Utility spots: science policy, knowledge transfer and the politics of proximity

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2. Utility Spots in the United States.

Architecture, Location and Circulation

2.1 Introduction

The United States is the birthplace of the science park, the pre-eminent spatial model of useful knowledge, innovation and techno-optimism in the 21st century. Since many countries, cities and universities have tried to replicate the success of, for example, Silicon Valley, Mile 128 and Research Triangle Park, the globe is 'littered with the ruins of all too many such dreams that have failed'.[129] These attempts in themselves are not surprising. The US was, for most Western European nations at least, the culturally, economically and politically dominant nation in the post-war period, and this also applied to science.[130] The North American hegemonic position has mostly been described in terms of the asymmetrical travel of scientific results, reputation and people, but also applied to the circulation of spatial modalities of

129 Peter Geoffrey Hall and Manuel Castells, *Technopoles of the World: The Making of Twenty-First-Century Industrial Complexes* (New York: Routledge, 1994), 8.

130 John Krige, *American Hegemony and the Postwar Reconstruction of Europe* (Cambridge, MA: The MIT Press, 2006).

research organisation. The failure of this circulation can be explained, at least partly, by a lack of situated understanding of how these places came about. Historians of US science have however extensively studied the political-economic, social and cultural conditions that made possible the emergence of industrial parks around academic institutions. Based on this scholarship, I situate the rise of science parks in a longer lineage of utility spots in the post-war US. It is in this period, namely, that a great variety of utility spots proliferated at, or close to, American universities.

In the previous chapter, I introduced the concept of utility spot to carve out a historiographical niche for the study of knowledge transfer practices and the societal legitimation of academic research in the post-war Western world. With utility spots I focus on the spatial arrangements that mediate the travel and translation of knowledge between heterogeneous actors and practices. In this chapter, I employ this working definition of utility spot to survey the post-war history of organised scientific research in the US: what spatial modalities of knowledge production and exchange manifest themselves, how did their quantity and quality change over time, and what narrative of the political economy of useful scientific research does this provide? By confronting the conjectural concept with ongoing debates in, and concrete spatial examples from, North American historiography of science, it is possible to develop and refine the spatio-historical approach to useful research.

This chapter offers a broad outline of the historiography of the organisation of scientific research in the United States in the twentieth century. It consists of two kinds of sections. Even-numbered sections discuss overarching spatial themes in the political economy of science (2.2, 2.4, 2.6). I will touch upon, amongst others, the spatiality of the linear model of innovation, the militarisation of the academic campus and the geography of the military-industrial-academic complex. Odd-numbered sections describe specific places of useful knowledge production and exchange (2.3, 2.5, 2.7). The examples highlighted have served as significant models for other post-war research facilities, and together span a wide range of possible relations between universities, industry, state (often: the military) and the public. The selection of modalities of organised research—corporate research laboratories (especially at Bell): radiation laboratories (at MIT and Berkeley)—work up towards the science park model. At Stanford University, these historical developments intersect in the emergence of Silicon Valley, the high-tech region that emerged around its research park. In the last section (2.8), I describe how this consecutively became a symbol of a more fundamental change in the political economy of scientific research taking place in the late 1970s, from a focus on national security to economic competitiveness.

In conclusion, I will reflect on the spatial and epistemological aspects of utility spots that have become manifest through the survey of US scholarship. To prepare the ground for subsequent historical excursions, I distinguish three main spatial aspects: architecture, location and circulation of utility spots. Here I introduce them only briefly; in the final section (2.9) I elaborate on them in relation to the historical developments in the US. *Architecture* concerns spatial separations between different types of research (e.g. in terms of funding, classification or goal) that typically also mediate a political-epistemic boundary between 'academic' and 'useful' research. This is closely related to the *location* of useful research, which symbolically says a lot about what relations are considered desirable at that spot. This can be interpreted at a small scale, in terms of *proximity*: many historical actors seem to assume a correlation between distance and interaction. It is also relevant at a larger scale, where a spot participates in a political-economic *geography*. Utility spots are established in certain regions because of their expected contribution to these areas and intersect with existing funding patterns and political-epistemic coalitions. These local complexities, of which the actors themselves are often readily aware, tend to get abstracted into clear-cut *geometries*, whenever they are put into *circulation*, with the promise of reproducing such highly situated success elsewhere. Architecture, location (including proximity and geography) and circulation (including geometry) will be highlighted throughout this, and later, chapters.

2.2 Linearity and Distortion in the Federal Political Economy of Science

The utility of scientific research in the post-war political economy of the United States has to be understood with respect to two historiographical themes: *linearity* (of the relation between science and society) and *distortion* (of the pursuit of science by society). Both themes follow from historical studies of the relations between academic, industrial and military actors, practices and places in the twentieth century. Scientific and political actors themselves observed how the Second World War changed for good the organisation of research in the US. The most significant aspect of this break was the emergence of a new primary patron of scientific research: the federal government and the Department of Defense in particular. Orchestrated by a scientific elite, two beliefs about the utility of (academic) research became commonplace: that *basic* science was the fountain of new technologies and profitable products, and that scientists *themselves*, not generals, engineers, politicians or industrialists, should call the shots on what new science to pursue. Later commentators dubbed the first belief the 'linear model of innovation', which arguably would have caused abundant funding of *basic* research, both on industrial and university campuses. The second belief conjoined the utility of basic science to its *autonomy* and corresponds to a debate between historians about distortion: whether the significant 'external' funding and interests of the government, military and industry have altered the course and usefulness of scientific development. The themes of linearity and distortion espouse general (constructivist) epistemological questions about how political economies and scientific research shape each other.[131]

David Edgerton has challenged the historical accuracy and agency of a linear model of innovation. If it ever existed, it was only as a self-indulgent argument of high-level academic scientists and policymakers. Edgerton concludes that later historians and analysts of science have inflated the importance and impact of this view on the utility of basic research. Instead, a revised historiography of twentieth-century science would view wartime R&D activity, for example, not just as the mobilisation of academic research but also, or more so, as the 'extension and strengthening of pre-existing military and industrial organizations'.[132] For the study of utility this means that academics' self-reporting has to be approached with healthy scepticism, and that attention should be paid to alternative sites and types of scientific activity besides academic research. As Edgerton notes, twentieth-century science is 'a great mass of non-research science, some "applied science," and a little bit of "basic" science'; and most of the scientific activity occurred not in academic spaces but in the laboratories of the government, military and industry.[133]
To study the usefulness of university knowledge production only in relation to the history of science policy would therefore produce a rather limited view. Instead, the addition of a spatial perspective, via hybrid spaces of knowledge exchange, does pay tribute to the historiographical insight that the very 'small space' for academic and fundamental research is overrepresented in academic studies of twentieth-century science. The identification and analysis of utility spots, in imagination, construction and action, can be used to problematize oversimplified models of innovation: they can precisely bring into focus the circulation of spatial models of organised research and the diverse political-epistemic coalitions that support them. Based on these historiographical insights, I begin the survey of US utility spots in the next section not at the university, but in industry.

The linear model cohered quite well, theoretically at least, with the autonomy of academic scientific research. But if the first did not exist, what about the latter? The historiographical debate about the distortion of science dealt with the issue of autonomy—or more specifically with the question whether

131 David Hounshell, "The Cold War, RAND, and the Generation of Knowledge, 1946–1962," *Historical Studies in the Physical and Biological Sciences* 27, no. 2 (1997): 238–39; Sismondo, *An Introduction to Science and Technology Studies*, 189–204; Mirowski, *Science-Mart*, 47–56.

132 Edgerton, "'The Linear Model' Did Not Exist," 46–47.

133 Edgerton, 46.

science develops in a certain direction because of, or despite, the relations with non-scientific actors. On one side of this debate are those who claim that the Cold War funding patterns significantly altered, or 'distorted', the development of scientific fields. Paul Forman has stated, for example, that alongside the quantitative change, effected by the increased budgets, a qualitative change took place in the purpose, character and practices of physics research.[134] Ultimately, this argument states that 'all the triumph cost Stanford, MIT and the nation at large a great deal—the militarisation of engineering and much of physics'.[135] In the history of the human sciences the federal patrons have also been identified as shaping the research agenda and methods both constructively and repressively.[136] Critics of this 'distortionist' view, like Daniel Kevles and Roger Geiger, instead describe the relation between the military and science as one of 'loose coupling' or 'symbiosis': without challenging the fact that the military shaped some research fields, they find it unlikely that certain basic laws and knowledge have gone undiscovered or unexplored because of it.[137] In addition, they identify (and challenge) a counterfactual assumption of the distortionist position: that science and engineering would have progressed in more societally useful directions without the defence funds. Rather, these historians hold that science and the military reciprocally shaped each other, and that attempts to instrumentalise science for military purposes often failed or left more than enough room for science to develop freely.

The 'militarisation' of academic research is a contested and complex issue. It is especially sensitive because it deals not just with the *results* of research, but also, or even primarily, with the *possible* results, or form, of scientific fields.[138] Questions, concerns and contract research structure what questions and concerns, and thus results, are thinkable and rational. Over time, this shapes the possible content of a research area (cf. my remarks about the 'significance' of research in the introduction). This subsequently also limits what usefulness is possible, etcetera. The study of the changing utility of research can therefore be directed at the conditions that shape the form of research, rather than attempting to uncover 'external' distortions in the content of science. The spatial organisation of research is one tangible way in which the potential space for scientific fields and their usefulness takes shape. In the following, I will review these issues therefore via a variety of spatial modalities of organised research located between federal government, military, industry and universities. It matters *where* the money flowed: on a national, regional and local scale. Nationally, federal and military funding created a particular political-epistemic geography by dispersing research to particular academic and industrial institutes, affecting regional economies. Locally, it changed the spatial organisation of research on and beyond campus. Before discussing

134 Paul Forman, "Behind Quantum Electronics: National Security as Basis for Physical Research in the United States, 1940–1960," *Historical Studies in the Physical and Biological Sciences* 18, no. 1 (1987): 150–59.

135 Daniel J. Kevles, "R&D Powerhouses," *Science* 260, no. 5111 (1993): 1161.

136 Joel Isaac, "The Human Sciences in Cold War America," *The Historical Journal* 50, no. 3 (2007): 735–36.

137 Kevles, "R&D Powerhouses"; Roger L. Geiger, "The Cold War and American Science: The Military-Industrial-Academic Complex at MIT and Stanford (Book Review)," *Technology and Culture* 35, no. 3 (1994): 629–631.

138 Ian Hacking, "Weapons Research," in *The Social Construction of What?* (Cambridge, MA: Harvard University Press, 1999), 163–85.

the geography of useful research and the emergence of buffer organisations to deal with the new contractual relation to the government, I turn to the rise of in-house laboratories and R&D campuses in industry.

2.3 Industrial Research from In-House Lab to R&D Campus

Several historical studies identify the rise of the industrial research laboratory as a major development in the organisation of scientific research in the twentieth century.[139] It is also a modality of research whose utility has been obvious for most of that period. In the US, industrial labs preceded universities as dominant examples of useful knowledge production. Before 1940, universities were quite peripheral to the industrial political economy of the US and regarded themselves primarily as institutions of learning. The university campus, located on the fringes of urban areas or in rural towns, resembled this ideal. The spatial organisation of universities in the 'pastoral' campus form—consisting in separation from the chaotic city and plenty of open, green space—was typical to the US from the late nineteenth century onwards.[140] Thomas Jefferson's 'academical village' at the University of Virginia, founded in 1819, long served as the spatial archetype of the American campus: especially its central lawn, for recreation, gossip and scholarly exchange was iconic.[141] At the beginning of the twentieth century, research and service to society were still much less visible in this miniature city of the academic community. Organised academic research was funded mainly by external patrons (industrialists, philanthropists and wealthy alumni) and housed in distinctive spaces on campus. The relatively isolated observatories, museums and laboratories created, according to Roger Geiger, a culture of 'separateness' between organised research and university life.[142]

Between 1900 and 1940, research did become increasingly present on the grounds of various American chemical, telecommunications and electronics companies. It should be noted beforehand that *scientific activity* in industry encompassed more than just research; analytical, testing and development labs typically preceded laboratories for research, and scientists were historically first employed for roles close to production and only later upgraded to positions to perform more fundamental forms of research.[143] Several international and national developments as well as scientific and economic factors help explain the establishment of corporate research laboratories.

