Striving for influence

A comparative analysis of Niels Bohr's and John von Neumann's ideas about nuclear deterrence and arms control in the Cold War.

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'It is a commonplace that the history of civilisation is largely the history of weapons. In particular, the connection between the discovery of gunpowder and the overthrow of feudalism by the bourgeoisie has been pointed out over and over again. And though I have no doubt exceptions can be brought forward, I think the following rule would be found generally true: that ages in which the dominant weapon is expensive or difficult to make will tend to be ages of despotism, whereas when the dominant weapon is cheap and simple, the common people have a chance. Thus, for example, tanks, battleships and bombing planes are inherently tyrannical weapons, while rifles, muskets, longbows and hand-grenades are inherently democratic weapons. A complex weapon makes the strong stronger, while a simple weapon - so long as there is no answer to it - gives claws to the weak.'

- George Orwell, *You and the atomic bomb* (1945)

A b s t r a c t

During the later part of the Second World War and the course of the Cold War, politicians, public intellectuals and scientists fiercely debated the development and use of nuclear weapons. This study focuses on two scientists who contributed to this debate: mathematician John von Neumann and physicist Niels Bohr. While both had access to the political and military leadership of the United States and the United Kingdom, the reception of their ideas about nuclear deterrence and arms control differed. Political and military leaders met Von Neumann's ideas with interest, while Bohr's plea for openness and transparency was not taken serious. This study aims to offer explanations for this by providing a comparative analysis of Bohr and von Neumann's ideas about nuclear deterrence and arms control and their reception in the political-military leadership of the United States and United Kingdom in the context of the Cold War. Next to this, it investigates how Bohr's and von Neumann's ideas about nuclear deterrence and arms control were connected to the core of their scientific ideas. Also, this study will try to explore some explanations why the political-military leadership held certain preferences in the first place, which underlying mechanisms influenced the coming about of these preferences, and, even more important, whether these preferences were justified.

Gratitude

I could not have written this thesis without the support and advice of some persons I hold dear. In the first place, I would like to express my gratitude to Jeroen van Dongen, my supervisor for this thesis, and Bert Theunissen, one of my professors. I could not have wished for more straightforward and intelligent counsellors during my studies at the Institute for History and Foundations of Science. I appreciate their advice in issues both in and beyond the world of academia.

It is a pleasure to thank Martha Oolbekkink and Hans Brouwers. It would not have been possible to finish this project without the peace and quit of their home, especially compared to the pandemonium of The Hague's *Binnenhof*. Finally, I would like to thank Eline for having infinite patience with a boyfriend whose spare hours, weekends and holidays were spent on musty articles and dusty books. I promise I'll make it up to you.

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C o n t e n t s

Introduction

On May 16th 1944, a mere three weeks before the Normandy landings commenced, a 58-year-old, Danish physicist entered the office of the Prime Minister of the United Kingdom at Downing street 10, London. Niels Bohr, a Noble-laureate and one of the pioneers of quantum mechanics in the 1920s, had fled Nazi-occupied Denmark in the late summer of 1943 and travelled to the United Kingdom, where he learned about the Manhattan Project: a secret research and development program based in the desert of New Mexico, led by the allied forces. The aim of this project was to construct the world's first nuclear weapon.[1]

Bohr realized that the successful construction of an atomic bomb would change the nature of warfare forever. But despite the dangers that this new type of weaponry brought, Bohr found hope in the idea that nation states were now forced to negotiate with each other, not despite these new dangers, but *because* of them. 'It appeared to me,' Bohr remarked later in an open letter to the United Nations, 'that the very necessity of a concerted effort to forestall such ominous threats to civilization would offer quite unique opportunities to bridge international divergences.'[2] According to Bohr, 'openness about industrial efforts, including military preparations'[3] was the only chance the leaders of the world had to prevent a future competition for nuclear weapons between nation states.

