respectively, and they did not want to come back to the Netherlands. Finally, Harry van der Laan was appointed to the chair of Oort. Van der Laan was a 34-year old lecturer who was born in Groningen and raised in Canada. He got his PhD in radio astronomy in Cambridge in 1963 and in 1967 he came to Leiden at the instigation of Oort. Van de Hulst in turn succeeded Oort as the director of Leiden Observatory.

It was not only in radio astronomy, but in Dutch astronomy in general that there were extensive changes in personnel around 1970. Historian David Baneke even talks about a 'leadership crisis' in Dutch astronomy (Baneke, 2014, p. 35).

These changes in Dutch astronomy around 1970 in turn, were to a large extent related to broader developments. First of all, around 1970 the rapid economic growth of the 1950s and 1960s came definitively to a halt. In 1973-1974, there was the oil crisis. This meant that the exponential growth of research budgets was really over now. Moreover, in this context of economic hardship, Dutch society became more and more critical towards huge amounts of government money spent on

[1] Historian David Baneke recently wrote an article that focusses on these profound changes in Dutch astronomy and Dutch science policy after 1970, see: Baneke, D., Sterrenkunde na Oort. De veranderende bestuurscultuur in wetenschap en universiteit in de jaren zeventig en tachtig, in: *BMGN – Low Countries Historical Review*, 1 (2014), pp. 25-54.

'useless' science. Oort, who had been used to get what he wanted without strictly following the procedure, had many difficulties to adapt to this. This led to a serious conflict between Oort and Bannier, the latter blaming Oort for the authoritarian way in which he led SRZM.

At the same time, the democratisation of higher education made an end to the authoritarian position of professors. More specifically, in 1971 a law was passed to reform the administration of the Dutch universities, the so called 'Wet Universitaire Bestuurshervorming'. This meant that from then on, university administrators were elected and not only professors, but employees and students were represented in the university administration (Baneke, 2014, p. 36).

The administrative reforms also affected radio astronomy. Under the new leadership of Van der Laan, a huge reorganisation of SRZM began. It was a process that took several years and that strengthened the central administration of SRZM. This reorganisation, however, did not always go smoothly. One of the most painful episodes was the departure of Muller. Muller was a typical person of the previous generation: like Oort, he wanted to run the whole show and did not like other engineers to have a say in the job. This kind of attitude, however, was an anomaly in the new era. At the end of 1970, Muller received an honourable discharge. It was time for a new generation to step forward.

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Abbreviations:

OA: *Oort Archives, University Library Leiden, Leiden University, the Netherlands.*

SA: *SRZM Archives, Leiden Observatory, Leiden University, the Netherlands.*

SA, NWO: *SRZM Archives, The Netherlands Organisation for Scientific Research, The Hague, the Netherlands.*

MA: *Minnaert Archives, Noord-Hollands Archief, Haarlem, the Netherlands.*

VdH: *Van de Hulst Papers, Leiden Observatory, Leiden University, the Netherlands.*

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NEDERLANDSE SAMENVATTING

Wanneer we de vroege radioastronomie bestuderen, blijkt Nederland een bijzonder interessante gevalsstudie, omdat de opkomst van deze discipline daar in verschillende opzichten afweek van wat er in het buitenland gebeurde. Dit boek biedt een antwoord op volgende vragen: hoe kunnen we het snelle en opmerkelijke succes van de Nederlandse radioastronomie verklaren? Hoe slaagden de radioastronomen erin de noodzakelijke fondsen voor hun dure projecten te verkrijgen? Hoe gingen ze om met het nieuwe type instrumenten? In welke mate werkten ze samen met radioastronomen in het buitenland? Waarom spitsten de Nederlanders zich toe op *galactische* radioastronomie, terwijl in het buitenland de focus lag op radioastronomie van de *zon*? Om deze vragen te beantwoorden, bekijken we de rol van de Nederlandse radioastronomen als strategische lobbyisten, netwerkers en organisatoren in een specifieke politieke en economische context.