In the late nineteenth century, not the US but European nations dominated scientific education, research and organisation. Germany especially set the tone in the emerging science-based industries in electronics, telecommunications and chemistry.[144]

139 See e.g.: Pickstone, *Ways of Knowing*; Mirowski, *Science-Mart*; Agar, *Science in the 20th Century and Beyond*, 160–85.

140 Margaret Pugh O'Mara, *Cities of Knowledge: Cold War Science and the Search for the next Silicon Valley* (Princeton, N.J.: Princeton University Press, 2015), 60–63.

141 Jonathan Coulson, Paul Roberts, and Isabelle Taylor, *University Planning and Architecture: The Search for Perfection* (Routledge, 2015), 16–20.

142 Roger L. Geiger, *Research and Relevant Knowledge: American Research Universities since World War II* (New York: Oxford University Press, 1993), 47.

143 Edgerton, "'The Linear Model' Did Not Exist."

144 Ernst Homburg, "The Emergence of Research Laboratories in the Dyestuffs Industry, 1870–1900," *The British Journal for the History of Science* 25, no. 1 (1992): 91–111. Industry and science were culturally intertwined in late nineteenth century Germany, see: Ursula Klein, *Humboldts Preußen: Wissenschaft und Technik im Aufbruch* (Darmstadt: Wissenschaftliche Buchgesellschaft) & Norton Wise, *Aesthetics, Industry, and Science: Hermann von Helmholtz and the Berlin Physical Society* (Chicago: Chicago University Press, 2018).

Their success was ascribed to a German model of scientific industrial research and development (R&D) that consisted of both industrial sponsorship of university research and the build-up of an in-house research organisation. Most American scientists would spend parts of their education at German institutions, where they experienced first-hand these new models of organised research. In this way, the German model would travel over the Atlantic and inform the establishment of large-scale industrial research laboratories in the United States, which rose to prominence well before academic research labs would. These labs replaced an existing pool of dispersed (external) inventors, working in small machine shops on which US firms had been relying for innovations up to the late nineteenth century. Thomas Edison is often perceived as the personification of the ingenious and perspicacious inventor and as a precursor to the first organised industrial R&D laboratories. In his Menlo Park laboratory in New Jersey, Edison gathered machinists, glassblowers, instrument makers, chemists and physicists to work on innovations for the telegraph industry. Increasingly, US firms required the application of chemistry and physics for the practical production and innovation problems they encountered. As they started to hire scientists for that purpose directly the R&D strategy that had based itself on dispersed inventors in small workshops withered.[145]

At the same time, scientists were professionalising and profiling themselves as a community separate from inventors. Academically trained scientists were not very willing to respond to the manpower needs of industry. Instead, they hailed the ideal of purity, independent of the pressure of practical interests. The corporate research laboratory was a better fit to this ideal. Between 1900 and 1920 a research system emerged in the US industry that was comparable to the German model of R&D, catalysed by the mobilisation of science during World War One. Major corporations like General Electric (GE), American Telephone and Telegraphy (AT&T), DuPont and Eastman Kodak initiated fundamental research programmes. They were motivated by competitive threats, antitrust law and reliance on foreign (German) intermediate products to establish research laboratories for the long-term survival of the company.[146] The in-house lab for commercialised science was not simply a factory churning out gadgets. Rather, its prime purpose was market control, managing the uncertain future and stifling external competition in a context of changing antitrust and intellectual property (IP) law. Invention, for example, was changed in IP law from the achievement of an individual into the effort of a collective, so as to ensure corporate ownership of innovations.[147]

While these successful industrial research laboratories may have ended the myth of the individual inventor, they continued to face the myth of pure science. In fact, they reinforced it.

145 David Hounshell, "The Evolution of Industrial Research in the United States," in *Engines of Innovation U.S. Industrial Research at the End of an Era*, ed. Richard S. Rosenbloom and William J. Spencer (Boston, Mass.: Harvard Business School Press, 1996), 16–19.

146 Hounshell, 20–22; J.W. Spurlock, "The Bell Telephone Laboratories and The Military-Industrial Complex: The Jewett – Buckley Years, 1925–1951" (Washington, The George Washington University, 2007), 11–16.

147 Michael Aaron Dennis, "Accounting for Research: New Histories of Corporate Laboratories and the Social History of American Science," *Social Studies of Science* 17, no. 3 (1987): 479–518; Philip Mirowski and E.-M. Sent, "The Commercialization of Science and the Response of STS," in *The Handbook of Science and Technology Studies*, Third (Cambridge, MA: MIT Press, 2008), 643–48.

Many academic scientists looked down upon research in industry, for a large part because most industrial science in the first half of the twentieth century consisted of other activities, like testing and analysis. Therefore, David Hounshell and others have argued that corporate laboratories were fashioned in the image of the university primarily to attract more academic graduates to industry. This fashioning consisted in imitating academic practices normally at odds with company policy—from liberal publication policies to a great deal of freedom in research topics—and mirroring the spatial organisation and architecture of the university campus.[148] Industrial laboratories and the academic community thus shaped each other.

Bell Labs: private interdisciplinary research in a campus setting

This reciprocal shaping becomes manifest in concrete spots, like the Bell Laboratories of AT&T. The Bell Labs came to be regarded as the 'epitome of organised research' in interwar industrial and academic communities in the US.[149] Officially established in 1925, Bell Labs was the result of two decades of a growing research programme in the Bell System, the association of companies directed by AT&T that basically functioned as a monopoly in telephone services. In the first decade of the twentieth century, AT&T felt the threat of independent telephone companies, a new wireless technology (radio) and the impending expiry of the Bell patents. The company leapt forward and planned to beat its competition by building a coast-to-coast telephone network. Research manager Frank Jewett, himself a physicist, argued that AT&T should hire more skilled physicists to realise this goal. In response, the company launched a relatively large-scale research programme in electronics, communications and circuit theory, staffed with physicists (most of whom had received training in Germany) and theoretically inclined engineers. In 1911 a separate 'research branch' was established, which was staffed with talented scientists whom Jewett drew from his academic network.[150]

In these early years, the Bell System also developed links with military organisations: besides personal relations and involvement of scientists in military operations, they also used each other's facilities during the First World War.[151] Later, AT&T would use this as an argument in Congressional discussions about its heavily criticised near-monopoly status: Congress should not threaten the industrial organisation of R&D because 'their' scientists had helped win the war. In the entire interwar period, researchers at the Bell Labs sustained close relations with the Navy and the Army, for example with respect to long-distance communications. In this way, the industrial research programme, and later the Bell Labs, were

148 Hounshell, "The Evolution of Industrial Research in the United States," 27.

149 Hounshell, 57; Spurlock, "The Bell Telephone Laboratories and The Military-Industrial Complex: The Jewett – Buckley Years, 1925–1951," 3.

150 E.g. through his doctoral supervisor Robert Millikan at the University of Chicago. Spurlock, "The Bell Telephone Laboratories and The Military-Industrial Complex: The Jewett – Buckley Years, 1925–1951," 79–83.

151 Spurlock, 106–10.

places where industrial and military interests could be productively combined. This was instrumental in Jewett's strategy to secure the military as a long-term ally of AT&T, so as to overcome future outbreaks of fear of big business in Congress and society.[152]

As well as functioning as argument in political discussions, the laboratory was supposed to bring AT&T a competitive advantage as an incubator for new profitable products and as a source of patents to achieve market protection.[153] Increasingly, this gave R&D a central place in the AT&T organisation, and by 1925 the Bell Laboratories were formally established with Frank Jewett as its first director. By then, its budget and staff made it the largest industrial R&D programme in the country.[154] At first, it was housed in a former manufacturing plant in Manhattan. This had the advantage of being close to the entry point for European visitors to the US, which made it very convenient for many international scholars to visit or give presentations at Bell Labs colloquia.[155] By the 1930s, plans were made to move the research facilities out of the New York City hubbub because 'vibration, dust, noise and electrical interference' all complicated proper measurements, and the lab had become overcrowded. After the Depression, this plan turned into reality at the Murray Hill Laboratories, in a suburb some 30 kilometres away from downtown New York and the central AT&T office. This also happened to be very close to the homes of the lab's president and research directors (resp. Frank Jewett, Oliver Buckley and Mervin Kelly).[156]

The move out of the city did not mean the lab's position in the Bell System deteriorated. Rather, it was the occasion to raise its standing, especially towards the world of science. After touring industrial labs in the US and in Europe, Kelly and Buckley decided that the Murray Hill facility should breathe more an academic than an industrial atmosphere. This fitted with the lessons learned at Bell Laboratories in the 1930s, namely that it was much to the company's advantage to give excellent researchers freedom in a university-like atmosphere. A lot of their technological problems required deep theoretical understanding of physics; to attract the best scientists to Bell, they created an environment that they deemed conducive to intellectual creativity and, at least as important, competitive with academic appointments. As new staff members established research seminars, study groups and journal clubs, the atmosphere became even more like a university.[157] But in contrast to an ordinary university campus, where each discipline was physically separated from others in different departmental buildings, Bell designed one single building to assure more intimate contact and easy interchange among departments. It had to retain the advantages of separate buildings while also discouraging departmental 'ownership of space'.[158]

152 Spurlock, 168–71.

153 Spurlock, 148–51.

154 Hounshell, "The Evolution of Industrial Research in the United States," 23–24.

155 Lillian H. Hoddeson, "The Entry of the Quantum Theory of Solids into the Bell Telephone Laboratories, 1925–40: A Case-Study of the Industrial Application of Fundamental Science," *Minerva* 18, no. 3 (1980): 437.

156 Scott G. Knowles and Stuart W. Leslie, "'Industrial Versailles': Eero Saarinen's Corporate Campuses for GM, IBM, and AT&T," *Isis* 92, no. 1 (2001): 1–33; Jon Gertner, *The Idea Factory: Bell Labs and the Great Age of American Innovation* (Penguin, 2012).

157 Hoddeson, "The Entry of the Quantum Theory of Solids into the Bell Telephone Laboratories, 1925–40," 445–47.

158 Knowles and Leslie, "Industrial Versailles," 19–23.

The H-shaped building was officially opened in 1942. The architecture of the laboratory building contributed to interactions between experimentalists and theoreticians, and between scientists, engineers and technicians. The offices and laboratories of technicians were located on different corridors, so that it was often necessary to walk from the ones to the others. And although the seemingly endless hallways might have appeared architectural weaknesses, in practice they facilitated many chance encounters during the commute. By the end of the war, 8000 staff members would work at Murray Hill on radar systems, sonar, electronic fire control and communication technologies. Already by the mid–1940s, many representatives of industrial laboratories visited the facility, to pattern their own laboratories after its image. After the Second World War, the military projects of AT&T were moved to Whippany, and the Bell Laboratories at Murray Hill became a centre for basic research in electronics and materials. Under Kelly's leadership, the lab was reorganised explicitly into interdisciplinary groups to work on new electronic technologies.

The Bell Laboratories became a model for organised industrial research with high degrees of freedom akin to academic practice: in the 1930s the laboratory brought forth both technological innovations and Nobel Prizes. This produced an image of useful research as simultaneously secluded (in a suburban area and like a university campus) and open and interactive (internally by co-locating different specialists, and externally by inviting academic scientists to visit). Spatial aspects, from location to architecture, were essential elements that legitimised industrial, and by implication federal, investments in R&D. Industrial, governmental and academic organisations would later try to mimic the dynamics of this utility spot.

