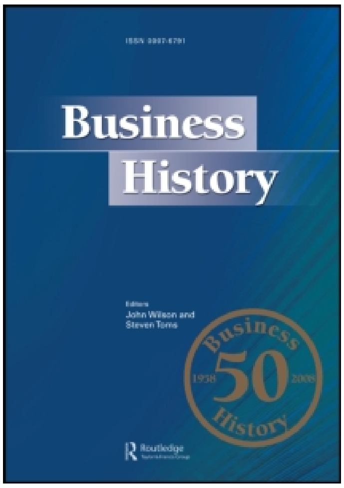

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Transitions in industrial research: the case of the Philips Natuurkundig Laboratorium (1914-1994)

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Transitions in industrial research: the case of the Philips *Natuurkundig Laboratorium* (1914–1994)

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In this article we describe the history of the Philips *Natuurkundig Laboratorium* (Nat.Lab.) in the Netherlands in the period 1914–1994. The article aims at considering three main research problems. Firstly, we pay attention to the process of institutionalisation of industrial research and development (R&D) in the twentieth century. Secondly, we place the history of the Nat.Lab. in the context of innovation in the Netherlands. Finally, we investigate the role of this industrial laboratory in its company, Philips Electronics. The historical account shows that the Nat.Lab.'s mission changed over time in accordance with the changes in its context and adapted its structure, culture and external contacts according to the needs of each new mission. Throughout time it remained a unique place for multidisciplinary research for the company.

Keywords: industrial research; Philips; research management

Introduction[1]

> Fundamental research and applied research are not in contrast to each other. I am against the idea of isolating the fundamental research part of the laboratory from the rest of the laboratory. I do not believe in an 'advanced research lab' in the corner of the organization. Many companies think about selecting and isolating a small group of researchers and make them work in a separate laboratory to think about wonderful new thinks. I do not want to say that this will never lead to anything, but I do not believe this is a good idea for Philips as a company. I believe that you have to lead the 'fundamental' research, let's say the 'basic' research, into the more applied part of the research activities. (Meijer, 1989, p. 318; translation by the authors)

The above opinion about the function of fundamental research for an industrial company was expressed by Dr. Feye Meijer, former CEO of the Philips corporate laboratory. This department was called the 'Natuurkundig Laboratorium' – the literal translation of which is Physics Laboratory, and it will be abbreviated in this article as the Nat.Lab. On 2 January 1914 a young physicist, Gilles Holst, started his work at Philips and his arrival was the formal beginning of the Nat.Lab. The Philips company had been established in the Netherlands in 1891 by Gerard Philips as a light bulb producing company (Blanken, 1999;

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Heerding, 1998). Philips' production of the incandescent lamps increased constantly – 75,000 lamps were manufactured in 1894 and 200,000 lamps in the following year. In 1895 Gerard's brother Anton, a salesman, entered the company and five years later Philips produced about 3 million lamps annually, which indicates that it had realised mass-production – Philips' growth and its development towards being a multinational company was unique in the Netherlands (Sluyterman, 2003). Its laboratory was an important part of the Philips strategy because it contributed to its innovative capacity.

Nowadays, the Nat.Lab. is called the High Tech Campus and known as one of the largest industrial research departments in the world. Philips has laboratories in five different countries (the Netherlands, England, Germany, China and the United States) staffed with around 2500 people. The Nat.Lab./High Tech Campus is situated in Eindhoven, in the southern part of the Netherlands, with a total staff of about 1500. Meijers' opinion, quoted above, represents only one of the many ideas about the role of research for an industrial company. It describes, however, one of the most important questions regarding industrial research: to find a balance between long-term investigations and business-oriented research. Thus far, mostly the histories of the American laboratories have been studied.[2] In this paper it is a European case, the 'Philips Nat.Lab.' that will be central.[3]

To establish and maintain a research and development (R&D) department in an industrial environment is not as obvious as it seems. In (economic) literature, the entrepreneurial choice to establish a research laboratory within the industrial corporation is questioned: should a big industrial company like General Electric (GE), DuPont or Philips carry out research activities *with its own money* (Rosenberg, 1990)? The dilemma is obvious: even if a company could enter the market with new products (the 'first-mover advantage'), management knows that the spillovers to other firms would enable late movers to gain the same level of knowledge and competence and thus save costly research. Paradoxically, companies spend large sums of money on research with too uncertain outcomes in order *to control* the market. Large companies like Philips, Siemens, GE and DuPont decided to start with in-house research activities at the beginning of the twentieth century by establishing a research department. In economic literature this entrepreneurial act, in Schumpeterian terms, is seen as an effort to disturb the economic equilibrium. It implies that the entrepreneur is the first cause of economic development – in his later work, Schumpeter argued that the innovative entrepreneur of the twentieth century was supported by companies and economic institutions that have the recourses and capital to realise his or her vision (Schumpeter, 1943).

If we take a historical perspective, we see that this Schumpeterian act cannot be taken for granted. At the beginning of the twentieth century, the companies' leaders and executives needed to invent how to manage the workforce of in-house research activities.[4] Rather than establishing a department with a given and well-known structural format, it was the organisation of the research department itself that was the subject for investigation and discussion. The historical studies illustrate how, in the twentieth century, the function of 'the' industrial research laboratory became institutionalised (Mowery & Rosenberg, 1998, especially Chapter 2 'The Institutionalisation of Innovation, 1900–90').

In this article the Philips R&D department is central. We will present the Philips case chronologically and contextually, which means that we place the events at the Nat.Lab. in their unique historical and dynamic setting (Pettigrew, 1985). Three research problems are central in this article, and the emphasis will be on the third question:

(1) How can we understand the institutionalisation process of industrial R&D?
(2) How can we understand the Nat.Lab. in the context of the Dutch history of industrial innovation and the Philips corporate innovative strategy?
(3) What was the 'driving force' behind the Nat.Lab.'s process of change during the twentieth century and (how) do these 'driving forces' differ from those of the American corporate laboratories?

Institutionalisation processes of industrial R&D

Historians of science and technology agree with the idea that the birth of the 'science-based' industry is a major factor in the rise of the knowledge intensive society (Schot, Lintsen, Rip, & De la Bruheze, 2003).[5] The industrial laboratory has led to the institutionalisation of knowledge creation within industrial sectors that had been based on more traditional knowledge. It is true that traditional knowledge remained important, but the introduction of scientific activities in industrial sectors transformed the dye industry, the electrotechnical and chemical industry into knowledge-intensive innovative places. The analysis of industrial research as an entrepreneurial activity is important to understand the dynamics of knowledge intensive innovation.

The histories of industrial laboratories – R&D departments – indicate that most of the research activities fit well with Alfred Chandler's model of an integrated company with centralised management and a diversification policy (Chandler, 1977).[6] Although his focus was first of all on the managerial hierarchies that developed in the United States, but the decision of European companies, like Siemens and Philips, to establish a research laboratory embedded in the company's structure are also in line with the historical features of the large enterprises that Chandler described. In line with this, Lou Galambos showed that most in-house R&D departments were established in precisely those firms that had worked primarily to stabilise their internal organisation structures, which were characterised by managerial hierarchy co-ordinating a variety of operational units.