Bohr did not succeed in convincing Prime Minister Winston Churchill and his scientific advisor Lord Cherwell, who also attended the meeting on the 16th of May, of this idea. The meeting proved a fiasco. According to Bohr's biographer Abraham Pais, Bohr felt 'scolded like a schoolboy'[4] by Churchill, who had not agreed with Bohr's analysis of the situation. According to Pais, Churchill had even remarked that he looked forward to receiving future writings from Bohr, although he expressed the hope that they 'would not be about politics'.[5]

Thirteen years after Bohr's failed attempt to convince Churchill of his ideas to stabilize the new nuclear world order, the Hungarian-American mathematician John von Neumann was diagnosed with pancreatic cancer.[6] Von Neumann, prompted by increasing anti-Jewish sentiments in Germany, had left his position at the University of Berlin in 1931 to take up a research-position at the Institute for Advanced Study at Princeton. He was naturalized as an American citizen in 1937 and from 1943 onwards, he played a prominent role in the Manhattan Project. As an advisor and consultant on nuclear strategy, von Neumann was an

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[1] See for a thorough account of the project R. Rhodes, The making of the atomic bomb (New York, 1986)

[2] N. Bohr, Open letter to the United Nations, in: F. Aaserud (ed.), Niels Bohr collected works volume two; the political arena (1934 – 1961), 171 – 189.

[3] A. Pais, Niels Bohr's Time; in physics, philosophy, and politics (Oxford, 1991), 499.

[4] Pais, Niels Bohr's Time, 501.

[5] Ibidem, 501.

[6] N. Macrae, John von Neumann; the scientific genius who pioneered the modern computer, game theory, nuclear deterrence, and much more (New York, 1992), 373.

influential figure in the Eisenhower administration, known for his 'hawkishness' and firm stance on nuclear deterrence.[7] Not long before his death, in January 1956, von Neumann left the hospital in a wheel chair to receive the Medal of Freedom from President Dwight D. Eisenhower. During the ceremony, von Neumann expressed the wish to be 'around long enough to deserve this honour.' Eisenhower replied that von Neumann would be with them for a long time. '*We need you*.'[8]

Research

Looking at the two histories presented above, a question arises. Why were von Neumann's ideas about nuclear strategy and stability in the newly created world order met with interest by military, diplomatic and political leaders, while Bohr's plea for openness and transparency was not taken serious? This study aims to clarify this problem by providing a comparative analysis of Bohr and von Neumann's ideas about nuclear deterrence and arms control and their reception in the political-military leadership of the United States and United Kingdom in the context of the Cold War. It investigates how Bohr's and von Neumann's ideas about nuclear deterrence and arms control were connected to the core of their scientific ideas: quantum mechanics in the case of Bohr and game theory in the case of von Neumann. By discussing the differences between Bohr's and von Neumann's ideas in the context of the political and military situation of the Cold War, an explanation will be sought for the varying receptions. Also, this study will try to explore some explanations why the political-military leadership held certain preferences in the first place, which underlying mechanisms influenced the coming about of these preferences, and, even more important, whether these preferences were justified.

Theoretical framework, periodization, demarcation

This study draws from both primary and secondary sources. Among the primary sources are the writings, books, essays and lectures of Bohr and von Neumann. Secondary sources consist of historical works, articles and volumes from scholars from the field of history of physics, history of mathematics, and history of foreign relations, in particular Cold War history.

The main focus of this study will be the period between 1942, the year that marks the start of the Manhattan Project at Los Alamos, and the year 1962, in which Bohr passed away, five years after von Neumann had died. This is also the year in which the Cuban missile crisis took place, which is generally regarded by Cold War historians as the moment at which Cold War hostilities had came to a head.[9] After 1962, American – Soviet enmities gradually subsided, which makes it an appropriate end for a study which aims to understand intellectual developments in high-risk political-military surroundings.

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[7] Macrae, John von Neumann, ix.

[8] Ibidem, 377.

[9] See for a thorough account of the development of the early Cold War C. Kennedy-Pipe, The origins of the cold war (Basingstoke, 2007)

A study aimed at providing an intellectual history of nuclear deterrence and arms control could contain multiple volumes, even when it is limited to the ideas of two scientists. Therefore, the amount of information on the political and diplomatic context of the Cold War is strictly limited. The main focus of this study is on the intellectual contributions of Bohr and von Neumann and their reception in the Cold War climate of the forties, fifties and early sixties.