The post-war industrial research campus

The in-house corporate laboratory, as we got to know its ideal form at Bell Laboratories, was a product of the interwar period. In a way, the trend to build large-scale research facilities in campus-like settings continued amongst large corporations in the 1950s and 1960s. But, in distinction to Murray Hill, the external aesthetics became as important as the internal structures. This transformation of the pre-war in-house lab is considered a consequence of the new political-economic context of the Cold War. This was linked to the emergence of the multidivisional bureaucratic managerial culture (the M-form) after the war, in which each division was its own profit centre. R&D divisions could survive as long as they were able to obtain their own income, which in the Cold War context consisted mainly of contracts from the Department of Defense. The corporate laboratories thus became more of an external research contractor. As a consequence, these R&D divisions had to deal with the protocols and accounting procedures of the military, which provided incentives towards a division of labour *within* companies, and *between* industry and universities, in line with the 'linear model'.[159] Partly motivated by military secrecy demands, corporate research labs were increasingly removed from production facilities, and placed in 'campus-style settings'. These spatial developments relied on the views of defence contractors and companies who heralded basic science and scientific freedom as the source of new products and profits. Historians argue that this view neglected the significance of manufacturing, engineering and construction capabilities for the wartime progress in (the application of) research and overlooked the importance of mass production capacities.[160]

However, the myth of the linear relation between fundamental research and technological progress survived the first two post-war decades. This was based on a handful of extremely successful examples like nylon (DuPont) and the transistor (AT&T). And, according to Philip Mirowski and Esther-Mirjam Sent, it was the federal, mainly military, patronage that transposed this linear relation between university and industry, actively inverting the pre-war relationship.[161] Indeed, many industrialists did not challenge these beliefs and accordingly implemented the university campus model of basic research for their R&D facilities. This isolated research spatially, organisationally and intellectually from the rest of the company, in particular its production and development departments.

One prominent architect, Eero Saarinen, designed the most architecturally distinguished corporate laboratories after the Second World War: the labs of GM, IBM and AT&T. Saarinen shared the conviction that the isolated campus was the ideal model for creative research and used it to create a new spatial and symbolic identity for basic research in industry. Contracting a famous architect for a landmark research campus was tenable only for very large, almost monopolistic companies (like General Motors, IBM and Bell) for whom a highly visible laboratory functioned as symbol of technological leadership and market control. Ultimately, Saarinen's designs focused on this corporate image and research ideal. Less attention was reserved for attuning architecture to stimulating environments for research. Still, the academic atmosphere of the industrial laboratories had to attract the greatest scientific talents and offer them independence and creativity. But the pre-war Murray Hill lab of AT&T had produced scientific excellence—both in terms of Nobel Prizes and in terms of products—notwithstanding its mundane architecture and defiant functionality (which turned out to be a secret strength). The trend-setting post-war corporate laboratories of GM, IBM and Bell defined the standards for the creative research environment, which university research parks would later reflect: isolation, low rises, and a visible contrast between steel and concrete building and surrounding greenery and landscaping.[162]

159 Mirowski and Sent, "The Commercialization of Science," 649–54.

160 Hounshell, "The Evolution of Industrial Research in the United States," 41; Knowles and Leslie, "Industrial Versailles"; Hoddeson, "The Entry of the Quantum Theory of Solids into the Bell Telephone Laboratories, 1925–40," 447.

161 Mirowski and Sent, "The Commercialization of Science," 649–54.

162 Knowles and Leslie, "Industrial Versailles."

2.4 The Spatial Model of *The Endless Frontier*

The establishment of fundamental R&D spaces in industry was informed, at least on the face of it, by a linear model. At the same time, the use of such legitimations can also be interpreted as window-dressing to conceal more practical concerns for manpower and market control. The linear model has figured in a similar way in the history of *public* funding of scientific research in the post-war US. Typically, historians and analysts of science present the famous 1945 report *Science: The Endless Frontier* as evidence of the existence of this model in federal science policy.[163] As part of his broader criticism of the linear model, David Edgerton has attacked these arguments: they exaggerate the importance of the context of origin of the report (the OSRD), as well as its institutional consequences (the NSF), and, most importantly, it is based on a misinterpretation of what Bush's report was about.[164] It was not a *linear* but a *spatial* model that the author of the report, Vannevar Bush, advocated. I will elaborate on these three points of criticism to come to an understanding of the spatiality of science policy more generally.

As director of the Office for Scientific Research and Development (OSRD), Bush was requested by President Franklin D. Roosevelt to draft the report. In this function, the 'staunch conservative' Bush coordinated scientific research for military purposes during the Second World War. In the First World War the research effort had been organised in separate government labs, clearly separating research for military purposes from academic research. In the 1940s, a new relation between the government and universities was established in the form of *contracts*, through which research activity in university laboratories was supported, without demanding specific results. This worked out especially well during the war, as long as goals and priorities were shared by all actors. Ample resources and little accountability allowed flexible relations between OSRD and the universities, and decentralised scientific choice to the scientific researchers themselves.[165] In this way, there was state intervention in science with minimal distortion of academic freedom. But, as Edgerton points out, the OSRD was only one amongst many wartime military organisations that funded research; and its budget was only a fraction of those of the Army, the Navy and the Manhattan Project.

The attention in scholarship for *The Endless Frontier* also does not match its limited impact on federal science policy. The primary outcome was the National Science Foundation (NSF). The NSF was officially established in 1950, after years of Congressional stalling, and came to play some role of significance only after the launch of the Sputnik satellite by the Soviet Union in 1957. The Russian achievement had a

163 Vannevar Bush, "Science: The Endless Frontier," *Transactions of the Kansas Academy of Science* 48, no. 3 (1945): 231–64.

164 Edgerton, "'The Linear Model' Did Not Exist," 40–42.

165 Geiger, *Research and Relevant Knowledge*, 3–12.

great impact on scientific research funding in the United States, especially causing rapid increases in funding for the NSF (and the establishment of NASA). It might seem that, more than ever, political leaders saw basic science, scientific excellence and education as key in winning the Cold War. But even then, the NSF subsidies for academic research in elite universities were only a fraction of total federal spending on research: the funds related to the military support of scientific research by far outweighed medical and basic research.[166]

The concrete origins and the limited practical effects of Bush's report revise the relative importance of the linear model, if this was indeed defended in *The Endless Frontier*. And that, argues Edgerton, is not the case. Rather, Bush advocated a spatial model for the organisation of publicly funded research. According to Edgerton, the model consisted of two parts: 'different kinds of scientific activity take place in different spaces, and secondly, the extension of scientific knowledge creates a new enlarged arena for the actions of others'.[167] Instead of a linear, chronological understanding of the utility of basic science, Bush embraced a 'reservoir' model with respect to the utility of basic science.[168] Similar to the historical exploitation of the 'fallow' land in the west of the US, science could create a resourceful space without frontier, to be developed by any entrepreneurial US citizen. Ultimately, post-war federal science policy was not just occupied with causal models of science and societal progress but can also be described in spatial and geographical terms.

The location of different types of scientific research was indeed a central concern in the political debate about the NSF, which dealt with the appropriate boundaries between academic research, the federal government, the military and industry.[169] The progressive liberal Senator Harley Kilgore, who took the first initiative in 1944, wanted to put an end to the 'laissez-faire' attitude to science of the federal government by supporting socially and economically useful science in federal laboratories. Kilgore also hoped to transform the hierarchical political geography of science by making the NSF a central federal agency, responding to the president, governed by a 'lay' coalition (including for example business leaders) and executed by (less biased) policy officials. This had to break the institutional favouritism that had developed during the war, where a political, military and scientific elite distributed most defence contracts to a handful of institutions like MIT and Harvard. Kilgore's proposal frustrated the military and scientific elite and also the research-based industries, as he argued for a non-exclusive licensing policy for the funds, so that inventions could circulate freely.[170]

Bush, in his final report *The Endless Frontier*, disagreed with Kilgore's proposal for the organisation of useful research on almost every aspect. Instead, the conservative

166 Geiger, 13–18.

167 Edgerton, "'The Linear Model' Did Not Exist," 40–42.

168 As observed by Arie Rip, cited in: Edgerton, 41.

169 Michael Aaron Dennis, "Reconstructing Sociotechnical Order: Vannevar Bush and US Science Policy," in *States of Knowledge. The Co-Production of Science and Social Order*, ed. Sheila Jasanoff (London; New York: Routledge, 2004), 236–264.

170 Daniel J. Kevles, "The National Science Foundation and the Debate over Postwar Research Policy, 1942–1945: A Political Interpretation of Science – The Endless Frontier," *Isis* 68, no. 1 (1977): 16–24.

Bush defended a conception of utility that did not interfere with the interests of the scientific, industrial and military elite. This was part of a broader meritocratic elitism that he had introduced in the report: the scientist and the engineer stood at the top of society and had the responsibility to guide policymaking. As part of this worldview, he advocated the support of basic research in non-profit institutes of higher education, and privileged universities above federal labs. Independence of research from any federal involvement was to be secured by making the NSF an elite body run by professional scientists. In addition, Bush's pre-war experience and close collaboration with industry, as dean at MIT and director at the Carnegie Institution, aligned him with business interests of large, vertically integrated companies with in-house R&D labs.[171] His focus on basic, not applied, research and his opposition to Kilgore's patent policy were not so much convictions about the linearity of innovation as they were an attempt to preserve the pre-war arrangement in which firms could use patents and R&D to control markets. Above all, Bush was a representative of an elite coalition of politicians, scientists, industrialists and military officers so he would never disturb existing geographies of power, between universities and corporate labs.

Bush thus strove to maintain different types of research in different types of spaces. In particular, he strove to keep relations with external parties outside academic spaces. Like many scientists, university administrators and politicians, Bush had thought that wartime organisations like the OSRD were of a temporary nature and hoped that it would be possible to return to the arrangements for organised research of the 1930s.[172] The failure of Bush and his industrial, military and scientific allies to realise how the military and researchers had transformed each other during the war—and to imagine its irreversible effects in the post-war world—informed the initial failure of his proposal for a national research foundation that based itself on an insulated image of science.[173] Instead, all kinds of research had already been supported extensively at universities before the NSF started to play a role. Several wartime practices of organising research for national security were continued almost silently into post-war patterns of federal funding. Often this funding flowed not directly to traditional, or 'pre-war', disciplinary departments, but instead to newly created 'interdepartmental labs' or 'organised research units'.[174]

Interdepartmental labs were on the one hand institutional innovations within the American university, buffer organisations to deal with the new contractual relation to the government. On the other hand, they set in motion the spatial transformation of campuses. In between the traditional on-campus department and the off-campus mission-oriented

171 Daniel Lee Kleinman, "Layers of Interests, Layers of Influence: Business and the Genesis of the National Science Foundation," *Science, Technology, & Human Values* 19, no. 3 (1994): 275–78.

172 Dennis, "Reconstructing Sociotechnical Order," 230–33.

173 Dennis, 247–48.

174 Stuart W. Leslie, *The Cold War and American Science: The Military-Industrial-Academic Complex at MIT and Stanford* (Columbia University Press, 1993), 15.

federal institute, Roger Geiger has discerned two intermediate ideal types of such buffer organisations—centres and institutes.[175] *Centres* were externally funded, multidisciplinary and interdepartmental organisations directed at complex problems. Typically, these would be located on campus and they were still rooted in academic departments and cultures. In practice, it proved difficult to unite the conduct of academic research with the ulterior motive set by the external funder. Often, the goal of the centres drifted in time towards those of the academics involved. As space, these centres do seem to have stimulated exchange between various academic specialties. For example, many centres for area studies were established, like the Russian Research Centre at Harvard, ultimately to inform military intelligence. But in practice, it also brought together various social scientific disciplines. *Institutes,* on the other hand, were more independent of the university. They housed (non-academic) professional scientists alongside faculty researchers, with a full-time director in charge. The research at institutes was more closely linked to the interests of the external funder, while the university basically took care of practical and administrative issues. Housing the advanced facilities helped them to increase their institutional prestige and to keep more entrepreneurial faculty satisfied. As space these institutes seem to have fostered exchange between academic research and external parties: broader utility motivated and dominated the institute research, which was partly performed by faculty professors and graduate students. The Research Laboratory for Electronics at MIT, discussed below, is an example of this. Moreover, federally funded organisations for communications research, like the Bureau of Applied Social Research at Columbia, functioned as institutes.