In this article we will compare Philips' research with the distinctive features of modern organisations of science and technology, and position it in an institutional, long-term perspective. Such an approach, we suggest, describes the industrial research laboratory as an ideal type in the Weberian sense, since it singles out some major stages of historical developments that have taken place in industry since 1900 (Schroeder & Swedberg, 2002). Two dimensions of this process of institutionalisation are important.

In the first place, the institutionalisation process of industrial research involved an intentional structuring of the research organisation in the company, in which various persons worked together in a business context. They invented, so to speak, the research function, which enabled endogenous *human capital* accumulation. It was a process in which durable patterns of social behaviour emerged. To be more precise: in the process of institutionalisation of the industrial R&D organisations relatively stable social expectation patterns emerged in which individual and collective action was possible. After building a stable internal structure, the researchers working within these R&D settings were eager to keep in touch with the scientific community outside the companies' walls (Galambos, 1979).[7] The latter is important, since innovative practices in a company such as Philips never took place in isolation.

In a recent article on solid-state technology and innovation at Philips, Davids and Verbong (2007) argue that the absorptive capacity of the firm enabled Philips to recognise and value the new, external innovative developments.[8] Furthermore, the absorptive capacity theory suggests that the competences in production, manufacturing, sales and marketing all contribute to the ability of the company to innovate. In this article, we focus on the internal organisational development of the Philips Nat.Lab. Therefore we will not pay much attention to the absorptive capacity of the Philips company per se. Instead, in reconstructing the history of the Nat.Lab. we will pay attention to the question how the research department enabled Philips to incorporate and combine specific scientific and technical (re)sources.

In the second place, if we want to understand the process of institutionalisation of industrial research, it is important to understand that the industrial laboratory was a *workplace*. Scientists, technicians, assistants and administrators worked together in a developing organisational setting in the first half of the twentieth century and in a rather well-developed organisational format (roughly speaking) after the World War II. In agreement with Knorr Cetina (2003, p. 8), we see the cultural dimension of laboratories (i.e. the research departments of multinationals) as 'the aggregate patterns and dynamics that are on display in expert practice and that vary in different settings of expertise'. We would like to add, furthermore, that the cultural dimension of the organisation is not to be seen as a static phenomenon. The organisational cultures of industrial laboratories have been subject to change during the twentieth century.

Based upon empirical research into industrial R&D departments in the electronics industry, Varma distinguished two periods in the research culture of US industry. In the first period the mission of research in industry was twofold: 1) to employ science and technology to improve existing products and manufacturing processes, 2) to discover scientific principles and properties of the natural world that could generate new commercial products' (Varma, 2000, p. 397). This strategy changed in the late 1970s and in the 1980s, in which years the research of high-technology industries became more product-driven. From the USA and European perspectives, the firms faced increased competition from Japan. In the multinational companies, questions were raised about the necessity of their in-house laboratories. After all, the investment that kept a research department in operation was – and still is – relatively high. Moreover, the absorptive capacity theory suggests that the research department was not the only vehicle for the company to stay innovative (for a theoretical discussion see Davids & Verbong, 2007). An outcome of this discussion was that many multinational corporations were (financially) restructured in the 1980s. The internal and external pressures ('driving forces') affected the corporate laboratories dramatically: the patterns of work within the research laboratories became more and more oriented towards business-driven activities. The R&D organisations were then managed against the – short term – business goals.

For a proper analysis of Philips in the perspective of both the structural and cultural dimensions of the process of institutionalisation as sketched above, it is important to place the history of this department into the broader (Dutch) context of innovation.

Philips Nat.Lab. in the context of the history of innovation

Knowledge creation within an industrial context is not a twentieth century phenomenon per se. In the nineteenth century the Dutch individual craftsman and inventors broadened their horizons by visiting companies abroad, by importing equipment, machinery and other devices and by attending international conferences (Visser & Hakfoort, 1987). It is only in the twentieth century that research in industry acquired a more structural character. Whereas in the nineteenth century the Dutch industry imported technological knowledge from abroad, the landscape of innovation and knowledge creation changed in the first half of the twentieth century (Schot et al., 2003). The new patent law in the Netherlands in 1912 was an important incentive for companies to start with in-house research and development (Schiff, 1971). For Philips it meant that it developed not only a tradition of innovation. The company also needed to create a stable company structure that enabled co-ordination between people and resources, necessary for developing innovations. It is obvious nowadays that the quality of the absorptive capacity of the high-tech industry in the twentieth century has benefited from research departments, whose employees were not only able to generate patents but also to interpret the knowledge of other companies and/or universities.

Besides the 'Schumpeterian' entrepreneurial behaviour of the Philips family (Schumpeter, 1943), there were more structural reasons for considering the start – and later the continuation – of an R&D department. The composition of the international high-technology market challenged Philips constantly to (re)consider its knowledge capacity. An example in the first decade of the twentieth century illustrates how important it was for Philips to stay alert in this respect. In the USA, GE dominated the light bulb market. This company had set up a laboratory in 1900. In this laboratory, in 1910, researcher W. Coolidge developed a method for drawing thin wires for tungsten wire lamp filaments. This leading role in the lamp industry enabled GE to influence the European market. Companies that acquired a GE licence seriously threatened those European companies that did not have such a licence. Thus, the German market became problematic for Philips when GE agreed a contract with German companies such as Siemens and Halske to form the so-called Patentgemeinschaft (the European Patent organisation). The Patentgemeinschaft was in the position to limit the number of light bulbs Philips could sell. Philips decided to search for sales opportunities in the USA. In order to avoid possibly dangerous competition in the US market, General Electric was prepared to offer a licence contract to Philips. In 1919 the contract was agreed and this was the start of a longstanding relationship between the two companies. The Philips Nat.Lab. was indispensable for Philips to interpret the relative value of the patent portfolio that was part of the licence contract. This is one example of the international context in which Philips and its research department operated. Philips needed to establish and maintain long-term solutions to keep up with the technological and market race, one of which was its research department.

The research departments of Philips and other companies in the Netherlands were not only important instruments at the international market. In the course of the twentieth century these institutes also proved able to build bridges between the industry and the academia, not least because it hired university professors.

The Philips Nat.Lab. before World War II

When Gilles Holst learnt that he had been appointed by Philips to become the first director of the Nat.Lab. he perceived his primary tasks to be the following: 'I am to be given a whole laboratory to equip, and I shall carry out all manner of investigations that will teach us the formula of the incandescent lamp.' This task was directly related to the aim of safeguarding the company's patent position in lamps as the main motive for starting the laboratory (Boersma, 2002, p. 32). From Holst's words it can be deduced that quality control was not to be the laboratory's primary concern. In fact, a test department to fulfil that task already existed. For solving practical production problems there was a chemical laboratory, located one floor above the room where Holst was to set up the physics laboratory. In these early years the scope remained limited to light bulbs and tubes.