Sinds de vroege twintigste eeuw vroegen Nederlandse astronomen zich af wat de structuur van de Melkweg was. Deze vraag beantwoorden, was echter een ander paar mouwen: ten eerste was het bewolkte Nederlandse klimaat niet echt geschikt voor astronomische observaties en ten tweede was het grootste deel van de Melkweg sowieso niet waarneembaar. Het zichtbare licht werd immers gehinderd door het interstellaire stof in de ruimte. Het is precies daar dat de radioastronomie soelaas zou brengen.

Eind 1940 las de Leidse astronoom Jan Hendrik Oort in *The Astrophysical Journal* een artikel van Grote Reber, een elektronische ingenieur uit Chicago. Reber was in staat geweest met een zelfgemaakte telescoop radiostraling te detecteren die afkomstig was uit de Melkweg en had bestudeerd hoe de intensiteit van de straling veranderde naargelang de positie aan de hemel en de golflengte. Oort realiseerde zich meteen het belang van Rebers bevindingen: aangezien radiogolven niet gehinderd werden door aardse wolken en door interstellair stof, konden ze een ideaal middel zijn om de vraag naar de structuur van de Melkweg te beantwoorden.

De oorlog was echter inmiddels uitgebroken en deze belemmerde de academische bedrijvigheid ernstig. De Duitse beslissing van 1940 om alle joodse professoren te ontslaan, stuitte op heftig protest, waardoor de Technische Hogeschool van Delft en de Universiteit Leiden werden gesloten. Onderzoek stagneerde, laboratoria werden geplunderd, academisch personeel werd gegijzeld of dook onder en internationale contacten werden verbroken. Oort zelf dook eind 1942 onder in Hulshorst, een klein dorpje op ongeveer 100 kilometer van Leiden. Toch kwam het astronomische werk niet helemaal tot stilstand. Geregeld ging Oort vanop zijn onderduikadres met de fiets (!) naar de Leidse Sterrewacht. Zijn collega Marcel Minnaert, directeur van de Utrechtse Sterrewacht sinds 1937, werd als gijzelaar opgesloten in het elitekamp Sint-Michielsgestel van 1942 tot 1944. Tijdens zijn verblijf daar legde hij connecties die later ontzettend waardevol zouden blijken. Zo maakte hij er onder andere kennis met Willem Schermerhorn, de naoorlogse eerste minister.

Het verblijf van Minnaert in Sint-Michielsgestel was voor diens begaafde student Henk van de Hulst een reden om zijn studies officieus naar Leiden te verleggen, waar hij geregeld afsprak met Oort. In de lente van 1944 vroeg Oort of Van de Hulst op zoek kon gaan naar een spectraallijn in het radiospectrum. Tijdens een clandestiene meeting van de Nederlandse Astronomen Club op 15 april 1944 in de Leidse Sterrewacht bevestigde van de Hulst dat er een spectraallijn van waterstof bestond op 21 centimeter, mooi binnen het radiospectrum. Bovendien is waterstof heel overvloedig aanwezig in de interstellaire ruimte in de Melkweg. Dit leidde Van de Hulst tot de conclusie dat deze zeer zwakke lijn waarschijnlijk wel waar te nemen viel. Via de waterstoflijn zou de structuur van de Melkweg dan ontrafeld kunnen worden. Het spreekt voor zich dat het belang van de ontdekking van deze lijn moeilijk overschat kan worden.

Nu was het tijd voor de volgende stap: de bouw van een radiotelescoop. En het is precies hier dat het anomale begin van de Nederlandse radioastronomie tot uiting zou komen. In Nederland waren de eerste radioastronomen 'echte' astronomen. Dat wil zeggen dat ze een opleiding in de astronomie hadden genoten. In het buitenland daarentegen, waren de eerste 'radioastronomen' ingenieurs en fysici met een achtergrond in radaronderzoek. Verrassend is dat niet: de technologie van radarinstallaties en radiotelescopen is nauw verwant en tijdens de oorlog werden veel radarwerkers geconfronteerd met interferentie door radiostraling, meestal afkomstig van de zon. Na de oorlog gingen sommigen onder hen deze radiostraling verder onderzoeken. Bijgevolg was het meeste onderzoek in de onmiddellijke naoorlogse periode radioastronomie van de zon. In Nederland lag de focus – net zoals vóór de oorlog - op het onderzoek van de Melkweg. Radioastronomie was daar dus eigenlijk gewoon een verderzetting van vroeger onderzoek met behulp van een nieuwe technologie.