In the following I will discuss different modalities of organised research, with special attention to spatial and geographic aspects of these utility spots. To understand the entanglement of the federal government, industry, and the universities in the development of organised research in the United States, it does not suffice to focus only on (hybrid) academic spaces. My discussion of the radiation laboratories located at MIT and UC Berkeley will end with a federal contract research laboratory and a private non-profit think tank. These kinds of institutions were, often more explicitly, continuations of wartime arrangements and had fewer academic linkages: the universities merely offered managerial services or occasional advice. Because of the classified nature of the work these were isolated on off-campus sites, because of which they resembled industrial spaces more than academic ones. Again, it becomes manifest that post-war developments in industrial research are pivotal to the understanding of the spatiality of useful academic research.

175 Geiger, *Research and Relevant Knowledge*, 48–57.

2.5 Hybrid Spaces on and Beyond Campus: Three RadLabs

The post-war contractual relation between government, industries and scientific institutions catalysed the establishment of hybrid spaces for useful research. Patterns of research funding and organisation that emerged during the war continued in peacetime but could not be housed in pre-war spaces. Utility spots emerged that embodied the altered relations between science and society. By way of three Radiation Laboratories, one on the east coast (at MIT) and two on the west coast (at UC Berkeley), I will discuss two different patterns in federally organised research. One pattern mirrored the experiences with nuclear physics in the Manhattan Project, for the construction of the atom bomb, and the other reproduced the mobilisation of other engineering and natural science fields for military applications, like radar and missiles.[176] The Atomic Energy Commission was installed after the war to coordinate and direct nuclear physics towards peacetime purposes. For the continuation of research for military applications, several offices of the Navy, the Air Force and the Army established or continued contractual relations with a variety of university laboratories. In the early 1950s, the Korean War led to another dramatic increase of military funding, further 'militarising' university research.

My choice of the three Radiation Laboratories as relevant utility spots follows from their paradigmatic status. They exemplified the 'best' the world war had to offer in terms of scientific mobilisation and technological warfare: the MIT RadLab was synonymous with radar and its applications, and the Berkeley RadLab had a crucial role in the development of the atom bomb in the Manhattan Project. After the war the Californian RadLab created a spin-off Radiation Laboratory at Livermore for all classified research in nuclear weapons. The immense societal impact of these applications created an aura of success around the RadLabs that also shone onto their innovative models of organised research.

RadLab, MIT, Massachussetts

Already before the war, the private Massachusetts Institute of Technology (MIT) actively nurtured relations with industry. Unlike most elite academic institutions in the US, MIT did not rely much on foundation grants and rather became very experienced in working with research contracts and providing services to industry.[177] During the 1930s, the new MIT president Karl Compton was urged (amongst others by Frank Jewett, who served on the advisory board of the electrical engineering department) to reform MIT towards a more fundamental science and research-based institute, rather than to continue the serviceable orientation to industry.

176 Geiger, 13–18.

177 Christophe Lécuyer, "The Making of a Science Based Technological University: Karl Compton, James Killian, and the Reform of MIT, 1930–1957," *Historical Studies in the Physical and Biological Sciences* 23, no. 1 (1992): 153–180; Hall and Castells, *Technopoles of the World*, 33–34.

Compton, who had previously been an administrator at Princeton and a consultant at General Electric (GE), introduced various changes that concurred with established practices at elite research universities. With these more academic aims in mind, foundations like Rockefeller were willing to support also MIT.[178] At the same time, Compton, with the support of Vannevar Bush (who managed research in electric engineering), reorganised the relations with industry so as to increase the institute's autonomy with respect to industry (especially Bell and GE). In order to raise sufficient funding, Compton was 'keen to show the usefulness of scientific pursuits…[fostering] approaches that privileged instrumentation and interdisciplinary cooperation and offered potential applications.'[179] As a result, MIT would soon become known precisely for its stimulation of fruitful interactions in research between scientists and engineers with useful result for industry.

During the Second World War, Bush and Compton played central roles in the wartime scientific organisations. This, as well as MIT's renewed reputation and industrial experience, definitely must have informed the Department of Defense's decision to concentrate research activities in the field of radar, based on one concrete device (the magnetron), there in a dedicated laboratory.[180] Hiding its true function, this was named Radiation Laboratory. Although some older academics doubted the usefulness of concentration on campus, and it led to strained relations with industry (Jewett had advocated Bell Laboratories as probable site), RadLab quickly expanded from borrowed space into several new buildings. During and after the war it came to function as framework for relations between the government and universities. Similar labs were established at Johns Hopkins University, for the proximity fuse, and at Caltech, for missiles. The experiences at these kinds of university facilities that developed military applications resulted in a relation of negotiation through contracts between the universities and the military. After the war, this was institutionalised most importantly in the Office for Naval Research (ONR) of the Navy. The ONR also funded a lot of basic academic research at universities, even being its main patron in the first post-war decade as long as the NSF bill had not yet passed Congress.

MIT emerged as the largest defence contractor after the war, continuing the pattern of its dominant wartime involvement. The RadLab had been most prominent during the war, and parts of it were transformed by the new MIT president James Killian into the Research Laboratory of Electronics (RLE). This lab became exemplary for the post-war political economy of knowledge, at least at MIT. The staff consisted of MIT faculty, professional staff as well as new graduates who had worked at RadLab. RLE was a hybrid of the physics and the

178 Lécuyer, 157–159.

179 Lécuyer, 164–167.

180 Lécuyer, 172.

engineering department, emphasizing both basic research and process development, and was a way to sustain the relationships with both the military and the industrial contractors that had been built up in the war. Through summer schools and graduate studentships, it also attempted to connect to the teaching mission of MIT, although it would always remain reflecting the military character of the research. This meant both performing classified research as well as complying with 'unwritten rules' of self-censorship with respect to results that might endanger national security.[181] Graduates from RLE went on to work in established companies, but also created many new ones. These spin-offs from RLE often relied as much on federal contracts as the laboratory itself. The industrial region on the periphery of Boston that later became known as *Mile 128* thus had its origin in research and production organised by defence contracts. Similar dynamics played around other MIT laboratories, like Lincoln Laboratory for advanced electronics in air defence. It was modelled after RadLab and RLE, functioned as meeting place for academics, professional scientists and engineers, and was a place where students gained practical experience with real-world problems. Different from RadLab, Lincoln functioned as a federal contract organisation, as it was located off-campus, and closer to an airbase and Mile 128 than to university buildings.[182]

The Berkeley and Livermore Radiation Laboratories, UC Berkeley, California

The Radiation Laboratory at the public University of California at Berkeley (UC Berkeley) exemplified 'west coast pride' and served as standard for the entire university.[183] After the war, it would emerge as the leading centre in government-sponsored research in high-energy physics. This RadLab differed from the one at MIT in several ways: it was established long before the war, it was a component of the, first dispersed, Manhattan Project, and in the post-war period it would rely on funding from the Atomic Energy Commission (AEC) instead of the Department of Defense. Physicist Ernest Lawrence established the Radiation Lab in 1931 and first focused on the development of a cyclotron. His success in building and using this magnetic particle accelerator brought him the 1939 Nobel Prize. Apart from this academic prestige, the Radiation Lab had already become known for its industrial approach to organised research. As the cyclotrons grew bigger and bigger, the lab and staff expanded correspondingly. And the use of the cyclotron to produce isotopes for medical and biological purposes as well as the ongoing design of new machines created a far-reaching division of labour and hierarchy in the lab.[184] Later commentators would credit Lawrence's laboratory as the first 'big science' lab because capital-intensive research took place in large interdisciplinary

181 Lécuyer, 176–177.

182 Leslie, *The Cold War and American Science*, 26–37.

183 Robert W. Seidel, "Accelerating Science: The Postwar Transformation of the Lawrence Radiation Laboratory," *Historical Studies in the Physical Sciences* 13, no. 2 (1983): 375–400; Geiger, *Research and Relevant Knowledge*, 75–77.

184 Seidel, "Accelerating Science," 384.

teams of physicists and engineers, was concentrated around single, complex instruments and supported by external funders and long-term research management.[185] In awe of its impressive results, European visitors also noted with a bit of doubt the frenetic pace and peculiar camaraderie of the industrial organisation of research.

In the 1940s, the potential of the 184-inch cyclotron was redirected completely to the war effort. The laboratory became of central importance to the aim of the military to realise an atomic bomb based on the newest nuclear physics. Partly because of the required secrecy, any informal pre-war group work was replaced with corporate discipline and formal research and development groups.[186] Cyclotrons were used to enrich uranium and Glenn Seaborg, one of the research group leaders, isolated plutonium. This contributed significantly to the Manhattan Project, which was first dispersed over various universities (UC Berkeley, Columbia, Chicago and others) and was concentrated into a 'huge multinational physics faculty' at the Los Alamos Special Weapons Lab only in 1943. Just like Berkeley RadLab this spot has been credited as the paradigm of big science, because it housed large multidisciplinary teams dealing with complex problems and sophisticated, expensive instruments.[187] Social relations between the two labs enabled the spread of this model of useful knowledge production: Robert Oppenheimer left the Berkeley lab to become director at the Los Alamos facility, after Ernest Lawrence had recommended him to General Leslie Groves, the director of the Manhattan Project. Sometimes the circulation of utility spots as model was even more direct, for example when Lawrence designed the Oak Ridge facility where uranium was to be enriched on a large scale.[188]

After the war, most RadLab researchers, who had been dispersed over the country during mobilisation, flocked back to the Berkeley hillside. In the meantime, the laboratory had expanded further, and consisted by 1944 of some thirty buildings and a staff of 1200. Lawrence, still lab director, first expected things to normalise as soon as the urgency of the war passed and proposed to scale down the activities. They also needed to reorganise research activity once more, to recapture the group spirit and scientific freedom that had characterised the pre-war work. But the useful aspects of the wartime corporation, like finance, design and engineering, also had to be maintained. These opposite demands were met by centralising administration and engineering, and decentralising scientific work into relatively autonomous research groups, which each worked on their own machines.[189] 'Outsiders' would visit these groups to acquire the specific know-how for each machine. Each group was supported by the developmental groups in mechanical and electrical engineering, medical physics and chemistry as well as the

185 Andy Pickering, "The Rad Lab and the World," *British Journal for the History of Science* 25, no. 2 (1992): 247–251; Michael Hiltzik, "The Origins of Big Science: And What Comes Next," *Boom: A Journal of California* 5, no. 3 (2015): 98–108.

186 Seidel, "Accelerating Science," 385.

187 Geiger, *Research and Relevant Knowledge*, 30.

188 Hiltzik, "The Origins of Big Science," 102–3.

189 Seidel, "Accelerating Science," 385.

centralised workshops and administration departments. Rival laboratories, like Brookhaven National Laboratory, tried to mimic the Berkeley model of centralised support for decentralised, interdisciplinary team research.[190]

By 1945 Lawrence came to realise that normalisation would not occur and tried to capitalise on the opportunities that federal patrons offered for peacetime research. The close ties to the military leadership that Lawrence had built, especially with General Groves, proved crucial in this respect. During the war Groves had led the Manhattan Engineering District (MED) that allocated funds for the research in the Manhattan Project. As the war drew to a close, Lawrence kept close taps on his intentions, and was able to persuade the MED to fund several projects at the Berkeley lab. The Atomic Energy Commission (AEC) took over most of the MED projects and became the main patron of the Radiation Laboratory at Berkeley. Allies of the lab had strategic positions in the AEC: Oppenheimer chaired the commission that decided its research policy and Seaborg had a seat in this committee of nine. Lawrence tinkered with his proposals so as to meet the demands and possibilities of the AEC, just like he had reached compromises with private foundations (Rockefeller) before, and, with the military, during the war. Lawrence's cultivation of the relationship with Groves and the AEC led to the building of a fourth major machine (the Bevatron) at Berkeley in 1948, which assured the continuation of its dominance in high-energy physics. Even though the official policy of the AEC had been to avoid concentration of resources in large institutions, it would pay due heed to Berkeley's 'special history'.[191]

The Berkeley Radiation Laboratory—later renamed Berkeley Lawrence Laboratory—successfully transformed itself back into an organisation for fundamental research in peacetime. The secrecy limitations during the war were discontinued, mainly by establishing an offshoot laboratory dedicated to classified research into nuclear weapon design. This Radiation Laboratory at Livermore, later baptised as the Lawrence Livermore Laboratory, had to compete with the development and innovations at the Los Alamos Laboratory. Similar to the Lincoln Laboratory at MIT, this institute was further removed from UC Berkeley, at a former air force base, providing more space for large experiments and, above all, making it possible to maintain higher levels of secrecy.