In the 1920s the Philips company grew dramatically. In 1922, Philips had about 5000 employees and in 1928 this number had increased to more than 20,000 employees. In the early 1930s the country was dragged into the worldwide economic crisis that had started in 1929. Compared to other European countries, its effect on the Netherlands was modest in the first year of that crisis. At Philips, drastic reorganisations were carried through, whereby about 10,000 employees were dismissed. At the same time the company was able to profit from the opportunities in the new radio market and this softened the impact of the economic crisis in its early years. In later years it became evident that further diversification was a suitable strategy for counterbalancing the continued economic problems and in 1937 the company again decided to extend its product range (Blanken, 1997).[9]

The first step in diversification was to move from light bulbs to a variety of tubes. From a physics point of view that is not a big step. In all of these tubes, glass, vacuum and gas discharges play an important role (Boersma, 2003). However, the Philips directorate's decision, made in the 1920s, to make complete radio sets, as well as transmitter tubes, for the Nat.Lab. meant a substantial extension of the research programme. In 1922, the laboratory staff had 12 scientific graduates and in total 33 people worked there (Heerding, 1998). A drawing of the extensions in 1926 shows that at that time there were laboratory sections for X-ray, acoustics, materials testing, radio and a chemical department.

The increase of personnel was interrupted by the economic crisis at the beginning of the 1930s. The number of scientists, technicians and assistants dropped from about 210 in 1930 to about 170 in 1933. In fact, this was a quite modest reduction compared to reductions in the rest of the company, in which the total staff was reduced from 22,672 employees in November 1929 to 9534 employees in May 1932. In a memorandum 'Division work discussion groups for the year 1932', nine laboratory groups were defined, with a list of scientists for each group arranged in alphabetical order, except for the first name, which seemed to refer to a sort of leader.[10]

In the 1930s Nat.Lab. researchers were very active in materials research, including semiconductor materials, which had become important shortly after World War II, and magnetic materials. Holst's strategy was to stimulate a constant awareness of the need for contributing to the industrial position of the company. He was keen to stimulate the scientists to orient themselves towards the latest developments in science, to contribute to science by publishing and, maybe most important, to gain patents (Boersma, 2004). The Patent Department had been initiated officially in 1921 (Heerding, 1998). In 1922, it had a staff of seven people (Heerding, 1998).

From 1928 on, the Philips directorate held meetings to discuss the company's policy (Blanken, 1992). Originally only the brothers Anton and Gerard Philips were in charge of the company. When Gerard retired in 1922, Anton was the only formal leader. Although he often delegated substantial responsibilities to his employees, he kept the greatest influence on the company's policy. This situation remained even when the company grew to 46 factories and 69 sales departments in 1935 (Blanken, 1997). To co-ordinate all activities staff departments were set up: a Commercial Department, a Financial Department, a Patent Department and the Secretariat, that served as the company's chancellery. Their influence increased as the size of the company increased. Gradually also the Philips factories started to set up their own laboratories. The need to co-ordinate the activities in the various labs is understandable given the 32 small laboratories that existed in 1936.[11] The laboratories spent almost 4% of the company's turnover in that year. The Nat.Lab. was the largest on the list, and spent about 1% of the total turnover.

A research organisation among autonomous product divisions (1946–1972)

During World War II, the Netherlands was occupied by the German enemy. Because the company's directorate considered the Nat.Lab. to be an important department, its budget was not reduced in 1940/41.[12] Holst's researchers wrote special reports on ongoing research activities for the German Verwalter, and the Nat.Lab. researchers were still able to publish their results in internal and external media. A survey of publications and reports in the autumn of 1947 shows, however, that during the last two years of the war only 12 publications appeared in scientific journals (which had to be published in German). The total number of publications between 1940 and 1947 was 151 and the total number of reports in the same years was 339. Drijver, the Nat.Lab.'s reports administrator, evaluated the total output of 490 issues during the war as quite low.[13]

By around 1950 the damage caused by World War II had to a large extent been repaired. Then a period of economic growth in the Netherlands started that lasted from 1951 to 1973 (Van Zanden & Griffiths, 1989). Philips resumed its process of growth that had been temporarily hampered by the war. In the 1950s the number of employees doubled to approximately 211,000 people, 75,000 of whom worked in the Netherlands. In the next ten years this number further increased to 359,000 people by 1970. The company's turnover grew 30% in 1948. This growth decreased to about 12–15% per year in the 1960s. The contribution of television to the company's turnover increased from 6% in 1950 to about 30% in 1960. The profit in 1947 was 4.2% of the turnover. In the 1950s this was about 6% and in the mid-1960s it started to decline again (in 1970 it was only 3%). This heralded the coming of a new, more difficult, period.

In 1946 it was decided to set up a Board of Management for the company. Until then the principle of only one person being the leader had been maintained (for many years Anton Philips had been that person). The first Board consisted of a presidium of four people and five other members (Blanken, 1997). A further formalisation of the company's structure was the definition of eight Product Divisions (PDs).[14] All factories were subsumed under the new PDs of Lighting, Electron Tubes, Apparatuses, Telecommunication, X-ray and Medical Equipment, Electro-acoustics, Products for Industrial Applications, Glass and Ceramic Products, and Related Businesses (Blanken, 1997). In 1948, another Product Division was initiated, namely for Pharmaceutical and Chemical Products ('Duphar') and in 1952 the Product Division of Industrial Components and Materials started. This Division took over the ceramics activities of the Glass and Ceramic Products Division.[15]

This formalisation of the company structure, and the fact that it was no longer the only place where research was done, created an identity problem for the Nat.Lab. What could justify the continuation of its position in the company? In the struggle to find an answer to that question, the laboratory management was faced with a most welcome development in the USA. The report *Science: the Endless Frontier* by Vannevar Bush in that country was based on the expectation that basic research would almost 'automatically' lead to important technological progressions (Bush, 1945). This expectation was motivated by pointing to the progress that was made in the war against diseases. The progress was said to be based on new scientific knowledge. The term 'basic' research was characterised as 'being performed without thought of practical ends, resulting in general knowledge and in understanding of nature and its laws' (Bush, 1945, p. 18). Although the actual influence of this report is much discussed nowadays, it seems that for the Bell company it was a reason to enhance the role of research into solid state physics, which decision certainly was a factor in the invention of the transistor in the Bell Labs (Hoddeson & Riordan, 1997). The total amount of money spent on basic research in the USA more than tripled in the period 1955–1966. The total amount of R&D expenditure nearly doubled. In 1966 the growth stopped for about a decade and the belief in 'basic' science waned. It is questionable whether Bush's concrete recommendations were realised,[16] but the rhetoric of the report certainly had an impact both on politicians' and industrialists' (including Holst's) expectations of basic science. In his last speech as a director of the laboratory, Holst referred to Bush's report. This rhetoric was exactly what the Nat.Lab. needed to justify the claim that in the new company structure they could be the unique place in the company where this important thing called 'fundamental' or 'basic' research was done.