Omdat radioastronomen in het buitenland dus eigenlijk geen echte astronomen waren, maakten ze geregeld zware fouten in hun astronomie, waardoor ze bij de optische astronomen aanvankelijk niet serieus genomen werden. Dit was een probleem dat zich in Nederland niet stelde. Anderzijds waren ze veel sterker in het ontwikkelen van de nodige apparatuur, iets waar de Nederlandse astronomen dan weer geen kaas van hadden gegeten. Dit gebrek aan kennis dwong hen tot het aangaan van strategische allianties met industriële partners zoals Philips, de PTT en de KNMI. Oort, maar vooral ook Minnaert, hadden tijdens en ook vóór de oorlog al goede relaties opgebouwd met mensen uit deze bedrijven. Minnaert had tijdens het interbellum zelfs op de KNMI gewerkt.

Deze partners hadden elk ook hun eigen redenen om in te gaan op de vraag van de astronomen: bij Philips hadden enkele personen van het NatLab een persoonlijke interesse in (radio)astronomie (hoewel de rest van het bedrijf en zeker de top weinig interesse toonde). De PTT was geïnteresseerd in mogelijke spin-offs voor telecommunicatie en de KNMI hoopte dat het onderzoek een beter inzicht in de weersomstandigheden zou geven.

Uiteindelijk zouden deze allianties de astronomen veel meer opleveren dan enkel technische kennis. Eerst en vooral was de eerste radiotelescoop een 'geschenkje' van de PTT. Nog tijdens de oorlog had Oort Philips, de Technische Hogeschool Delft en Reber zelf gecontacteerd om hem te helpen bij het ontwerpen van een radiotelescoop. Het zou een telescoop moeten worden met een spiegel van ongeveer 25 meter had bij laten bereken. De firma Werkspoor zou de telescoop kunnen bouwen. Het hele project zou ruw geschat 100 000 gulden kosten. Met zijn gebruikelijke doortastendheid probeerde Oort op elke manier dit bedrag los te krijgen van de overheid: via een persoonlijk bezoek aan de eerste minister Schermerhorn en via de KNAW. Hij ving echter bot. Het bedrag van 100 000 gulden was namelijk excessief hoog, ongeveer even hoog als het totale budget van de overheid voor wetenschappelijke instrumenten.

Gelukkig zorgde de PTT voor een alternatief. De PTT had na de oorlog enkele 'Würzburg Riesen' - radarreflectors die de Duitsers hadden gebruikt tijdens de oorlog - naar zijn zendstation in Kootwijk gebracht om de ionosfeer te onderzoeken. Eén van deze aangepaste Würzburgs stelden ze in 1948 ter beschikking van de astronomen om de radiostraling van de Melkweg te onderzoeken. Dit was natuurlijk een klein en weinig gesofistikeerd instrument, maar het was een begin.