To conclude, the organisation of nuclear physics in the Manhattan Project led to a pattern in federal science policies on topics with high costs and high stakes. This was institutionalised in the Atomic Energy Commission that funded self-contained, but university administered, laboratories on campuses like the two Lawrence laboratories associated with UC Berkeley. The various 'big science' spaces stimulated interdisciplinarity and relied strongly on relations with the

190 Seidel, 387–88.

191 Seidel, 392–99.

military and industry. The relation between secrecy and utility in the highly controlled transfer of knowledge could translate into specific locations and architecture. While utility concerns could dictate a location close to academic expertise or industrial production, secrecy measures were easiest at separate buildings located off-campus.

2.6 The Geography of the Military-Industrial-Academic Complex

The post-war organisation of research in the United States, described in the pages above, was famously baptised by Dwight Eisenhower as the 'military-industrial complex'. In his farewell speech as president in 1961, he introduced the term to warn the American people of its unwarranted influence on politics. This military-industrial complex consisted of a close alliance between the Department of Defense and the armed forces on the one hand, and very large industrial contractors on the other. In between, there were government laboratories as well as university centres and institutes, in which academic and professional scientists worked on lavishly funded research projects with a, sometimes distant, military interest. This 'golden triangle' of military, science and industry made some also call it the 'military-industrial-academic complex'. Although universities played a 'minor but indispensable' role, the golden triangle very visibly materialised around elite institutions like MIT and Stanford.[192] In some locations, the military-industrial-academic complex took actual physical shape. It is in concrete places of knowledge production and exchange at and around universities that the structural effects of this Cold War political economy of research, and continuities with subsequent neoliberal developments, can become clearly visible.

There is quite some agreement among historians and other scholars on the organisational impact of the military-academic-industrial complex on science: its scale increased, security restrictions were sometimes enforced, and interactions between different disciplines, engineers and societal actors were stimulated. As reconstructed above, the complex was supported by a political-epistemic alliance that had its roots in the Second World War. The mobilisation and dispersion of academic researchers and the redirection of industrial research to national purposes defined the post-war political economy of research. Funds, people, technologies and knowledge circulated in the triangle between the federal government, industry and university, sectors that had previously been more separated.

The opposite positions in the *distortion* debate about the militarisation of the content and form of science (see section 2.2), in the end come down to a political dismissal of the military as a warranted patron for science or an economic

192 Leslie, *The Cold War and American Science*.

appraisal of military necessity as the mother of invention. Increasingly, the consensus amongst historians has become that historical reality for scientific actors in the Cold War was often ambiguous and that each relation between research and its patrons needs to be understood in context.[193]

It was in such ambiguity that universities and their administrators could play an active role by mediating between professors and patrons.[194] In the post-war political economy, each university would imagine its role in society also spatially. Stuart Leslie and Robert Kargon have argued that a 'mental and physical geography' of the university defined the boundaries of their societal community. Where, for example, Princeton University situated itself on a national scale, Stanford University aspired to be connected to regional businesses and government labs in physical proximity of the university.[195] Stanford was therefore not just oriented to a community of scholars, but also to a broader group of scientists, engineers and entrepreneurs. In these territorial imaginations the universities functioned as regional engines of economic development, urban planners and political actors. These aspired and actual roles of academic institutions are the product of broader political-economic developments in the Cold War period. The regionally biased political geography of science funding and the suburbanisation of science should therefore also be taken into account.

The flow of defence contracts not only steered research and education programmes in particular directions, it also reshaped university campuses and transformed the surrounding regions. Margaret Pugh O'Mara has demonstrated how the military-industrial-academic complex created a very specific political-economic geography. Where the universities had been a historically independent and elite sector, their research became increasingly organised as big science and through governmental intervention. This intervention, in terms of research contracts for defence purposes, had geographical consequences. The flow of funds followed existing hierarchies of scientific excellence (institutional favouritism) and existing spending patterns of military production (regional favouritism). This made scientists and university administrators (sometimes unwillingly) political actors in a skewed economic geography.[196] To increase their political standing, universities more remote from Washington opened offices in the capital. Stanford University was one of the first to open an office, in 1945. Ultimately, such efforts could not prevent a skewed geography of the military-industrial-academic complex emerged that concentrated scientists and engineers in a few regions (Illinois, California, New Jersey, New York, Ohio and Pennsylvania) and around a handful of elite academic institutions.

This geographical hierarchy coincided with the spatial spread of military production and led, in O'Mara's terms, to 'cities of knowledge': 'consciously planned communities' as

193 Mark Solovey, "Science and the State During the Cold War: Blurred Boundaries and a Contested Legacy," *Social Studies of Science* 31, no. 2 (2001): 165–70; Isaac, "The Human Sciences in Cold War America," 739.

194 Rebecca S. Lowen, *Creating the Cold War University: The Transformation of Stanford* (Berkeley: University of California Press, 1997), 6–11.

195 Robert Kargon and Stuart Leslie, "Imagined Geographies: Princeton, Stanford and the Boundaries of Useful Knowledge in Postwar America," *Minerva* 32, no. 2 (1994): 121–143.

196 O'Mara, *Cities of Knowledge*, 5–9.

'physical manifestations' of a political ideal, with research universities at their heart.[197] Research facilities and defence manufacturers privileged the same regions, which were characterised by high rates of suburban growth.[198] The preference for locating defence facilities in suburban areas was the outcome of several policy incentives for decentralisation. To decrease the vulnerability of central business districts to a potential nuclear attack, firms were stimulated (with cost and tax reductions) to locate in dispersed areas outside the cities. In addition, a dispersal policy also structured the spread of defence contractors who became ideally located in the suburbs. Implicitly, this approved the suburban space as the logical home for scientific work.[199] When in the 1960s economic development policies centred more on the university, campus expansion was stimulated in *research parks* to strengthen partnerships with government and industry. This was the kind of industrial development that was well suited to a suburban setting, as these parks aesthetically mimicked both the university campus and the white-collar suburb. Ultimately, O'Mara stated that even *without* the ideologically loaded Cold War spending pattern, science would probably still have 'suburbanised'. But, she continues, the high degree of it, and the clustering in specific regions, was highly dependent on the geography of the military-industrial-academic complex. Federal suburbanisation policy reorganised urban space in such a way that new networks of innovation and production between university and industry could emerge, 'away from the distractions and disorder of the changing industrial city'.[200]

So far, I have described the post-war development (and demise) of campus-like industrial research laboratories and more generally the places and geography of the 'military-industrial-academic complex'. These histories of the public and private organisation of scientific research intersect in the next section at Stanford University. After 1945, this private elite institute of higher education in Palo Alto, California, came to serve as prototype for federal science policymakers. It has been regarded, both by contemporary commentators and historians, as archetype of the 'Cold War University'. Globally Stanford has in addition become known as the nucleus of a model of science-based economic development: Silicon Valley.[201] Compared to preceding discussions of particular places, the treatment of the Stanford case will be relatively elaborate because it ties together the previously discussed twentieth-century developments in the spatial organisation of research. By zooming in on the pastoral Palo Alto foothills where Stanford is situated, it is possible to expose the architecture, geography and circulation of that exemplary late-modern utility spot—the research park.

197 O'Mara, 1–2.

198 O'Mara, 27–36.

199 O'Mara, 44.

200 O'Mara, 1–2.

201 Lowen, *Creating the Cold War University*, 6–11; O'Mara, *Cities of Knowledge*, 97–98.

2.7 Stanford University: From Research Park to Silicon Valley

From its inception, Stanford University has been oriented on research and its practical application.[202] Already before the war, close ties with the local business community in the Palo Alto region existed. Especially for electronics, it has been argued that cooperative structures between university and industry existed since the beginning of the twentieth century.[203] During the war, however, Stanford was not very active and acquired almost no defence contracts. Instead, most Stanford scientists dispersed over the nation, to work at laboratories geared to the war effort, like those mentioned before at MIT, Harvard and Los Alamos. Frederick Terman was one of those scientists. He had gained his PhD at MIT under Vannevar Bush, and during the war worked at the Radio Research Laboratory (RRL) at Harvard University. This lab was itself a spin-off from the MIT RadLab.[204] When Terman returned to the west coast in 1945, as dean of the School of Engineering, he concluded that Stanford had been 'underprivileged' during the war.[205] As dean he hoped to undo this harm by remaking his faculty in MIT's image. To this end, he initiated cooperative programmes with industry, strengthened ties to electronic firms and turned Stanford into a centre of radio research with a focus on real-world problems of industry.[206]

Initially, Stanford University did not aspire to rely on federal funding for its remaking. Like many private institutions, Stanford cherished its independence from government involvement, and it pursued a position like Harvard: focused more on basic science than relying on military funds. However, to acquire such a privileged position, it had to be 'hungrier' than its east coast competitors: this drove dean Terman, for example, to accept ONR funds for two electronics research laboratories. Eventually, Stanford secured a well-defined niche and would fully participate in the huge future of electronics. However, electrical engineering was the outlier. For most other university departments academic advancement was a more 'grudging process'. Funds from private sources played a significant role in other departments, like the support of the Ford Foundation for Institute for Advanced Behavorial Studies and the Business School, for example, were stimulated by the Ford Foundation. When Terman became provost of Stanford in 1955, he hoped to apply the lessons from electrical engineering, MIT and Harvard to the entire university.[207] Even in the federal political economy of research, individual university administrators could play motivational and catalysing roles. For Terman, Stanford was a space to realise his technocratic model of society, with an essential role for the university as efficient

202 Leslie, *The Cold War and American Science*; Hall and Castells, *Technopoles of the World*; AnnaLee Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128* (Cambridge, MA: Harvard University Press, 1996); Lowen, *Creating the Cold War University*; Martin Kenney, ed., *Understanding Silicon Valley: The Anatomy of an Entrepreneurial Region* (Stanford, CA: Stanford University Press, 2000); O'Mara, *Cities of Knowledge*, 99.

203 Timothy J. Sturgeon, "How Silicon Valley Came to Be," in *Understanding Silicon Valley: Anatomy of an Entrepreneurial Region*, ed. Martin Kenney (Stanford, CA: Stanford University Press, 2000), 15–47.

204 Stuart W. Leslie and Robert H. Kargon, "Selling Silicon Valley: Frederick Terman's Model for Regional Advantage," *Business History Review* 70, no. 4 (1996): 439–40.

205 O'Mara, *Cities of Knowledge*, 106.

206 Stuart W. Leslie, "The Biggest 'Angel' of Them All: The Military and the Making of Silicon Valley.," in *Understanding Silicon Valley: Anatomy of an Entrepreneurial Region*, ed. Martin Kenney (Stanford, CA: Stanford University Press, 2000), 51–53.

207 Geiger, *Research and Relevant Knowledge*, 120–25.

and rational production centre of scientific and technical knowledge and expertise.[208] I will explore how this played out practically and spatially for the exceptional case of research in electronics at Stanford University.

Electronics research: ERL, SRI & SIP

In the post-war period, a 'triangular nexus' emerged around electronics, tying together electrical engineering at Stanford, the Department of Defense and the young electronics industry. Booming electronics firms cultivated continuing relationships with the academic laboratories. Varian and Hewlett Packard are especially interesting in this respect: both were founded by Stanford alumni who were actively stimulated by Terman to start companies. The ties were so close that Varian, for example, had access to faculty laboratories in exchange for a university stake in any resulting patents. More practices existed in which industrial and academic scientists came into contact, could exchange skills, ideas and instruments, and through which they visited each other's site of work: honorary cooperative programmes, faculty consulting and advanced courses for industrial scientists.[209] To grasp the relations between Stanford and industry, and the emergence of a 'city of knowledge', I will highlight the histories of three places of exchange, buffer organisations, or utility spots for electronics research: the Electronics Research Laboratory (ERL), Stanford Research Institute (SRI) and the Stanford Industrial Park (SIP)—arguably the first research park.