Maybe the most important change, however, for the actual content of the lab's research programme was an invention, or rather a series of inventions made elsewhere. Shortly after World War II, in 1948, the point-contact transistor was invented by Shockley, Bardeen and Brattain and this changed the electro-technical industry dramatically. Whereas Philips and its competitors had invested in electron tubes and research into (solid-state) materials before World War II, after the war the semiconductor became the most important technology. During this period of change, Philips could profit from its researchers directly (they had the knowledge to understand the developments) and indirectly (they were the human capital that had increased the company's absorptive capacity). The research and development work on magnetic materials had resulted in a strong patent position for Philips (Hutter, 1988). The patent portfolio in the field was so strong, that Bell Laboratories offered Philips a cross-licence in the field of electrical devices. This cross-licence enabled Philips to 'survive' the transformation from tubes to conductors in a period where many former producers of light bulbs and tubes failed to make the transformation.

A new task profile for the Nat.Lab.

We saw that the Vannevar Bush report offered the Nat.Lab. a welcome opportunity to claim a role for itself in the new company structure. This new role, being the only laboratory in the company for fundamental or basic research, also offered the Nat.Lab. a welcome excuse to 'protect' itself against interference of the PDs in its research programme. It could refer to the PDs' own development laboratories for research work that was directly relevant for the PDs. As we will see, this was not always appreciated by the PDs, but also from their side a lack of commitment grew. In the formalisation of the Philips company's structure, they had been awarded a autonomy with respect to the decisions about which new products were to be developed. Their development laboratories worked according to the PDs' own ideas, because these labs were controlled by the PDs themselves. The Nat.Lab.'s budget was allocated directly by the company's Board of Management and the PDs had no formal say in the Nat.Lab.'s research programme. The result of this was that the PDs started to behave rather selectively with respect to the product ideas that the Nat.Lab. offered to them for their product portfolio. They did not see it as a loss of their own resources when they refused to transfer certain research outputs. This mutual lack of commitment between the Nat.Lab. and the PDs created a very delicate situation.

In 1947, a series of meetings of the company's Board of Management representatives and research representatives was held. The title of these meetings was: 'Onze laboratoriumplannen' ('Our laboratory plans'). At the first of these meetings a report by Casimir, Rinia and Verwey, the three new directors who had succeeded Holst, was discussed. In this report the authors defended an independent position of research to enable 'fundamental' research to be done. 'Fundamental research' in the document was defined as 'aimed at understanding nature'. It was opposed to 'industrial research', which 'in the end aims at making better and new products'. According to the report, a centralised laboratory would yield an opportunity for a broad-based and multi-disciplinary resource of expertise for the whole company. In the Holst period, all research in the Nat.Lab. was somehow related to concrete products, and there was no research entirely without envisioned concrete products. But in the new era the Nat.Lab. would also serve as a think-tank for the PDs' long-term product policy by doing research for which no concrete products were envisioned yet (although in the end, of course, new products would emerge from it). According to the meeting, the organisation of the laboratory should be disciplinary, because a division of research according to the PDs was expected to be 'fatal' to its proper functioning.[17] Here we can see the rhetorical value of the Vannevar Bush doctrine in full action.

In the period 1946–1972 the debate on the proper role of the Nat.Lab. in relationship to the PD development labs, was continued. This debate took place mostly in the Corporate[18] Research Conferences (CRCs), a series of meetings of research directors that were held every other year.[19] Holst chaired the first of these meetings in 1948 and was still present at the 1952 CRC.[20] From 1965 onward, a more frequent series of directors' meetings, the so-called Research Directors Conferences[21] (RDCs), was introduced. The CRC and RDC debates show how the ideas about the three types of research tasks for the Nat.Lab. at the level of the lab management changed due to the fact that there were new PDs, each with their own development labs and their own commercial and technical directors that could decide on what products would and what products would not be taken into production.

As a result, the Nat.Lab. researchers initiated new areas of scientific research that were not directly related to product diversifications for which the company had decided, and for which no PD had expressed any need. By doing the sort of research that had been promoted in Vannevar Bush's report, for which the Nat.Lab. directorate often used the term 'fundamental', rather than 'basic',[22] the Nat.Lab. would be unique in providing entirely new options for product diversification or product improvement to the company.[23] It was in this period that Hendrik Casimir, an internationally well-known and respected scientist who worked with physicists such as Bohr and Pauli, became the major leader of the Nat.Lab.

Culture and structure for a 'fundamental' research lab

With respect to the division of the development work between the Nat.Lab. and the PDs, the Nat.Lab. directorate displayed a changing attitude compared to the Holst period. The Nat.Lab. directorate to some extent still saw development-oriented research as a task for the Nat.Lab. as long as the Nat.Lab. itself could decide about this part of the work, too. Also the company's Board of Management expected the Nat.Lab. to do that sort of work.[24] The Nat.Lab. argued that the PD laboratories had to take over the development of new products at an early stage.[25] When the basic design problems had been solved by gaining a better understanding of the underlying phenomena, the Nat.Lab. would transfer the research output to the PD and the PD laboratory should be able to transform the prototype into a manufacturable product. Doing development work in co-operation with a PD was once rejected by Casimir with the argument that 'that only gives trouble'.[26] However, in practice the transfer of research output appeared to be difficult. Often the Nat.Lab. management was not confident in the PD lab's ability to fulfil that task. It can be questioned if that was really the problem. A more probable cause for the problematic transfer of research output was the doubt of the PD about the commercial feasibility of the Nat.Lab.'s product ideas. The Nat.Lab. sometimes interpreted this as stubborn unwillingness.[27]

Casimir, like Holst, displayed an interest in the latest developments in the natural sciences, but not just for the sake of their academic status. In his time the fame of the Nat.Lab. had been already established. In the CRCs Casimir always asked the question if the new theory or field could be absorbed into the Nat.Lab.'s research programme. Thus, a careful scanning of the latest scientific developments under his leadership became a continuous (first) issue on the CRC agendas. Because of this orientation towards scientific developments some new disciplines entered the research programme.

With respect to the academic orientation, contacts with universities about the content of the scientific work were hardly ever mentioned in the management (CRC and RDC) debates. The main role of the universities at that time was the education of new scientists. The importance of 'fundamental research' as a particular Nat.Lab. activity influenced the Nat.Lab. culture (at the level of the scientists). Not only the management, but also the scientists themselves had a concern for the position of that type of research. This concern was expressed by them at the so-called Directors-CoCo (Contact Committee) meetings. These meetings had been initiated by Holst in 1945 to establish contacts between the laboratory management and the workers.[28] In the Directors-CoCo meetings several times the issue of 'fundamental' research was raised by the CoCo members. The researchers expressed a concern that the laboratory management sometimes seemed to have more appreciation for 'applied' research than for 'fundamental' research.[29] This for Casimir was a reason to give special attention to the issue in his presentation at the Directors-CoCo meeting on 14 June 1962. The scientists already were eager to defend 'fundamental' research against what they perceived as threats of increasing applied research efforts.