In 1948 gingen de astronomen dus aan de slag met hun Würzburg. Helaas gingen de eerste waarnemingen niet helemaal naar wens. Een groot probleem was dat men moeilijk goede ingenieurs vond. Aan de competenties van ingenieur Hoo, die eind 1948 werd ingehuurd, werd al snel getwijfeld. Toen in 1949 het plan voor de radiotelescoop met de spiegel van 25 meter werd voorgelegd aan ZWO ('Zuiver Wetenschappelijk Onderzoek', de nationale Nederlandse financieringsorganisatie voor wetenschappelijk onderzoek), werd het niet goedgekeurd. De belangrijkste reden was dat het nut van dat instrument onduidelijk was. Observaties van enige betekenis waren in Kootwijk inderdaad nog niet gedaan. Waarom zou dan een nieuwe en extreem dure telescoop gebouwd moeten worden? Bovendien verwoestte een zware brand in de observatiekamer van de telescoop in maart 1950 bijna al het materiaal. De zaken moesten zo snel mogelijk hersteld worden. Philips bouwde een nieuwe ontvanger. Gelukkig geraakten de zaken in een stroomversnelling, toen Muller eind 1950 werd aangenomen als hoofdingenieur. Maar hoe competent Muller ook was, de 21cm-waterstoflijn kon niet gedetecteerd worden. Een cruciaal onderdeel ontbrak en de oplossing zou komen uit… Harvard.

Rond dezelfde periode probeerden ook de Amerikanen de 21cm-waterstoflijn te detecteren. In Harvard was de fysicastudent H.I. Ewen onder leiding van E.M. Purcell voor zijn doctoraat een radiometer aan het bouwen om interstellair waterstof te detecteren. Zoals de meeste vroege radioastronomen – buiten de Nederlandse – hadden ook Ewen en Purcell volstrekt geen achtergrond in astronomie. Ze waren actief geweest in radar tijdens de oorlog.

Het toeval wou nu dat Henk van de Hulst – die op dat ogenblik al docent was aan de Universiteit Leiden – enkele maanden in Harvard verbleef om daar een cursus radioastronomie te geven. Kort nadat hij was gearriveerd, kwam het onderzoek van Ewen en Purcell hem ter ore. Het duurde niet lang of er ontstond een vruchtbare samenwerking tussen de drie. Ewen en Purcell staken heel wat op van Van de Hulsts astronomische kennis. Van de Hulst van zijn kant leerde dat Ewen en Purcell hun radiometer gebruik maakte van de 'Dicke switch', genoemd naar de Amerikaanse fysicus Robert Henry Dicke die eveneens werkzaam was geweest in de radarindustrie tijdens de oorlog. Deze 'Dicke switch' was het cruciale ontbrekende element geweest dat de detectie van de waterstoflijn in de weg had gestaan.

Toen gingen de dingen snel: in Harvard slaagde Ewen erin de waterstoflijn te detecteren op 25 maart 1951. In Nederland kwamen de eerste signalen binnen op 11 mei en eind juni kwam er ook een bevestiging van Australië. In Australië was de interesse voor de waterstoflijn er pas gekomen, doordat F. Kerr, een staflid van het Radiophysics Laboratory in Sydney (waar radarapparatuur werd ontwikkeld tijdens de oorlog), op dat moment net een jaar in Harvard was om astronomie studeren. Toen de lijn er werd gedetecteerd, bracht hij zijn Australische collega's onmiddellijk op de hoogte.

In augustus 1951 legden de Nederlandse astronomen het plan voor de grote telescoop nogmaals voor aan ZWO. Toen werd het onmiddellijk goedgekeurd, ondanks de geschatte constructiekost van 436 000 gulden. Om een idee te geven of dit veel of weinig was: tot ongeveer midden de jaren vijftig kregen de radioastronomen ongeveer tien procent van het jaarlijkse budget van ZWO. Ze kwamen daarmee op een verdienstelijke tweede plaats. Wie nog meer kreeg was FOM (Fundamenteel Onderzoek der Materie), de Nederlandse organisatie voor fundamenteel onderzoek in de natuurkunde. FOM kreeg jaarlijks ongeveer vijftig procent van het budget van ZWO voor zijn onderzoek in de kernfysica. Het aantal projecten dat ZWO steunde, begon met twaalf in 1947, maar dat steeg zeer snel.

De detectie van de waterstoflijn was de *directe* aanleiding om de dure telescoop te financieren, maar het blijft merkwaardig dat zo'n groot budget zo gemakkelijk vrijgemaakt werd voor schijnbaar vrijblijvend wetenschappelijk onderzoek, terwijl het land nog in volle wederopbouw was.