At the Electronics Research Laboratory (ERL) Terman, then Dean of Engineering, actively used the triangle between university, industry and the military to secure academic control over the research agenda. Partly, he was trying to reproduce the dynamics that he had observed at Harvard's RRL during the war, where scientists were giving directions to, rather than taking them from industry, while being paid by the military. At the ERL at Stanford, Terman reproduced similar systematic liaisons, based for a large part on (often free) consulting services. In his reading, the university scientists did not need industrial patronage, since they could be well funded through federal channels. Industry, however, did need academic expertise and graduates. Terman used this situation to the university's advantage, by declining industrial subcontracts and instead proposing a system of informal consultancy. In this way, the Stanford scientists and engineers controlled the interaction with industry and as such established the in their eyes 'appropriate' linear relationship between the university expertise and technological development. In the early 1950s, Terman carved out a powerful niche for the ERL, which functioned as mediator between the military and private industry, acting both as consultant and contractor.[210]

208 Lowen, *Creating the Cold War University*, 14–15.

209 Leslie, "The Biggest 'Angel' of Them All," 52–56.

210 Lowen, *Creating the Cold War University*, 123–28.

At the Stanford Research Institute (SRI), established upon instigation of the same Terman, similar dynamics of exchange, funding and control emerged. Stanford President Donald Tressider had envisioned SRI as an embodiment of an opposite ideal of the relationship between university and industry: contract research on particular problems, defined by industry patrons. This mirrored pre-war practices between Stanford and the Sperry Gyroscope Company. Many academics, including Terman, disliked them however. Terman instead took the relationship with Varian as exemplary arrangement of the university-industry interaction: long-standing friendships, geographical proximity, as well as financial and legal bonds. A conflict ensued between Tressider and Terman over the organisation of useful research at the SRI, and this boiled down to different epistemological distinctions, which ultimately were expressed spatially. Tressider characterised different types of research in terms of their funding—either government or industry sponsored—and he wanted to emphasize industrial research to avoid political conflict. Terman, on the other hand, had adopted an epistemic model from Bush's *Endless Frontier*: based on the distinction between basic and applied research, academic staff should work on fundamental issues at the beginning of the whole R&D process, while the SRI should focus on the intermediate process of applied science. Similar to the RLE, this would avoid corporate control over research priorities. Terman, ultimately, used SRI to his benefit by allocating all federal contracts for *applied* research to the institute: this separated applied research spatially from regular academic research in departmental laboratories, while also sustaining close relations to the military patrons.[211]

By 1947, the Navy, through the ONR, accounted for 70% of SRI's external funding. Tressider became increasingly concerned about the very small contributions of private industry to SRI, and higher education in general. After the Korean War, which further boosted federal funds, ONR desired more control over the research projects they funded. Most importantly, this led to the classification of *all* research under defence contracts. Both 'basic' and 'applied' projects, the former taking place in ERL and the latter in SRI, were now subjected to secrecy restrictions. Terman's dislike of 'applied' research in academic laboratories had been decreasing—even using contracts for applied research to cover part of professors' salaries—but he could not accept the ERL research's becoming classified. Thus, Stanford established a new laboratory, the Applied Electronics Laboratory (AEL). Administratively, Terman reorganised the ERL and AEL into 'one' lab, the Stanford Electronics Research Laboratory (SERL), but in practice—and in space—classified and unclassified research were now separated physically in different buildings.[212] By 1967, the success of SRI in acquiring defence contracts would

211 Lowen, 113–17.

212 Lowen, 138–42.

even lead to its outgrowing the university in terms of size and reputation.[213] Partly for this reason, but also because students and faculty protested at its entanglement with the Department of Defense, SRI was spun off as an independent institute in 1970. The defence contracts had to be put at 'a distance' from the university.[214]

If not at the SRI, contact with industry was warmly welcomed at the Stanford Industrial Park (SIP), established in 1951. Terman, who initiated the SIP, also formalised the relations between industry and the university through the Honors Cooperative Program and the Industrial Affiliates Program, both of which responded to the need of companies for access to information, advanced training and potential employees. The Affiliates programme was introduced to Stanford from MIT by John Linvill in 1954. Linvill first set up a microelectronics affiliates programme that mimicked the support system for the establishment of the Laboratory for Nuclear Science and Engineering at MIT, which received large endowments from industries in exchange for access to research results.[215] Although the scope of the Stanford Affiliates programme in solid-state microelectronics was national in scope, there was also the idea that proximity of these companies would enhance the likelihood of such ties.[216] HP and Varian not only served as primary examples and customers for these programmes but also were the first tenants of the Stanford Industrial Park. Also for Lockheed Corporation, the giant aeronautics manufacturer from southern California, the close relations to the Stanford faculty and laboratories were a good reason to lease a facility at the Industrial Park. The SIP became the centrepiece of the university-centred economic development taking place in Palo Alto.

It was not the first industrial park, but its spatial proximity to and close association with the university were distinctive. However, there were ulterior motives for the university to develop their land into a business park. Stanford was extremely privileged in terms of the size of the land endowment they had at their disposal. But up to the 1950s, they had been making only small profits on it. After the war, tax regulations were changed in such a way that it became highly unfavourable *not* to develop land. Municipalities could even requisition private land for public purposes if that was regarded necessary for the economic development of the region. Thus, in the late 1940s, university administrators commissioned several advisory reports to decide on the use of the undeveloped land. An industrial purpose fitted better with the university's interests than, as one report advised, a residential area. The Stanford Industrial Park came to occupy about half of the available land in the proximity of the university and was established with the purpose to 'strengthen Stanford's position as a top national research university'. Institutionally Stanford would benefit,

213 Leslie, *The Cold War and American Science*, 243–44.

214 Leslie, "The Biggest 'Angel' of Them All," 66.

215 Elizabeth Popp Berman, *Creating the Market University: How Academic Science Became an Economic Engine* (Princeton, NJ: Princeton University Press, 2011), 26.

216 Lowen, *Creating the Cold War University*, 130–31; Berman, *Creating the Market University*, 34; O'Mara, *Cities of Knowledge*, 124–25.

its administrators thought, from profitable connections to local business and the reputation of a net contributor to regional economic development.[217]

As space, the Industrial Park was a combination of various planning traditions, cultural currents and economic developments. According to Terman the SIP would serve as example of the peaceful coexistence between high-tech industrial development and affluent suburban life. This was achieved through high standards for the types of companies that were welcome and the aesthetics of the buildings and the surrounding space. Low-rise, cleanly modernist architecture, lush greenery and spatially distant facilities made this new type of industrial development mirror both suburban space and university campus. This recreated a pastoral environment in which, arguably, scientific creativity would flourish and which would attract and please a scientific and technological workforce. Again, the demands of the elite workers were dominant in shaping the spatial model of useful research.[218] The pastoral aesthetics of the research park related to cultural currents (amongst the white middleclass) about the rejection of the cities and the 'old' heavy industries, in favour of the healthy outdoors.[219] The mirroring of the campus planning tradition, seen above also in corporate settings, could be observed at Stanford Industrial Park where the combination of pastoral isolation, separation of functions and comprehensive design were applied to an industrial area.

This peaceful coexistence was as much hope as reality. In the late 1950s, several community organisations from Palo Alto, as well as Stanford alumni, opposed the expansion plans of the Industrial Park into the foothills that had been so characteristic of the Stanford campus. Although the image of high-tech industries was always 'clean', residents around Stanford worried and complained about several forms of pollution. Also, they successfully challenged the zoning buffers between industrial buildings and surrounding residential areas. Ultimately, Stanford University was able to forge a strong alliance with willing local government and the local chamber of commerce, so that expansion of the park could proceed. But, as they catered to the needs of industry, and chased additional leasing income, they were generally disdainful of community concerns. The eventual rebranding of the Industrial Park into 'Stanford Research Park', in 1961, was an attempt to defuse future community suspicion.[220]

Around Stanford University and its Research Park high-tech industrial activity in advanced electronics, especially semiconductors based on silicon, grew to such an extent that, from 1970 onwards, it would be referred to as 'Silicon Valley'. Stanford provost Terman is often remembered as the 'father' of this region. His various initiatives in strengthening the ties between academic science, industry and federal patrons

217 O'Mara, *Cities of Knowledge*, 111–20.

218 O'Mara, 67–68.

219 O'Mara, 101.

220 O'Mara, 132–39.

definitely were catalysts. It is also an example of the ingenuous ways in which individual university administrators, like Terman, used the relation to federal government not as an alternative to industrial patronage, but as means to achieve their own aims of industrial support, consulting opportunities and employment.[221] But all this came at a cost and could take place only because of a specific political and geographic context. Ultimately, it did lead to the accommodation of research programmes to the interests of patrons, for example in electronics but also in behavioural sciences. Also the eventual success of the Stanford Research Park was due to 'extraordinary circumstances' and favourable historical conditions: the location amidst a booming wartime economy, desirable residential areas, an ecosystem of electronics innovation that dated back to pre-war times, the emergence of unobtrusive, white-collar technological spin-offs, the rising political status of science, a wealthy, entrepreneurial, politically savvy university with a large endowment of undeveloped land and close ties to local civic leaders.[222] Many of these factors were often lost on imitators who hoped to replicate this type of university-based economic development.

Circulation of the Stanford Model

Since the name Silicon Valley was introduced, in the early 1970s, it came to stand for a myth of entrepreneurial individuals and instantaneous development.[223] This made, and still makes, Silicon Valley appealing to politicians, businessmen and scientists across the world. However, Stanford and the Palo Alto region had some, partly coincidental, advantages. The booming area of high-tech entrepreneurship did not arise 'in spite of' government involvement: rather, the 'entrepreneurial drive', also amongst academics, stemmed largely from the competitive dynamics set up by the federal government.[224] Thus, it might be clear now that a much broader context and longer history of academic-industrial development in the region, in electronics especially, has to be taken into account to understand its emergence as high-tech ideal of economic development. Silicon Valley was the result of a historical co-evolution of high-tech industry and a high-tech academic institution between which horizontal relations of interdependence and collective learning existed. Its famed firms, like Varian, Hewlett-Packard, Shockley and Fairchild, were not the first movers of this model, but rather an outcome of these historical conditions.[225] Place and historical context set the limits for path-dependency of a regional economy.

Already in the 1950s, many admired the Stanford Industrial Park as a model for regional economic development. For example, at the 1958 World Fair in Brussels it featured in a colour film of 'Industrial Parks USA'.[226] Following this exhibition, many international visitors passed by the actual

221 Lowen, *Creating the Cold War University*, 236.

222 O'Mara, *Cities of Knowledge*, 107; Leslie, "The Biggest 'Angel' of Them All."

223 Saxenian, *Regional Advantage*; Gwendolyn Wright, "The Virtual Architecture of Silicon Valley," *Journal of Architectural Education* 54, no. 2 (2000): 88–94; Christophe Lécuyer, *Making Silicon Valley: Innovation and the Growth of High Tech, 1930–1970* (Cambridge, MA: MIT Press, 2006).