Tensions in the relationships with Product Divisions

The relationship between the Nat.Lab. and the PDs in this period were problematic. It has already been stated above that a lack of mutual commitment was the cause of this problem. There were regular contacts between the Nat.Lab. and the PDs, but these mainly served an informative role. The Nat.Lab. told the PDs what it was doing and vice versa, but no clear commitments were made. There were different ways through which the Nat.Lab. tried to reach its goal of influencing the company's long-term product strategy and development. It was the director Casimir himself who became a discussion partner in the company's strategic debates at the highest level.

In the period 1957–1963 Casimir was both managing director of the Nat.Lab. and member of the Board of Management. In the 1950s and early 1960s, Casimir and PD representatives met in the so-called *Quo Vadis* (Latin for: 'Where do we go from here?') meetings. These were initiated by the Board of Management to serve as strategic discussions on new or developing product fields. At those meetings, the Nat.Lab. received ample opportunity to inform about ongoing research activities.[30] The focus of the discussions was always the desirable development of the PDs' activities. In some cases a PD explicitly uttered doubts about the long-term policy role that the Nat.Lab. claimed to have for the PDs. The minutes of these meetings leave us with mixed feelings. On the one hand the Nat.Lab. and the PDs were able to inform each other about their activities and the meetings show several examples of good communication and co-operation. On the other hand, both from the Nat.Lab. and the PD side we found problems. Former directors and co-directors that were involved in the directors contact meetings still today remember those many informal meetings where no real decisions for transfer were taken.[31]

In spite of the variety of ways that the Nat.Lab. had available to exert an influence on the PDs, the overall impression is that the increase of formal meetings certainly did not guarantee a better transfer. This impression is confirmed by the report of a special committee, called the Efficiency Contact Committee that in 1963 reported to the Board of Management about the contacts between the research labs and the PDs. The outcomes were not very positive: it was stated that in general a good transfer from research to the PDs was not guaranteed. The committee saw one of the reasons for this in the observation that there were no systematic, organised contacts between the research management and the PD managements.[32] The existing contacts were informal. In 1968 a report about the Nat.Lab.–PD interface was also critical about the exploitation of research. Two statements (underlined) open the report: 'we are strong in our research; we may have been offering too many uncorrelated results to our Product Divisions'. The cause of this was seen in interface problems (again underlined in the text). The report stated that the Nat.Lab.'s support to the PDs was more targeted towards the professional PDs than to the consumer PDs.

While the Nat.Lab. thus had a clear impact on the professional PDs, the consumer PDs brought out some important products that the Nat.Lab. had not been involved in. An example of this is the compact cassette. It was developed by the factory development laboratory only, without any Nat.Lab. involvement (Interview with L. Ottens, 5 March 1998). The stereo gramophone also was primarily the result of the development lab (Philips Annual report 1958). Likewise, the PD Light brought out several new types of lamps that the Nat.Lab. had not done any work for (Interview with P. Broerse, 10 March 1998).

Yet all these tensions cannot take away the fact that in the period 1946–1972 there were some substantial successes through which the Nat.Lab. made a very important contribution to the company. Apart from the two big successes of the Plumbicon (a television pickup tube) and LOCOS (a process for making Integrated Circuits (ICs) there were the many new insights that were gained in materials research, which had a more subtle (i.e. less easily traced) influence on the development of new products. It can be doubted if major successes as Plumbicon and LOCOS would ever have been reached without the great freedom of the researchers and the possibilities they had to make studies of the phenomena underlying the new products.

In that sense the Nat.Lab. approach in the period 1946–1972 must be judged against the circumstances of those years. There were many opportunities for launching new products on the market and the company could afford to have a laboratory with a great scientific freedom. This freedom may have caused a lot of personal frustrations in the contacts between the Nat.Lab. and the PDs, but it certainly resulted in a (limited) number of great successes.

Redirecting the research organisation for mutual commitment (1972–1994)

From 1973 on the growth of world trade decreased, which caused Dutch exports to decrease also, and inflation and interest rates to increase. The first years of economic decline affected the Netherlands less than other countries in Europe because consumption still increased. This was possible because in the 1970s the economic problems mainly impacted on government finances (raising of allowances and minimum wages). But the economic problems hit the Netherlands more from 1979, when this effect was no longer there. The development of the unemployment rate in the Netherlands also differed from other countries. An industrial overinvestment policy in the 1960s had led to a strong rise in salaries, which in the late 1960s started to cause financial problems for a number of industrial companies. Between 1969 and 1973 the number of unemployed people doubled. In the years 1980–1984 the unemployment rate increased even more than in other countries because of an increased supply of female labour.

These economic problems also had their impact on Philips. Van Zanden and Griffiths (1989, p. 271) wrote about the 'relative success' of the Philips company in dealing with the economic decline, but the first signals of financial problems became visible in Philips rather early.[33] The turnover kept growing rapidly until the mid-1970s, which illustrates the continuing consumption in the early 1970s in spite of the economic decline. The company's profits fluctuated. One of the most troublesome factors for the company in the early 1970s was the monetary instability and the relatively high rate of the Dutch guilder. Also in the 1970s the Netherlands became one of the most expensive countries in terms of labour costs. During the whole period 1972–1994 special measures had to be taken to increase the efficiency of the Philips company. The climax was no doubt the company-wide Centurion programme that CEO J. Timmer initiated in 1990. Some business activities were completely abandoned in order to get rid of unprofitable parts of the company. Also a customer-oriented product development was strongly stimulated. 'Customer days' were organised to raise an awareness among the employees of the need to focus on customer needs. The role of industrial design to improve the quality and appearance of a great variety of products was enhanced.

Towards a Product Division-oriented Nat.Lab. task profile

In 1972 Pannenborg, an engineer who had been educated at the Delft University of Technology, succeeded Casimir as the research representative on the company's Board of Management. In the same year he presented his view on the desirable developments of research within Philips for the Nat.Lab. management.[34] In this presentation Pannenborg sketched a number of differences between the period 1946–1972 and the coming years as he foresaw them. In the first place, his impression was that there was now, more than 'in the time of Langmuir and Coolidge', a lot of scientific knowledge outside industries that should be 'translated' by industrial research organisations for use within their companies. He was also of the opinion that the knowledge to be developed in these research organisations was of a less 'basic' character than before (he mentioned the development of the transistor as a contrast with the situation in 1972).

From 1972 on, Pannenborg chaired the Corporate Research Conferences, at which the research programme was discussed by the managing directors and directors of the Nat.Lab. and of the foreign sister laboratories. Strikingly, the scanning of the recent scientific and technological developments in the world, that always had a prominent place on the CRC agendas in Casimir's time, had disappeared from the agenda. That illustrates a change in priority in the debates. Instead of the scanning of scientific development at the beginning of the CRC, the participants were informed extensively about the company's state of affairs. This fitted well with the ideas that Pannenborg had expressed in the speech mentioned above: research should be oriented on making scientific developments of the past fruitful for the company, more than on starting research into new scientific fields.

The task profile changed from doing research of a 'fundamental' character towards making 'fundamental' knowledge fruitful to the PDs.