Het is echter zo dat in de context van de Nederlandse naoorlogse politiek wetenschap – en vooral 'zuivere wetenschap' – net werd gezien als een cruciale factor in de wederopbouw van het land. Wetenschap zou immers leiden tot toepassingen die de economie zouden stimuleren. Niettegenstaande de sterke retoriek van 'zuivere' wetenschap verhoogden partnerschappen met de industrie de kansen op overheidsfinanciering aanzienlijk. Zo'n partnerschap maakte de belofte op mogelijke toepassingen immers heel wat geloofwaardiger. De Nederlandse radioastronomen speelden hier handig op in. Ze lieten geen gelegenheid voorbijgaan om in hun onderzoeksaanvragen mogelijke spin-offs in telecommunicatie te benadrukken. Ironisch genoeg had Minnaert zich al in het najaar van 1949 gerealiseerd dat een spiegel van 25 meter enkel bruikbaar was voor onderzoek van de Melkweg en niet voor onderzoek van de zon. En het was enkel het zonneonderzoek dat die spin-offs kon opleveren. Niettegenstaande dit nieuwe inzicht bleven ze dit argument van de spin-offs gebruiken in hun aanvragen.

In de argumentatie van de adviescommissie van ZWO die het project beoordeelde, werden niet alleen de grote wetenschappelijke waarde van het project en de spin-offs benadrukt, maar ook gevoelens van nationaal prestige: radioastronomie was een nieuw vakgebied waarin Nederland een rol van wereldbelang zou kunnen spelen.

Tot slot was het ook een meevaller dat astronomie nog een zeer kleinschalige onderneming was in de vroege naoorlogse periode. Er was slechts een handjevol mensen bij betrokken. Oort en Minnaert hadden dus geen noemenswaardige concurrenten. Ook ZWO verkeerde nog in een embryonaal stadium. Er waren bij de hele onderneming zo weinig mensen betrokken dat de impact van een persoonlijk netwerk gigantisch kon zijn. Wanneer we de financieringsprocedure van dichterbij bekijken, zien we dat de mensen die over het project moesten oordelen vaak goede bekenden van de astronomen waren. Bovendien waren heel wat mensen rechter en partij.

Nadat de radioastronomen financiering hadden gekregen van ZWO voor de bouw van de telescoop, moesten ze op zoek gaan naar een geschikte locatie. Na enige overweging viel de beslissing op het 'Kraloër veld' naast de gemeente Dwingeloo (Drenthe). Dit was een interferentievrije zone in een natuurreservaat. Er kwam echter hevig protest van de gemeenteraad van Dwingeloo en van de Vereniging tot Behoud van Natuurmonumenten. De laatste bleef zelfs protesteren, nadat de bouw van de telescoop al enkele jaren voltooid was. Het verzet tegen de bouw van de radiotelescoop maakt duidelijk dat het vakgebied nog erg jong was en er nog geen draagvlak was bij het bredere publiek. Gelukkig voor de radioastronomen waren er ook positieve geluiden te horen. De handelsvereniging dacht dat de telescoop toeristen zou aantrekken en ook de Rijksdienst voor het Nationale Plan en de provinciale en de nationale overheden stonden achter het voorstel. Uiteindelijk werd er dus toch groen licht gegeven voor de bouw van de telescoop.

De constructie startte in 1954. De telescoop werd ingehuldigd in april 1956. Maar de observaties waren nog maar net bezig of er kwamen al ideeën op om een nog groter en beter instrument te bouwen. De reden was dat een groter oplossend vermogen nodig was om bij te blijven met de recentste ontwikkelingen in de radioastronomie. De Nederlanders kozen aanvankelijk eerst voor een interferometer in kruisvorm, naar analogie van de instrumenten die op dat ogenblik ook in het buitenland gebouwd werden. Door verschillende buitenlanders in te huren – zoals de Australiër Christiansen, de Zweed Högbom en de Amerikaan Erickson – haalde Oort de wereldwijde expertise in radiotelescopen naar Nederland.