Justification and historiographical positioning

A comparative analysis of the ideas of Bohr and von Neumann and their reception in the political-military leadership of the United States and United Kingdom does not just provide an insight in the course of events in the early Cold War. It also touches upon a broader theme: the relation between science and social affairs, such as war and politics. Historians of science have produced a flood of research that bears on the question of how political and social circumstances influence science, scientists and scientific developments. The amount of literature on the impact of science and scientists on political and social circumstances however, is limited.[10] Therefore, a comparative analysis of the nature of Bohr and von Neumann's ideas on nuclear deterrence and arms control and their reception in the political-military leadership offers insights into how receptive to scientific ideas military and political officials in fact are, and how their preferences are shaped.

Outline

Chapter one provides a general account of the scientific and diplomatic community in the United States at the dawn of the Cold War. It begins with a discussion of the exodus of European scientists in the 1930s, caused by the political turmoil in Germany. The fact that some of Germany's most promising scientific minds left Europe for the United States, and that some of them contributed to the coming about of the atomic bomb, makes it a relevant event to pay attention to. In the second section of this chapter, the construction of the first atomic bomb through the Manhattan project will be described. Furthermore, this chapter will discuss the early development of the nuclear strategy of the United States, which to a large extent took place at the RAND Corporation; a Santa Monica based military think-tank. The fourth section will discuss the history of the Cold War. It will cover the successful testing of the first Soviet atomic bomb and the development of the American hydrogen bomb. Both developments had a significant impact on the coming about of the arms race between the United States and the Soviets. This part closes with a discussion of the dominant schools of thought within American nuclear strategy and diplomacy.

Chapter two investigates these events from the perspective of Niels Bohr. After offering a short biography, in which, inter alia, his scientific contributions and his work at the Manhattan project are being discussed, this chapter explores how Bohr's political views were connected to his scientific work as a theoretical quantum physicist. The chapter ends by providing an overview of Bohr's diplomatic activities during the last fifteen years of his life.

[10] Exeptions are, for example, historical works on the history of social-darwinism and eugenics, such as C. Buskes, Evolutionair denken; de invloed van Darwin op ons wereldbeeld (Amsterdam, 2005)

Chapter three covers the life and views of John von Neumann. Just as the previous chapter, it commences by providing a biographical overview of von Neumann's life. Then, it analyses the connections between his scientific efforts and his political views. The chapter ends with an overview of von Neumann's political and diplomatic activities, dating from 1943 until his passing away in 1956. In the fourth chapter, questions on the nature of science and its influence on political and military organisations are being discussed. I will end with some concluding remarks in chapter five. In this section, the central question of this study is discussed: why did von Neumann's ideas about nuclear deterrence resonate more strongly in the political-military leadership of the United States and the United Kingdom than Bohr's ideas about transparency and arms control?

Chapter one
Physics and diplomacy at the dawn of the Cold War

''Given that knowledge,' he said, 'mark what we should be able to do! We should not only be able to use this uranium and thorium; not only should we have a source of power so potent that a man might carry in his hand the energy to light a city for a year, fight a fleet of battleships, or drive one of our giant liners across the Atlantic; but we should also have a clue that would enable us at last to quicken the process of disintegration in all the other elements, where decay is still so slow as to escape our finest measurements. Every scrap of solid in the world would become an available reservoir of concentrated force. Do you realize, ladies and gentlemen, what these things would mean for us?'
The scrub head nodded. 'Oh! Go on. Go on.'
'It would mean a change in human conditions that I can only compare to the discovery of fire, that first discovery that lifted man above the brute.''[1]

- H.G. Wells, *The world set free* (1914)

As the dialogue from H.G. Wells' 1914 novel *The world set free* quoted above shows, the intellectual history of the atomic bomb commenced decades before the first prototype was manufactured. To understand the intellectual, political and strategic implications of the coming about of the atomic bomb, it is essential to describe some developments in politics as well as in the scientific community in Europe and the United States first. In this section, the following elements are discussed. First, we will describe the exodus of European scientists to the United States in the 1930s, motivated by the political turmoil in Germany. We will see that some key players in the history of the atomic bomb escaped the European continent in this period, in most cases because of their Jewish background. Second, we will discuss the history of the Manhattan Project. In this part we will gain a fuller understanding of both the roles of some key players and of the goals and expectations that scientists, military officers and politicians had in mind with the project. In the third section, we will shift our attention to the years following the bombing of Hiroshima and Nagasaki, in which the groundwork for the United States post-war nuclear strategy was developed. The RAND Corporation, a Santa Monica based military think tank, played a central role in this development, which will be discussed in this part. The fourth section describes the events that accelerated the coming into existence of the Cold War: the successful manufacturing of a Soviet atomic bomb in August 1949 and the construction of the first hydrogen bomb. This part closes with a sketch of the state of affairs in international relations in the early 1950s, in which some dominant schools of military and political thought are discussed. It is against this background of scientific, cultural and political developments that we should see the intellectual contributions of both Bohr and von Neumann.