Ending projects had been something exceptional in the period 1946–1972. There were always opportunities for taking up new research topics that were interesting from a 'fundamental' point of view. But in the period 1972–1994 the PDs' needs became more important as a criterion for initiating or terminating research topics. Research lines were abandoned if no PD showed a serious interest in it. Diminishing attention to 'classical' physics was replaced by an increase of efforts to make quantum mechanics fruitful for the development of new products such as ICs. The laser also became very important for the research programme. As Pannenborg had stated in general terms in his 1972 speech for the laboratory management, the focus shifted from developing the fundamentals of quantum physics towards using the newly gained understanding of the behaviour of microscopic structures and particles for industrial goals.

The growing emphasis on research that was more useful for PDs in a certain way stirred up the debate on 'fundamental' versus 'applied' research again. Evidently there always remained some opportunity for 'fundamental' research into new phenomena for which no application was yet envisioned. In 1974 Polder (from a physics group) made a plea for keeping 'a healthy bit of physics' in the laboratory programme, even though no continuous stream of new applicable phenomena was to be expected.[35] Several other directors supported this plea for 'fundamental' research. But it was clear that the role of 'fundamental' research was no longer the same as it had been in the 1950s and 1960s. The need to work according to a 'Philips awareness' and not from a laboratory chauvinism or an ivory tower position was underlined. The following new areas for 'risky' research were identified: software and systems, new devices, human interfaces, and manufacturing concepts.

It was also stated – and here we see another important difference from the period 1946–1972 – that marketing should have a say in the selection of these 'risky' research areas. But in 1986 the Board of Management representatives Van der Klugt and Van Houten (Pannenborg's successor in the company's Board of Management) at a CRC meeting gave the first signals that the company would take further steps to force the Nat.Lab. to focus on the direct needs of the PDs. The amount of corporate-funded research (100% of the Nat.Lab.'s budget at that time) was announced to be reduced so that the percentage of short-term research for Product Divisions would grow. This soon became reality for the research organisation, because contract research was introduced only a few years later, in 1989. From then on, the research organisation had to acquire approximately two-thirds of its budget by submitting contract proposals to the PDs.[36]

The concern for the continuation of long-term research and maintaining the balance between materials, devices and systems research in the 1990s was phrased in new terms such as 'key technologies' and 'capability management'.[37] When F. Carrubba, who had come from Hewlett Packard to Philips in 1991 and had succeeded S. van Houten (Pannenborg's successor on the Board of Management) in 1992 as holder of the research portfolio on the Philips Board of Management, presented a survey of what had happened in the first years following the introduction of contract research, he spoke of realignment of the research portfolio in the direction of key technologies that should underpin the company's core competencies. The concepts of key technologies and capability management were an enhancement of the idea that the research organisation should remain the knowledge centre of the whole company. That meant that a number of key technologies and capabilities should be kept active even though there were no possibilities for contract research related to these.

Increase of communication with Product Divisions

In the same period, several efforts were made to put the new relationship between the Nat.Lab. and the PDs into practice. Pannenborg started to formalise the contacts between the Nat.Lab. and the PDs.[38] Until then those contacts had been of an ad-hoc character and they had not been very intensive at the directors' level. Others, in particular those who were in management positions in the PDs, said that they did not experience a clear transition from Casimir to Pannenborg. According to them, Pannenborg was just as keen to protect the research organisation's independence as Casimir had been.[39]

Yet it is a fact that Pannenborg started special committees in the 1970s to establish contacts with individual PDs at management level. They were called the 'R-PD management committees' (R-PD standing for Research-Product Divisions) and were seen as a clear signal of the need to grow towards mutual commitment. They were meant to reach agreement between Research and the Product Divisions in an early stage of innovations and to get more adequate market information for research. The approach to reach these goals would not be the same for all PDs because the need for pre-development differed between the PDs. In 1979, 34 R-PD management committees were established. There were different numbers of R-PD management committees for the different PDs.[40] The mutual feelings of a gap between research and development seemed too hard to be bridged and the R-PD management committees had not removed those feelings.

The bi-annual scheme for the R-PD meetings that was used for several PDs was not frequent enough in the eyes of the Philips Board of Management. In 1980, Pannenborg announced that the Board had asked for a more intense discussion of the research programme with the PDs.[41] Although it is difficult to draw firm conclusions from this, the number of negative remarks about the relationship with the PDs, noted in the CRC minutes in the 1980s, noticeably decreased. This may be a signal that gradually an understanding of the position of the PDs emerged in the research organisation.

Furthermore, a new type of research activity, the so-called Transfer Projects, was defined as a part of the Corporate Research Programme.[42] The definition of Transfer Projects was the following:

> Transfer Projects are sizeable research topics, of which technical feasibility has been proven, which are wanted by the Product Divisions and where the results of the work in the form of components devices, systems, tools or processes, justify and require a common approach to transfer knowledge, skills, hardware or software to the PD. A concise document is signed by both parties; this contains the agreed goal of the project and its key topics, specifications, the project leader, time schedules and milestones, resources (including the names of the people involved), initial marketing and business plans.[43]

These projects can be seen as the Nat.Lab.'s ultimate effort to keep away the introduction of contract research by showing their good will. But it did not succeed in that respect.

Organisational change in the company

The company-wide Centurion operation that started in 1990 was an important factor in the Nat.Lab.'s new task profile. In March 1991, in a second phase of this operation, a meeting was held with representatives from Research, together with representatives from two other parts of the company, chaired by Van Houten.[44] This Centurion II meeting ended up with a 'Declaration' in which the participants stated the following:

> We, the senior management of Corporate Research, CFT and CPT, hereby declare that to us a research success is a real success only if it is a business success. Specifically we commit to deliver projects, which will increase significantly the number of business successes and decrease the time to market of new products. Our aim is to become the world's leader based on these criteria. We have formulated ten actions that are instrumental to this goal. On the basis of these actions we will contribute significantly to (1) creating major new businesses for Philips, (2) moving existing businesses to the number one position in the world, (3) changing fundamentally the rules of the competition game to boost substantially the profitability of existing Philips business.[45]

This text illustrates the strong rhetoric that was used in the operation. For the Nat.Lab. it meant that the road towards becoming a PD-oriented corporate lab had reached a culmination. It was clear now that the Nat.Lab. had no alternative but doing research that was mostly commissioned by the PDs. New products would no longer be born in the Nat.Lab. The PDs had to developed the ideas for new products and the Nat.Lab. had to deliver specific knowledge that was needed to realise these new products. Our analysis shows that the transition towards this new role was not a matter of just a couple of years, but in fact characterised the whole 1972–1994 period in the laboratory's history.

Conclusion: the changing role of the Nat.Lab. for the Philips company

In a 2007 article on the rise and fall of corporate R&D, *The Economist* makes the observation that 'The traditional separation of research and development enshrined by Bush in 1945 is rapidly disappearing' and 'Even though big American firms still spend billions of dollars on R&D, none has any attention of filling the shoes left empty by Bell Labs or Xerox PARC. The research and development that Bush tore asunder are once again becoming entwined' ('Out of the dusty labs', 2007, p. 69). In fact, Varma (2000), to whom we referred in the introduction of this paper, came to a similar conclusion. Like Varma in her article, *The Economist* refers to the situation in the USA in which the mission and culture of corporate research changed from a scientific-investigation attitude to product-driven orientation.