Van in het begin werd er wel gevreesd dat het instrument zo duur zou zijn dat de overheid er geen geld voor zou vrijmaken. Daarom was de zoektocht naar een internationale partner noodzakelijk. Oorts keuze viel op België. Dat leek perfect aan te sluiten bij de traditie van Belgisch-Nederlandse culturele en economische samenwerking. Wat echter het begin van een succesvol gezamenlijk project leek, was in feite de start van jaren vol frustratie, spanningen en uiteindelijk de beslissing van België in juni 1966 om zich terug te trekken uit het project.

Hier zijn verschillende redenen voor te vermelden. Ten eerste waren de Belgische en de Nederlandse astronomische tradities sterk uit elkaar gegroeid sinds de vroeg twintigste eeuw. Sinds de dagen van Kapteyn waren in Nederland de structuur van de Melkweg en stellaire dynamica – waaraan radioastronomie later belangrijke bijdrages zou leveren - de belangrijkste onderzoeksdomeinen geworden. In België waren deze echter verwaarloosbaar.

Een tweede struikelblok was de verschillende manier waarop beide landen omgingen met 'internationalisering'. Sinds de late negentiende eeuw was België één van de meest geïnternationaliseerde landen van Europa. De Nederlandse wetenschap daarentegen was in die periode opvallend weinig geïnternationaliseerd. Hoewel de Nederlandse astronomie op dit vlak in zekere zin een uitzondering vormde – Nederlandse astronomen werkten wel degelijk nauw samen met wetenschappers in het buitenland – verschilde de kijk van de Nederlanders op internationale samenwerking ook hier grondig van die van de Belgen. Men kan zeggen dat de Nederlanders veel pragmatischer waren: voor elk project werd afzonderlijk bekeken of het baat zou hebben bij internationale samenwerking of niet. In België was er eerder sprake van 'internationalisering om de internationalisering'. Wetenschap moest gewoon bijna per definitie internationaal zijn. Een verdere internationalisering van het radiotelescoopproject was voor de Belgen dan ook een *conditio sine qua non*, terwijl de Nederlanders daar absoluut het nut niet van inzagen. Een en ander had ook te maken met het feit dat Armand Delsemme, een invloedrijke Belgische astronoom, eveneens een hoge positie bekleedde in de OESO en de OESO had een klein deel van het project gefinancierd. Delsemme benadrukte dat de OESO had beslist het project te sponseren, net omdat andere Europese landen hadden gehoopt dat ze op lange termijn ook zouden kunnen deelnemen.

Een ander probleem was dat radioastronomie te veel 'zuivere' wetenschap was voor de Belgen. De retoriek van zuivere wetenschap was in België in 1950 al lang gedateerd. Toepassingen en industriële belangen kwamen op de eerste plaats. In de aanvragen voor de kruisantenne waren de beloftes op technologische spin-offs veel te vaag. Dit is ook de reden waarom de Belgen bijvoorbeeld wel gretig meededen met het ruimteonderzoek. Dit leverde hun industrie namelijk heel wat gunstige contracten op. Bovendien was (aardse) astronomie in het algemeen in België geen prioriteit meer van de overheid. Dit kan deels verklaard worden door de afwezigheid van technologische opportuniteiten, maar er was meer. Rond 1960 was het Belgische wetenschapsbeleid hervormd en men wilde vanaf dan veel meer aandacht voor vakgebieden als moleculaire biologie, ruimteonderzoek en menselijke genetica. De Nationale Raad voor Wetenschapsbeleid vond dit uiterst belangrijke sectoren die nog onderontwikkeld waren in België. De sector die echter het meeste geld opslorpte, was – net als in Nederland – kernonderzoek. In 1962, bijvoorbeeld, ging hier 826 miljoen Belgische frank naartoe van het totale jaarlijkse overheidsbudget voor wetenschap van 4080 miljoen Belgische frank.