[1] H.G. Wells, fragment from The World Set Free, in: C.C. Kelly, The Manhattan Project; the birth of the atomic bomb in the words of its creators, eyewitnesses, and historians (New York, 2007) 22 – 24, 22.

1.1 An exodus of minds

At the time when Adolf Hitler took office as *Reichschancellor* of the Weimar republic in January 1933, the scientific communities at the universities of Berlin, Göttingen, Munich and Heidelberg flourished.[2] Not only did the universities house well-known German physicists such as Max Born, Werner Heisenberg and Albert Einstein, they also hosted numerous scientists from other European countries, such as Hungary. The Hungarian-Jewish physicists and mathematicians Eugene Wigner, Edwar Teller, John von Neumann, Theodore von Kármán and Leo Szilard had all travelled to the republic of Weimar during their early careers, in search for a place that offered the possibility to be surrounded with physicists who belonged to the top of their fields.[3] Physical chemist and historian of science István Hargittai lists ambition as the prime motivation for these non-German scientists: they 'arrived in Germany to seek university education and higher scientific degrees and eventually employment that corresponded to their aspirations.'[4] For many of these non-German scientists, their decision to settle in the Weimar republic was 'a turning point' in their lives.[5]

Much of this had to do with the status theoretical physics had achieved in Germany from the beginning of the twentieth century onwards. Traditionally, experimental physics had a higher status than the work of the theorists, but during the first decades of the twentieth century, the fame of experimental physics gradually subsided. This is particularly well illustrated by the establishment of the Institute for Theoretical Physics at the University of Munchen in 1906 by Arnold Sommerfeld. The 'steady stream of first-rate theorists'[6] the institute produced left many in the scientific community amazed, as a letter by Einstein to the director of the institute shows: 'What especially impresses me about you is that you have produced so much young talent, like stamping them out of the ground. That is something entirely unique.'[7]

The success of German science and the Weimar universities was not a coincidence. According to historian D.C. Cassidy, two social factors enabled German science to maintain the leading position throughout the First World War.[8] Cassidy states that physicists 'skilfully utilized their social standing to encourage public enthusiasm for German science and to gain the generous support of government bureaucrats and industrial philanthropists.'[9] Cassidy's second reason for the dominance of Weimar universities is that 'German scientists perfected the ideal of an apolitical, "value-free" science and the ideology of the so-called "self

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[2] Rhodes, The making of the atomic bomb, 117.

[3] I. Hargittai, Martians of science; five physicists who changed the twentieth century (Oxford, 2006), x.

[4] Hargittai, Martians of science, 33.

[5] Ibidem, 33.

[6] D.C. Cassidy, Uncertainty; the life and science of Werner Heisenberg (New York, 1991), 102.

[7] Cassidy, Uncertainty, 102.

[8] D.C. Cassidy, Heisenberg, German Science, and the Third Reich, in: Social Research, 59 (Fall 1992), 643-661, 643 – 644.

[9] Cassidy, Heisenberg, German Science, and the Third Reich, 644.

government" of science.'[10] This helped the universities to direct their full attention to the development of knowledge.

Considering these developments in the scientific community of the Weimar republic, it is no wonder that the greater part of scientific developments in the field of theoretical physics between 1905 and 1930 took place at German universities. Interestingly enough, scientists with a Jewish background, such as Einstein, Born, Teller and von Neumann, conducted a relatively large part of the research.