In this article, we have shown that the Nat.Lab. at Philips underwent a similar pattern. At the same time, however, our story makes clear that the driving forces behind the change in R&D management at Philips were different from those of its American competitors. Clearly, the role of the Nat.Lab. in determining the company's product portfolio (as an 'innovation centre') has changed over time. In the conclusion we will reflect upon these changes.

In the pre-World War II period research seems to have shown 'follower' behaviour rather than initiator behaviour.[46] In the first main part of the history of the Nat.Lab. (1923–1946) its main goal was to enable to company to realise the product diversification that it had decided on. the Nat.Lab. researchers developed new knowledge that was protected by patents and was used to realise the desired product diversification. Holst, in an attempt to attract excellent scientists, created a culture in the laboratory in which academic status played an important role; at the same time he stimulated an industrial awareness among those scientists. In this period the structure of the lab was rather informal, which allowed some individuals to behave very independently. This pattern was usual for similar industrial research laboratories at that time. In fact, the GE Lab in the USA often functioned as a model for the Nat.Lab.

The transition from the first to the second period, though, may seem to follow the 'normal' patterns of industrial research laboratories starting to put more emphasis on 'fundamental' or 'basic' research, but for the Nat.Lab. the motives were different from the

USA laboratories. After World War II the company's structure was formalised. In this structure there were Product Divisions each of which had their development lab(s). This put the Nat.Lab. in a new position. In the need to search for a new culture and identity, the Nat.Lab. embraced the doctrine of 'fundamental' research as foundational for industrial developments as an opportunity to claim a unique role for itself in the company. For the USA labs this need to define a new role was not there because World War II had not caused the necessity for a 'new start' after the war as in the Netherlands that had been occupied and denied many resources for five years. So in the second main part of the its history (1946–1972) the Nat.Lab. directorate saw as its specific goal and contribution to the company (different from the development lab's contributions) to gain an understanding of all sorts of natural phenomena that in the long term could be useful for developing new products ('fundamental' research), as well as for major improvements to existing products (this type of research was also done in the foreign labs that were added to the research organisation). At the same time the Nat.Lab. scientists often felt themselves forced to do development work because the PDs' development labs in their eyes lacked sufficient competency to make optimal use of the research output. The academic dimension in the laboratory culture was enhanced and in a lot of discussions management concern was expressed about the 'fundamental' research (this term was used to indicate a type of research that should particularly be a Nat.Lab. research task).

Although the researchers got a lot of freedom, the structure of the lab became more formalised and groups with group leaders were established – a hierarchy of managing directors, directors, group leaders, scientists and assistants and technicians emerged. The influence on the company in terms of new products was a painful process in this period due to a lack of mutual commitment on the sides of both the Nat.Lab. and the PDs. The PDs felt that they had no say in the Nat.Lab.'s research programme and, vice versa, the Nat.Lab. felt frustrated because the PDs left a lot of research output unused. For improving existing products to production processes there were good contacts at practical level.

The shift towards a more market-oriented and PD-oriented approach to research in the last period (1972–1994) seems 'logical' from our contemporary point of view. Indeed it seems to have been the most logical reaction to the changing economic and social conditions. In this period the goals of the Nat.Lab. shifted slowly towards the needs of the PDs rather than the Nat.Lab.'s own ideas on desirable new developments. Gradually a balance emerged between maintaining certain key capabilities that were seen as necessary by the lab itself, and activities in application areas for the PDs. At the same time, new knowledge and patents were now gained on the basis of the PDs' needs and interests. The culture of the Nat.Lab. gradually became more PD-oriented, although a high level of scientific quality was still seen as important. In this period, the structure of the Nat.Lab. was further extended to contain new functions that were related to the orientation of PDs' needs (e.g. the R-PD co-ordinators) and the influence of the Nat.Lab. became that of knowledge centre from which the PDs could draw for their product development. In the late 1980s and the 1990s a dramatic reduction and rationalisation of the whole company took place. For the Nat.Lab. this meant a last strong incentive to focus on the PDs' needs and to learn to live with limited resources for the acquisition of which a serious effort was needed. In the mid-1990s this process to a certain extent had been completed.

Here, too, the transition from one period to the next had certain particular characteristics in the Nat.Lab. case. Several other comparable companies made this transition by splitting up the corporate research laboratory into PD-related labs, with perhaps only a small corporate lab left. This enabled a quick move from an independent position toward a PD-oriented attitude. In the case of the Nat.Lab. the company preserved the whole corporate laboratory and gave it the opportunity to make the transition by itself. This appeared to be problematic, and therefore in the end contract research was forced upon them by the company's management. The result was that in fact the whole 1972–1994 period can be seen as a transition. Probably the motive for keeping the Nat.Lab. intact was that the Nat.Lab. was the only laboratory in the company where a great variety of disciplines was present and co-operated. This multidisciplinarity therefore must be seen as the constant factor in the lab's history that determined its perceived value for the company.

Notes

1. In reconstructing the historical narrative presented in this article, we have used archival data collections alongside various historical and theoretical expositions. Over the years (the data were collected during the period 1998–2003), we have visited various archives in the Netherlands, Germany and the US, collecting administrative records as well as technical reports. The most important archive used in this study was the Philips Company Archief (abbreviated as PCA, in Eindhoven, the Netherlands: the Archives of Philips Electronics NV). Besides the documents that we found in the archives, we held about 20 interviews with (former) researchers at the Nat.Lab. They were all important sources of information when it came to determining the Nat.Lab.'s role in Philips' innovation process. We are indebted to Ben van Gansewinkel, staff member of the Philips Company Archives (Eindhoven, the Netherlands) for assisting us while carrying out archive research there.
2. Articles and (parts of) books that present a survey of these histories are: Dennis, 1987; Hounshell, 1996 (pp. 29–41 focus on the period before the Second World War). These are historical studies into industrial research organisations that have given historians a paradigm for the historical reconstruction of such departments. The US studies set the agenda (Carlson, 1991; Graham, 1986; Hounshell & Smith, 1989; Reich, 1979, 1985; Wise, 1985).
3. Recently, three important contributions have come out of the Netherlands (Boersma, 2002; Faber, 2001; Rooij, 2004).
4. '[T]he modern industrial research and development laboratory did not emerge full blown from the minds of executives at such firms as General Electric, Du Pont, Eastman Kodak, and American Telephone and Telegraph. History of research and development ... provides a window through which to observe the changing relationships between science and corporate strategy as they were subject to both internal and external pressures' (Hounshell & Smith, 1989, p. 1).
5. Of course, the role of other players, such as delivery firms, intermediary actors such as client organisations and even the end users in the whole process of innovation cannot be denied. This, however, is of course a different matter, and one that cannot be dealt with within the scope of this article.
6. Especially in Chapter 11 'Integration Completed' Chandler pays attention to industrial research. In later work, Chandler broadened his view of Europe in a comparative study (Chandler, 1990).
7. In addition, ethnographic studies indeed have shown that scientists who function within a non-homogenous (business) environment possess 'liminal' (in-between) identities, because they identify neither with the organisation (the company they work for) nor with the scientific community (the university they often refer to) (see Zabusky & Barley, 1997).
8. See also Faber (2001), who wrote about the Dutch (small and medium) companies' strategies to keep their technical knowledge up-to-date.
9. The success of this strategy of diversification was due to the fact that the consumer market kept growing in spite of the economic crisis. Between 1929 and 1939 the household use of electricity was doubled.
10. Memorandum 'Indeeling werkbesprekingsgroepen voor het jaar 1932 Natuurkundig laboratorium', dated 12 December 1931, PCA-NL.
11. Appendix 17 to Minutes of company's Directorate meeting 30 June, 1936, PCA.
12. PCA/NL 605. Bienfait. Berekening van kosten (Cost calculations).