Het feit dat astronomie niet langer een prioriteit was voor de Belgische overheid, maakte ook dat de behandeling van het project soms traag en nalatig was, tot grote ergernis van de Nederlanders. Tot slot was het Belgische wetenschapsbeleid – in tegenstelling tot dat in Nederland - rond 1960 al sterk gebureaucratiseerd, wat een snelle behandeling van het project sowieso onmogelijk maakte.

In 1965 leek er een doorbraak te zijn bereikt, nadat de Belgische overheid officieel beslist had deel te nemen. Toch trok België zich het volgende jaar plots terug door de ontwikkelingen in een totaal ander project dat toen liep: de Antarctische expedities. Van 1963 tot 1967 waren er drie Belgisch-Nederlandse Antarctische expedities geweest. Op het einde van juni 1966 kondigede een Nederlandse delegatie in Brussel aan dat de Nederlandse regering beslist had geen financiering te geven voor een volgende Antarctische expeditie. In de ogen van de Belgen waren deze projecten onlosmakelijk met elkaar verbonden, hoewel ze in realiteit niets met elkaar te maken hadden. Een maand later kondigden ze dus hun terugtrekking uit het radiotelescoopproject aan.

De terugtrekking van de Belgen dwong de Nederlanders het ontwerp van de radiotelescoop te vereenvoudigen. Dit was echter al de vierde verandering op rij. Heel vaak was de beslissing om het ontwerp te veranderen niet ingegeven door wetenschappelijke overwegingen.

Het eerste ontwerp werd in 1961 gemaakt door de Australiër Christiansen en de Zweed Högbom. De kruisantenne zou bestaan uit cilindrische parabolische reflectors van elk ongeveer 30 meter groot. De armen van het kruis zouden elk 5 km lang en 60 m breed zijn. Deze telescoop zou vooral dienen om observaties te doen op 75 cm.

Al in hetzelfde jaar ontstonden echter plannen om het ontwerp te veranderen. Een van de belangrijkste redenen was dat het al snel duidelijk werd dat de telescoop veel meer zou gaan kosten dan aanvankelijk geschat. En er waren nog twee andere redenen: er waren geen garanties dat een kanaal naast 75 cm zou gereserveerd worden voor radioastronomie en het ontwerp had weinig flexibiliteit had om over te schakelen naar andere golflengtes. De belangrijke 21cm-waterstofllijn zou er bijvoorbeeld niet mee geobserveerd kunnen worden.

In 1962 presenteerden Högbom en Erickson daarom een tweede ontwerp. Deze telescoop zou goedkoper zijn, zou opereren op een golflengte van 21 cm en zou een resolutie bieden van één boogminuut. De keuze voor deze golflengte had bovendien tot gevolg dat de telescoop veel kleiner kon zijn: 1,5 km in plaats van 5 km.

Hoewel een resolutie van 1 boogminuut in 1958 erg goed was, was dat al niet meer het geval in het begin van 1963. Daarom werd opnieuw een volledig nieuw ontwerp voorgesteld door Högbom. Het radicaal nieuwe aspect in dit ontwerp was dat de kruisvorm werd opgegeven: de telescoop zou uit een rij van van oost naar west opgestelde antennes bestaan en zou gebruik maken van apertuursynthese gebaseerd op de draaiing van de aarde. Hij zou een resolutie bieden tussen de tien en twintig boogseconden.

Er ontstonden echter al snel nieuwe complicaties: door de verslechterde relaties met de Belgen begonnen de Nederlanders erover na te denken alleen verder te gaan. Dit betekende natuurlijk dat het project veel goedkoper zou moeten zijn. In januari 1964 stelde ingenieur Muller daarom een vierde ontwerp voor, een vereenvoudigde versie van het vorige.