224 O'Mara, *Cities of Knowledge*, 10–13.

225 Sturgeon, "How Silicon Valley Came to Be," 16.

226 O'Mara, *Cities of Knowledge*, 127–28.

Stanford site to see for themselves 'this wonder of modern industrial development'. Also within the United States, various cities and localities tried to recreate the same kind of dynamics around 'clean' industries, notwithstanding major contextual differences. And many universities, eager to enter into real estate and economic development, looked at Stanford as instructive example. Berkeley city officials, for example, toured the Stanford Industrial Park in 1961 to assess whether they could engage in similar economic activities. They returned north 'painfully aware' of the spatial, demographic and political differences between Berkeley and Palo Alto that made it impossible to copy the Stanford model (even though it is only a one-hour drive, if traffic runs smoothly). Berkeley lacked available space and a similar pro-business attitude within its university administration. Also, they noted a difference in the socio-economic make-up of the two towns: the racial and economic homogeneity of Palo Alto, or its affluent whiteness, made it especially appropriate for science-based economic development. Minorities were underrepresented in science and technology while the whiteness of the Palo Alto area made it appealing to professionals during a 'time of racial change and social upheaval'.[227]

From the mid–1960s onwards Terman, by then retired, played a pivotal role as consultant in attempts at circulation of the Stanford model of regional economic development, in other American states and in Korea.[228] In these cases, both imitators and consultants usually overestimated the importance of the educational institute as catalyst and underestimated the importance of a cooperative business culture and generous government subsidies. Post-war defence subsidies had fuelled the economic development of the region, in which the Stanford Research Park flourished. It was also not always sufficiently realised how different large vertically integrated firms and small high-tech start-ups fitted in the science park model. The start-ups that spread in Silicon Valley had actively sustained open and informal relations with external parties—both academics and other companies—which benefitted from proximity. More traditional companies, however, moved close to excellent institutions of higher education not for direct knowledge transfer, but because they hoped to stay competitive on the scientific and technological job market. Research parks were a way to demonstrate ties to a university and convince a highly educated (and in demand) workforce to move to, e.g., Texas or New Jersey.[229]

Most studies that deal with the imitation and circulation of the Stanford Research Park and Silicon Valley model come to similar conclusions: a successful outcome relies heavily on local implementation, social context and historical conditions.[230] O'Mara, for example, has compared developments of research parks at University of Pennsylvania, in Philadelphia, and at

227 O'Mara, 127–30.

228 Leslie and Kargon, "Selling Silicon Valley."

229 Leslie and Kargon, 445–47; Leslie, "The Biggest 'Angel' of Them All," 59–61.

230 Sturgeon, "How Silicon Valley Came to Be," 47.

Georgia Tech, in Atlanta. In Philadelphia, the racial and class politics of an urban neighbourhood—instead of a homogeneous and affluent suburban area—proved incompatible with the university model of high-tech development. Georgia Tech, on the other hand, could not play the same role as Stanford, as it lacked the political and economic engagement with the local community.[231] Internationally, the replicability of Silicon Valley in localities from East Asia to Europe appears even more problematic. The export of the silicon dreams were based mostly on glossy but weakly studied consultancy reports that distilled all too simple formulas of the economic success.[232] For the United Kingdom, Doreen Massey, David Wield and Paul Quintas likewise have observed a widespread, superficial assumption that a combination of a prominent academic community and a growing high-tech industry was the causal, and therefore reproducible, factor behind Silicon Valley.[233] Hans Weiler has identified physical proximity and cultural affinity as the pillars under the Palo Alto success story. As Weiler notes, these depend on a historically developed 'knowledge ecology', which makes international travel of the model unlikely.[234]

The attempts to circulate and replicate the Stanford model of science-based economic development can be situated in a broader history of transnational circulation of knowledge in the post-war period. The *hegemonic* position of the US in science existed in a tense competition, and sometimes conflict, with the Soviet Union in the first three to four decades after the Second World War. American hegemony thus existed mainly in the 'Western' or capitalist part of the world, as well as in decolonising low-income countries. In these regions of the world, the examples of MIT, Stanford Research Park and Silicon Valley were, at different times, admired and functioned as models. This was also actively stimulated by the 'missionary fever' to export American models of research organisation. Visiting Europeans were often both fascinated, by the energy, efficiency and organisation, and contemptuous, of the emptiness and uniformity of mass production and consumption.[235] However, models are abstractions of reality, and need to be accommodated in each instance of application. This makes imitation and circulation of utility spots, especially transnationally, a great challenge, if not improbable.

Ultimately, many attempts at imitating the 'putative advantages of the US regime' for useful scientific research stranded on social and cultural barriers. This does not, however, warrant O'Mara's conclusion that *only* in the US 'cities of knowledge' are the 'organic outcome' of policy structures, while abroad they are *just* imitations of the American model.[236] Also Weiler's claim that 'Europe' lacked proximity between academic and industrial communities in spatial, epistemic and cultural terms, is too simplistic.[237] Such assertions recreate the lack of attention for local context that missionaries and imitators of Silicon

231 O'Mara, *Cities of Knowledge*, 7–9.

232 Hall and Castells, *Technopoles of the World*, 8.

233 Doreen Massey, David Wield, and Paul Quintas, *High-Tech Fantasies: Science Parks in Society, Science and Space* (Routledge, 1992), 5–6.

234 Hans N. Weiler. "Proximity and Affinity: Regional and Cultural Linkages between Higher Education and ICT in Silicon Valley and Elsewhere." In *The Use of ICT in Higher Education: A Mirror of Europe*, edited by Marijk van Der Wende & Maarten van de Ven, 277–297. Utrecht: Lemma, 2003.

235 Krige, *American Hegemony*, 261–66.

236 O'Mara, *Cities of Knowledge*, 9–10.

237 Weiler, "Proximity and Affinity."

Valley embodied; instead, I will demonstrate in subsequent historical reconstructions of European developments that hegemonic spatial models of useful knowledge production were actively used and appropriated in political-epistemic localities there.[238]

2.8 Increasing Space for Industry and Commercialisation on Campus

The story so far has focused on the most intense period of the Cold War, between 1945 and 1968, in which a huge bubble of federal funding for scientific research was inflated. In US historiography less attention has been paid to the subsequent 'comprehensive deflation of that bubble', even though this created the dynamics that still structure scientific practice today.[239] Some argue that although the amounts of federal patronage fluctuated between 1960 and 1980, the basic triangular relationship between government, industry and science persisted.[240] But the focus of federal science policy, and the political notion of the usefulness of publicly funded scientific research, shifted from national security to economic competitiveness.[241] We can capture this political-epistemic shift, and the concurring cultural and scientific developments, by focusing on four hybrid spaces on the fringes of campus in the period 1960–1980: contract research institutes embody the removal of military research *from* campus, whereas research parks, University-Industry Research Centers and Technology Transfer Offices typify the attraction of industrial actors *to* campus.

First of all, new buffer organisations, like SRI at Stanford, dealt with contract research for the federal government, in particular the military, and emerged in response to financial success of the interdepartmental labs *and* anti-war activism. From the late 1960s onwards student protests against the war in Vietnam and Cambodia fuelled controversies over military research *on* campus.[242] This explicit moral revaluation of military patronage put pressure on the all-pervasive and tacitly accepted alliance between science and national security. These protests participated in a broader culture of challenges to the public image of science and its self-proclaimed freedom, following issues like environmental pollution (Silent Spring), weapons research (Agent Orange) and general responsibility for social effects (thalidomide). Discontent with military support might have been brewing longer though, also amongst faculty: as the federal research economy drove one segment of academics towards military sponsors, it drove the remaining segment further away from any applications.[243] The friction that this produced was reinforced by the ideological representation of the nationalised system of science as an autonomous invisible college of creative individuals, which allowed academics to

238 Jeroen van Dongen and Friso Hoeneveld, *Cold War Science and the Transatlantic Circulation of Knowledge* (Leiden: Brill, 2015).

239 Cyrus Mody, "How I Learned to Stop Worrying and Love the Bomb, the Nuclear Reactor, the Computer, Ham Radio, and Recombinant DNA," *Historical Studies in the Natural Sciences* 38, no. 3 (2008): 457.

240 Lowen, *Creating the Cold War University*, 235.

241 Ann Johnson, "The End of Pure Science: Science Policy from Bayh-Dole to the NNI," in *Discovering the Nanoscale*, ed. D. Baird, A. Nordmann, and J. Schummer (Amsterdam: IOS Press, 2004), 217–30.

242 Leslie, *The Cold War and American Science*, 243–44.

243 Mody, "How I Learned to Stop Worrying," 456–61.

believe in ivory tower isolation of basic science.[244] To deal with the friction and disparity between interdepartmental labs lavishly funded from military sources and other faculty and activist students, these labs either divested or remoulded their purpose. Organisations like SRI at Stanford and MITRE at MIT (founded already in 1958) were established at a greater administrative and physical distance from academic departments to shake off the military image. When academic linkages were broken, these contract research institutes did not necessarily suffer, partly because informal relations often remained in place. But in the campus imagination, the military was banned at least to the periphery.

The first research parks, or 'cities of knowledge', in which companies could locate proximate to academic institutes, emerged at the intersection of Cold War science policy, industrial dispersion and mass suburbanisation.[245] The history of these utility spot can be traced back to the 1950s, as described in the previous section. Subsequently, the research park development 'mushroomed' moderately in the 1960s and dipped again in the 1970s, so that only a handful of parks can be considered a success (amongst which Stanford). Universities underestimated the difficulty of convincing companies of the comparative advantage of proximity and no additional public funds were available to develop the parks further.[246] It was only in the 1980s that the model of the research park spread more widely and successfully with the support of local and state governments, which hoped for technology-based economic development.[247]

Only with public support could the research park model become more viable for universities, which in addition hoped to gain income from industrial tenants. From the side of industry, interest in locating R&D close to universities grew. This is because in the late 1970s firms increasingly outsourced their research activities on the global marketplace, to new private R&D corporations, but also often to 'academic and hybrid settings, like research parks and quasi-academic start-ups'.[248] In response to a globalising economy and consecutive oil crises, vertically integrated companies had to reform. Especially the semi-autonomous corporate research laboratories became a liability for these companies. The belief in basic science had already received some blows, as new blockbuster products failed to materialise and global competition threatened market positions. At the same time, previous inventions like the transistor became the battleground for scholarly and policy debates about the relationship between science and technology. Increasingly, funds for research and development would be reallocated to shorter-term projects.[249] Eventually, it became all together unprofitable to sustain a division with a campus ambiance and an external orientation. As an effect of these developments, research was outsourced to new hybrid spaces close to campus.

244 Mirowski and Sent, "The Commercialization of Science."

245 O'Mara, *Cities of Knowledge*, 1–9.

246 Berman, *Creating the Market University*, 26–34.

247 Berman, 150–51.

248 Mirowski and Sent, "The Commercialization of Science," 655–61.

249 Hounshell, "The Evolution of Industrial Research in the United States," 45–51.

University-Industry Research Centers are one example of the hybrid academic-industrial spaces that, for various reasons, started to spread to and flourish on university campuses in the US after 1978. Of course, multiple initiatives directed at the interaction between actors from university and business existed before. Above, I have touched upon the establishment in the 1950s of a research park and an industrial affiliates program at Stanford. Both these practices, as well as 'industry extension offices' that helped local small businesses with technical problems, emerged at several institutes of higher education but, according to Elizabeth Popp Berman, never became widespread. This lack of success would be due to a culture gap between the two worlds (different goals, values and reward systems) and, especially, an unconducive policy environment. By way of contrast, Berman discusses the success of University-Industry Research Centers (UIRC) in the 1980s. Similar to the research parks, some (engineering-oriented) universities, like MIT, Caltech and Rensselaer Polytechnic Institute, experimented with such spaces already in the 1960s and 1970s. But only after 1980 the UIRC spread widely with the help of lavish public funding and were regarded as acceptable spaces on campus.[250] By the end of the decade, NSF had supported about 40 centres in such fields as ceramics, robotics, material sciences, and microelectronics, often located at state universities. In an UIRC, faculty could periodically discuss research agendas with industrial sponsors, actively collaborate and publish with visiting industrial researchers, or facilitate annual meetings with industrial affiliates to share important results and meet potential employees.[251]

The UIRC was first modelled after the existing phenomenon of organised research institutes (or interdepartmental labs), in which many universities housed interdisciplinary research not fit for disciplinary departments; the only difference was the explicit goal of the UIRC to collaborate with industry.[252] The UIRC combined a well-known organisational form with the functionality of previous attempts, like the affiliates programme and extension office. After some early bottom-up instances of this type of space struggled, it was an experiment started by the NSF in 1973 that made the first of these centres viable. The NSF's break with its commitment to basic science by turning to fund cooperation with industry was actually a strategy to circumvent the political pressure to fund industrial research directly. The MIT-Industry Polymer Processing Program (PPP) was the biggest success and came to function as a model for all later UIRC funded by the NSF: it had a strong director in a powerful role—'a champion'—and worked for an industry with a pre-existing orientation to R&D and common, relatively fundamental technical concerns. The spread of this model took off after 1978 for two reasons: considerable funding by federal and state governments, based on the belief that the interaction