13. PCA/NL 579. Algemene Zaken. Verslagen Diversen. Betr. Publicaties en Verslagen (general affairs and miscellaneous reports on publications), report of M. Drijver, 27 August 1947.
14. In Dutch the name Hoofdindustriegroep was used, which literally translates as Main Industry Groups; in many archive materials we find this term used in English.
15. Van Royen (1991, p. 169) offers a survey of the names of the PDs in the course of the period 1946–1991.
16. Edgerton even claims that the linear model that was preached in the Vannevar Bush report, never was practised. Our findings show that it did have an impact on Philips, but not necessarily because the linear model was believed it; for the Nat.Lab. it rather served as a welcome excuse to preserve an independent position in Philips (see Edgerton, 2004).
17. Minutes of the first meeting on 'Onze laboratoriumplannen', 23 January 1947, PCA-NL.
18. The name that is used in the written documents is Concern Research Conferences. But as the word Concern does not have the right sense in English and has been replaced now by the word Corporate, the term Corporate will be used in this text.
19. The main motive for starting these meetings and for the Research Directors Conferences (RDCs) was the fact that foreign labs were added to the research organisation. These will be described later on in this section.
20. In 1950 a similar meetings was held but was totally dedicated to television and this is probably why it is not counted as a CRC.
21. The RDCs were meetings of the international research managing directors; in the CRC meetings also members of the company's Board of Management and occasionally PD representatives participated.
22. In the minutes of the 1964 CRC we find the term 'not product-oriented' research as opposed to 'fundamental' research.
23. An example of this is the field of industrial control, where Casimir expected the research output to lead to new commercial activities; the minutes of the 8th CRC in 1964.
24. In the minutes of the 9th CRC in 1966 Tromp explicitly expressed this as the opinion of the Board of Management.
25. In the minutes of the 10th directors' contact meeting with the PD PIT there is a discussion about the Nat.Lab. support for developing ICs for the PD. It was agreed that this support should end with the first series of prototypes and then the PD should take over the initiative. This is an example of the Nat.Lab.'s perspective on its development task as mentioned in the text.
26. We refer to the series of letters between Casimir and Kistemaker Fundamental Research on Matter (FOM) in February and March 1969, PCA-NL. Casimir's remark was a response to Kistemaker's proposal for a joint institute for medical research and development.
27. This feeling was expressed for example by H.J.G. Meijer with respect to the index tube (interview on 16 September 1997, and by R.J. Meijer with respect to the Stirling engine (interview, 4 August 1998).
28. Minutes 1st Directors-CoCo meeting on 10 August 1945.
29. For example Minutes Directors-CoCo meeting 16 February 1962, 12 December 1962 and 20 May 1963.
30. Only in the Minutes of the Quo Vadis meeting on radar on 27 January 1954 do we find the remark that Holland Signaal, a military branch of the company, was given the word first, which deviates from the normal practice of first giving the word to the Nat.Lab. Minutes of the Quo Vadis meeting on Radar, dated 27 January 1954, PCA-NL.
31. Interviews with Dr. Teer on 9 September 1997, with Dr. De Haan on 9 September 1997, and with Dr. H.J.G. Meyer on 16 September 1997. Casimir himself (interview, 3 February 1998), could not recall any specific remembrances of the directors contact meetings, which probably means that he was not very much involved in those meetings.
32. Report Efficiency Contact Committee 1962/1963, PCA.
33. Data have been derived from the Annual Reports of the company.
34. 'Mijn opvattingen over de taak van de research-organisatie', by A.E. Pannenborg, 11 August 1972.
35. Minutes 13th CRC in 1974.
36. The remaining one-third may seem much compared to the 20% for 'exploratory' research that was mentioned as desirable earlier on. But one should keep in mind that this percentage includes more than 'exploratory' research. All research of which the desirability was established by Philips Research itself was included under this percentage.

37. Memorandum Philips Research, 10 June 1994, F.P. Carrubba.
38. Interviews with E.F. de Haan on 9 September 1997, G. van Houten on 19 November 1997, F. Meijer on 18 December 1997 and K. Teer on 9 September 1997. H.J.G. Meyer (interview on 16 September 1997) expressed as his opinion that it was mainly De Haan who realised the formalisation of the contacts between the Nat.Lab. and the Product Division.
39. Interviews with J.R. van Geuns on 10 June 1998, and J.C. van Vessem on 3 March 1998.
40. Report 'Bespreking Raad van Bestuur met Philips Concern Research', 13 March 1979. For some PDs (Lighting, Video, Small Domestic Appliances, Main Domestic Appliances, Electro Acoustics (ELA), Data Systems, Glass and the Nederlandse Kabel Fabrieken (NFK)) there was only one R-PD management committee. For Audio there were two: one presided over by Teer and one by Valster. Two professional PDs had two R-PD management committees: Science & Industry and Medical Systems. Two PDs had a larger number of R-PD management committees. For the PD Telecommunications and Defence Systems six such committees existed, most of them focused on a specific area: radio, radar and fire control, transmission, switching, and infrared. One of them had a more general title: Advanced development. The largest number of R-PD management committees was for Elcoma. A list of titles gives an impression of the variation in content: materials and components, ohmic resistance, magnetic materials, non-linear resistance, electrolytic capacitors, ceramic capacitors, professional sub-assemblies, discrete semiconductors, professional tubes, consumer tubes, and integrated circuits. Besides these there was a tripartite R-PD management committee TDS-Elcoma-Research. The number of committees related to Elcoma, illustrates the importance of Elcoma as a 'client' of research.
41. Minutes 16th CRC, 1980.
42. Minutes 90th RDC meeting, September 1987.
43. Research Review Book 1988.
44. Presentation 'Operation Centurion' by J.D. Timmer, Evoluon conference centre, 3 March 1991.
45. Declaration, 7 March 1991, Corporate Research, CFT and CPT senior management.
46. According to Chandler, product diversification was often caused by a 'push' from the research laboratories (see Chandler, 1977). In the case of Philips, however, the Nat.Lab. rather followed the companies' strategy. This image of the research laboratory as a follower also seems to fit the description of C.E. Kenneth Mees in his 1920 book on the organisation of industrial scientific research: 'the primary business of an industrial research organization is to aid the other departments of the industry' (see Mees, 1920, p 70).

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