Als locatie voor de telescoop viel de keuze uiteindelijk op de 'Boswachterij Hooghalen' in Drenthe. Daar waren nog overblijfselen van het kamp 'Schattenberg' en er woonden nog enkele Ambonese families. Het gemak waarmee deze locatie verkregen werd, maakt het verschil met de Dwingeloo-periode meteen duidelijk. Toen kregen de astronomen nog heel wat tegenkanting. Nu was dat heel anders. Op de plaats waar de 'Westerbork Synthese Radio Telescoop' (dit werd de uiteindelijke naam) kwam, moesten eerst wat serieuze obstakels uit de weg geruimd worden: een weg moest gesloten worden, een boerderij en een militaire schietbaan moesten uit de weg geruimd worden en de resterende Ambonese families moesten elders ondergebracht worden. Oort kreeg dit allemaal zonder moeite gedaan, wat veel zegt over het aanzien dat hij genoot en de invloed die hij had op de besluitvorming van de Nederlandse overheid. Ook maakt het duidelijk dat radioastronomie als vakgebied een enorm prestige genoot rond het midden van de jaren zestig.

Toch ging niet alles even eenvoudig. Hoewel het uiteindelijke ontwerp een sterk vereenvoudigde versie was van wat aanvankelijk beoogd werd, bleef het een van de duurste Nederlandse wetenschappelijke projecten. Helaas voor de astronomen begonnen de overheidsbudgetten sinds het midden van de jaren zestig in te krimpen. Die bezuinigingen werden ook sterk gevoeld door ZWO, waardoor de aanvraagprocedures veel strikter werden. De eerder dominante Oort kon hier slecht mee omgaan. Als kind van de naoorlogse tijd waarin geld voor wetenschap overvloedig vloeide en de dingen snel geregeld konden worden door een praatje met de juiste persoon, was hij gewend altijd zijn zin te krijgen. Maar deze tijd was voorgoed voorbij.

De radiotelescoop in Westerbork werd gebouwd in een tijd waarin kosmologie en brontellingen belangrijke onderzoeksdomeinen waren in de radioastronomie. Uiteindelijk zou de telescoop echter voornamelijk voor heel ander onderzoek gebruikt worden. Dat is ook niet echt verbazend. Het hele proces van plannen, ontwerpen en bouwen tot de inhuldiging in juni 1970 nam bijna twaalf jaar in beslag. Het wetenschappelijke onderzoek ging vooruit in die periode. Toch was het onderzoeksprogramma enorm divers: reuzenradiomelkwegstelsels werden in kaart gebracht, onderzoek werd gedaan naar neutronensterren, clusters van melkwegstelsels, continuümstraling van spiraalvormige sterrenstelsels etc.

CURRICULUM VITAE

Astrid was born in Deurne, a district of Antwerp (Belgium) on 28 July 1979. She attended the Sint-Ludgardisschool in the centre of Antwerp.

After having completed secondary school, she started studying history at the University of Antwerp where she obtained her bachelor's degree. She continued her studies at the Free University of Brussels where she obtained her master's degree (magna cum laude). As she developed a strong interest in history and philosophy of science, she also completed the postgraduate studies in logic, history and philosophy of science (magna cum laude) at Ghent University. Her thesis was on experiments in Descartes' *Les Météores*.

Having completed her studies, Astrid was offered a job as a researcher at Leiden University and started work on her PhD on the history of Dutch radio astronomy. She presented the findings of her PhD-research at several conferences in the Netherlands as well as abroad, in Phoenix, San Diego, Indiana, Aberdeen, Exeter, Brussels and Aarhus. She was a member of the Huizinga Institute, the national Dutch research network for cultural history, and devised and taught a seminar *Science and the Public* for graduate students together with some colleagues. Her work resulted in two scholarly articles as well as several contributions in conference proceedings and popular scientific magazines, book reviews and journalistic articles.

In addition to her research in Leiden she worked as a volunteer researcher at the Museum for the History of Science of Ghent University and became the author of two publications accompanying the exhibitions.

Astrid obtained an additional degree in applied linguistics (journalism) from the Erasmus University College Brussels. She is currently working in this field. She teaches Dutch as a second language at the Institute for Language and Communication (Linguapolis) of the University of Antwerp and at a centre for adult education (Encora).

In her spare time, Astrid is a dedicated ballet dancer and a pianist.