250 Berman, *Creating the Market University*, 11–34.

251 Berman, 119.

252 For the following discussion of UIRC I rely completely on Berman, 119–45.

between universities and industry was key for innovation and economic growth, and active promotion by the NSF of a replicable model for this interaction. Through programme evaluations, practice manuals and historical profiles of all centres, the NSF funded UIRC's had a 'disproportionate impact' on the spread of this utility spot that, according to later commentators, became 'the most prevalent means of providing technological development services for industry' in this period.[253]

A last novel place of exchange, to characterise the changes taking place in the 1970s and 1980s, is the Technology Transfer Office (TTO). Most universities nowadays house such a research support organisation, staffed by small teams of transfer officers, to make scientific advances available to
the public via patenting and licensing of research results.
The spread of TTOs is intimately tied to the 'watershed' in the history of organised university research brought about by the rise of biotechnology and commercialisation of research.[254] That many situate this break in 1980 is due to three legal innovations which all took place in that year and stimulated the practice of patenting at universities. The Bayh-Dole Act rationalised patenting rules, explicitly allowing universities to patent publicly funded inventions and to grant exclusive licenses to commercial parties. The Stevenson-Wydler Act became known for making technology transfer to the private sector a mission for federally funded research. Federal laboratories were subsequently required to establish Offices of Research and Technology Applications (ORTA). Lastly, the *Diamond v. Chakrabarty* Supreme Court decision made genetically modified microorganisms, and more complex life forms, patentable. Together, these developments did not so much make legal what was previously illegal, nor can it be proved that they led to all-round radical changes in practice. Ultimately these policy decisions had differential effects but did legitimise hybrid academic practices that in a previous decade had seemed dubious and made industrial-university collaborations more attractive. This was further improved by the 1986 Federal Technology Transfer Act (FTTA), which allowed government laboratories to engage in cooperative research and development agreements (CRADA) with other (private) parties and made it possible for employees to receive a part of the royalties.[255]

In this context, David Guston has described the model of the TTO as a boundary organisation that 'promotes collaboration between non-scientists and scientists over the assurance' of the productivity or, I would say, utility of research.[256] The boundary between science, politics and industry became permeable in this space, especially for the technology transfer specialists who mediated the commercialisation process. In addition, CRADAs introduced a formalised and interactive version of scientific discovery, collaboration and dissemination.[257] These types of developments have been reason for Philip Mirowski

253 Berman, 134–39.

254 Geiger, *Research and Relevant Knowledge*, 297–305.

255 David H. Guston, *Between Politics and Science: Assuring the Integrity and Productivity of Reseach* (Cambridge, MA: Cambridge University Press, 2000), 119–25; Johnson, "The End of Pure Science: Science Policy from Bayh-Dole to the NNI," 220–21; Berman, *Creating the Market University*, 94–114.

256 Guston, p. 115.

257 Guston, "Stabilizing the Boundary between US Politics and Science."

to argue that in these decades the 'meaning of knowledge' changed radically: by the end of the 1980s, neoliberal doctrines had transformed research and development, and the knowledge resulting from it, from a public good in need of state support into a fungible commodity in a sufficiently competitive market.[258] Bio- and information technology functioned as paradigms for this commercial knowledge production and so did places like research parks, TTOs and UIRCs.

Often, 1980 is thus identified as a hinge point for a fundamental change in the research system: the emergence of the 'market university', 'privatised' science, and commodified knowledge. Traditional explanations point to two factors: first, corporate outsourcing of R&D due to globalisation and, second, cash-strapped universities that, following the money, embrace contract research.[259] The relative defunding of scientific research by the military in the 1970s was an underlying cause for both developments. Firms had relied on defence contracts for basic research, and universities reinvented themselves as key contributors to economic competitiveness. More specifically, universities transitioned from a passive 'resource' model of their economic function—in which universities relied on their basic knowledge to help industries with their problems—to an active 'engine' model, in which the university became the source of innovations, companies and economic growth.[260] The quick growth of commercial biotechnology start-ups was the exemplary model of this; they attracted both manpower and resources by offering, once again, an 'academic' environment for creativity and innovation. This also forced universities and existing industries into new forms of cooperation.[261] As discussed above, many of these practices geared at the private sector pre-date 1980. But they were boosted significantly after 1980 by changes in policy, state funding of research and political-economic context.

The historiographical themes of distortion and linearity identified for the post-war political economy did not disappear but transformed with respect to the context and spaces of the 1980s. If the concern over the autonomy of university research was previously directed at the militarisation of research, commercialisation became the new concern. It was again a question whether the most societally useful science and technology were being produced, this time questioning the profit-driven interests of libertarian high-tech entrepreneurs on suburban science parks. The linear model of innovation was carried to its grave by many scholarly and (neoliberal) political commentators. By retrospectively projecting linearity, previous interventionist science policies were criticised by the figureheads of neoliberalism, from Reagan to Thatcher.[262] The necessity of (public funding for) basic research for technological development was explicitly questioned, which we have seen reflected in increasingly collaborative practices and hybrid spaces between the university and industry.

258 Mirowski, *Science-Mart*, 6–7.

259 Mirowski, 16–20.

260 Berman, *Creating the Market University*, 30–33.

261 Martin Kenney, *Biotechnology: The University-Industrial Complex* (New Haven; London: Yale University Press, 1986).

262 Mirowski, *Science-Mart*, 54–56.

2.9 Conclusion: Utility Spots and the US Historiography of Science

The societal legitimation of university research in the post-war United States has typically been described in terms of funding streams, policy measures and related discourses. In such narratives, an organisation like NSF receives a lot of attention. When we turn our attention instead to the spatiality of useful university research and the transfer of knowledge, other kinds of places and organisations become manifest and abstract concepts appear in architectural or physical terms. The survey of spatial themes in the US historiography of organised science in the twentieth century helps construct a historical-geographical methodological approach. Using the utility spot as a heuristic concept, the subsequent chapters examine the history, political economy and epistemology of utility in other geographical contexts.

To grasp the historical, political and epistemic aspects of the utility spot, two observations on American historiography are specifically relevant. First the historical observation that a large number of epistemic spaces can be identified where interactions between academic and extra-academic actors took place, were allowed or stimulated. What is more, it seems that the number of purposely built hybrid spaces increased after the Second World War. More informally, networks and exchange between university, government and industry actors already existed, sometimes even sharing (academic) space. The surge in hybrid utility spots does not necessarily entail a greater intensity of this cooperation, although it seems likely. What it definitely implies is a stronger public image of, and political-epistemic coalition behind, these particular modalities of useful knowledge production. The visibility of specific types of utility spots therefore indicates changing ideas and values in the socio-political context of universities. The removal of military-related research from campus in the 1970s, by housing them in new extra-academic institutes, and the subsequent establishment of industry-oriented spaces is a case in point.

Second, a historiographical reflection. Historians and sociologists of US science have posited a variety of concepts to describe some of the places discussed above. Geiger, for example, described various 'buffer organisations' or inter-departmental labs, distinguishing between centres and institutes. Leslie baptised similar places of exchange as 'organised research units'. Galison used 'trading zones' in his analysis of increasing cooperation between different types of specialists in big science environments. Berman identified the rise of an ideal type of University-Industry Research Centers in the 1980s. Guston dubbed the offices that mediated between science, politics and commerce 'boundary organisations'. O'Mara, lastly, spoke of 'cities of knowledge', in her study of university-based economic development of the research park type. The utility spot is not introduced as a challenge to these concepts; it is meant to encompass the complete scope of places that are considered necessary and desirable to streamline and improve relations between science and society. *Utility spot* functions therefore on a different analytical level: it does not so much provide a description of one concrete historical phenomenon, but rather is meant as a methodological approach to study the history of science, universities and their societal meaning in space.

From the survey of the US historiography it is possible to derive a set of spatial, geographic and architectural aspects of the utility spot concept. The actual *architecture* of these places can have intended and coincidental effects on the conduct of research. Organisational innovations aimed at solution of practical problems, like interdisciplinary collaboration as well as trading between different specialists (e.g. engineers, scientists and instrument makers), can be both enabled and obstructed by the physical constraints of a building. The strategy of architectural separation is applied to install a difference: between basic and applied research, between different funding streams, or between classified and unclassified activities. Often, issues of public legitimation and institutional responsibility of different types of research at universities inform such spatial choices. These boundaries are political-epistemic separations: they respond to a broader political economy of research and have epistemic consequences for the kinds of research that are considered acceptable on campus.

That brings us to location, because, as we have seen, it matters a great deal *where* a spot is located with respect to the university and societal space in general. Many proponents of new hybrid interactive spaces advocate a rather simple distance function of cooperation: proximity increases (the likelihood of) interaction between university researchers and non-academic actors. On-campus location then usually implies stronger ties to academic departments, whereas these decrease in strength the further away a utility spot moves from campus. Inversely, the relation to the external patron—industry, the military or the government—intensifies. My main concern is not the reality of these proximity effects, but rather their complex intertwinement with other social, cultural and political aspects. The case of Stanford University for example demonstrated that there were ulterior, financial motives to attract industry to campus. There is thus a politics to proximity, especially because the power of the argument is seldom challenged. Another example of the politics of proximity is the tendency of both traditional large-scale companies and smaller high-tech spin-offs to locate close to university campuses. Where the latter might have their reasons—because the entrepreneurs studied at that university or nourish active relations with a department there—the former often have one main rationale: to attract workforce.

Throughout the twentieth century, the relative scarcity of highly skilled scientific and technological manpower had far-reaching spatial consequences. From industrial research labs creating an 'academic atmosphere' on their grounds, multinationals relocating to the vicinity of famous universities or establishing entire R&D campuses with a futurist aesthetics, all the way to universities creating in-between places for entrepreneurial academic staff: they were all informed by a concern for sufficient scientific workers in their own institution. The relation between proximity and interaction can therefore also be more publicity than practice.

At various sites, we have also seen how utility spots fitted in larger political-economic *geographies*. Where patrons spend their dollars structures the development of scientific research and endorses what counts as useful. Institutional and regional favouritism, by the federal government and the military, created a nationally skewed geography of science in the US. Connected is the concern whether centralisation, decentralisation or even state-regulated regional spread is the best model for epistemic progress—both for science and for society. And it is not only about *what* works best; the image of useful science depends on such geographical patterns. The suburbanisation described above was a result of the geography of funding and created a very tangible, white and affluent, model of high-tech economic development. This model, known so well today as Silicon Valley, points us to the local and regional conditions for a particular place of exchange to function: the contingent co-location of production facilities and the importance of relations with local city councils, business community and societal groups.[263]

This, lastly, also significantly limits the likelihood of successful *circulation* of spatial models of useful knowledge production elsewhere. The desire to copy examples from abroad seems inexhaustible, but this is not often matched by a similar willingness to investigate these histories. The Stanford model and the case of UIRCs hint that a lot of work goes into the replication of utility spots. Instead, many have accepted simplified geometries of the relations established in a certain spatial example of knowledge exchange. In the period described above, especially linear and triangular models, between science and production, or universities, the military and industry, circulated to describe in highly simplified form the organisation and epistemology of the interactions between university knowledge production and societal use.

Architecture, location, proximity, geography, geometry and circulation: these six spatial themes intersect in utility spots. Combining these different aspects can provide tangible histories of utility spots as the products of local conditions, regional environment, national political economy and international geopolitics. The spatiality of useful research is

263 Others have called this the 'Corporate-Government-Education' environment of scientific research. Mirowski and Sent, "The Commercialization of Science," 665.

thus very specific to the context in which it emerges, and the political-epistemic alliances on which it relies. In the next few chapters, this tension will come to the fore when I reconstruct how spatial models of useful knowledge production circulated in debates about the Dutch and Western European organisation of research. The three main themes of architecture, location (including proximity and geography) and circulation (including geometry) inform, both explicitly and implicitly, these historical reconstructions.