Anti-Semitism

Although to most of the physicists their Jewish background meant not much more than being part of a cultural tradition, some of them were practicing Jews.[11] From 1933 onward, however, their Jewish background would play a central role in their lives and careers for all of them.[12] Well before Hitler's coming to power, anti-Semitism ran rampant in Germany. As Einstein wrote in December 1919 to Paul Ehrenfest, an Austrian physicist who was naturalized as a Dutch citizen: 'Anti-Semitism is strong here and political reaction is violent.'[13] Three months later, students disrupted one of Einstein's lectures.[14] However, anti-Semitic sentiments intensified after Hitler's coming to power in January 1933. In May of this year, students and academics burned more than 20,000 books written by 'un-German' authors at the Opernplatz, near the University of Berlin.[15] In April 1933, a new civil service code was signed into law, declaring that every civil servant in Germany had to be 'of Arian origin'.[16] Considering that universities in Weimar Germany were state institutions, the code had an impact on German science that can hardly be overestimated. Historian of science Manjit Kumar describes the cleansing of the universities that took place, following Hitler's decision to ban Jewish scholars: 'Soon more than a thousand academics, including 313 professors, were dismissed or resigned. Almost a quarter of the pre-1933 physics community was forced into exile, including half of all the theorists. By 1936 more than 1,600 scholars had been ousted; a third of these were scientists, including twenty who had been or would be awarded the Nobel Prize.'[17]

This upheaval in the scientific community caused theoretical physicist and Noble laureate Max Planck, President of the prestigious *Kaiser-Wilhelm-Gesellschaft*, to approach

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[10] Cassidy, Heisenberg, German Science, and the Third Reich, 644.

[11] Hargittai, Martians of science, xxiv.

[12] Ibidem, xxiv.

[13] M. Kumar, Quantum; Einstein, Bohr and the great debate about the nature of reality (London, 2009), 129.

[14] Kumar, Quantum, 129. For a more thorough account of Einstein and anti-Semitism see: J. Van Dongen, Reactionaries and Einstein's Fame: "German Scientists for the Preservation of Pure Science," Relativity, and the Bad Nauheim Meeting, in: Physics in Perspective, June 2007, Volume 9, Issue 2, 212-230.

[15] Kumar, Quantum, 292.

[16] Ibidem, 292.

[17] Ibidem, 292 – 293.

Reichschancellor Hitler, hoping to persuade him to change his mind.[18] Hitler, however, would not budge. 'If the dismissal of Jewish scientists means the annihilation of contemporary German science, then we shall have to do without science for a few years'[19], he remarked. 'Hitler's campaign against the Jews cost him most of the greatest people I had studied with'[20], said Hungarian-Jewish physicist Eugene Wigner years later.

Exodus

Most physicists with a Jewish background who lived and worked in Weimar Germany looked for possibilities to leave the continent after the events of 1933. Historian of science I. Hargittai put together a list of physicists that were (more or less) well known in Germany in the 1930's, but who left in the years following Hitler's coming to power:

> 'Erwin Schödinger (who was not Jewish, but left anyway), Victor Weisskopf, Max Born, Michael Polanyi, Leo Szilard, Dennis Gabor, Walter Heitler, Fritz Haber, James Franck, Hans Bethe, Edward Teller, the Italian Enrico Fermi (whose wife was Jewish), and above all, Albert Einstein. Wolfgang Pauli lived and worked in Zurich, but he did not find Switzerland safe enough and also moved to America. Herman Mark first went to his native Austria, and then to America after the Anschluss. Paul Ehrenfest in Holland took his own life at least partly because of the threat of the Nazis.'[21]

Most of these physicists did not travel directly to the United States. A relative large share of them took residence in Great Britain. However, at the end of the Second World War, most of the leading scientists of Weimar Germany had settled in the United States. Historian Walter Laqueur has calculated that of the twenty-nine leading nuclear physicists that escaped Germany, eighteen ended up in the United States.[22] What these numbers demonstrate in the first place, is that Hitler, just as Wigner had remarked earlier, lost one of his major assets to his opponent (the allied forces) well before the second World War commenced: some of the best scientific minds of a generation. The fact that many scientists after their initial travel to Britain left for the United States is an interesting figure to keep in mind when we discuss the Manhattan Project.

1.2 The Manhattan Project

Eight years after most of the Jewish physicists from Weimar universities left Germany for Great Britain and the United States, the United States were drawn into the Second World War. The Japanese decided to attack the American air force base Pearl Harbour. Their army

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[18] Kumar, Quantum, 293.

[19] F. Gregory, Natural science in western history (Boston, 2008), 545.

[20] Hargittai, Martians of science, 65 – 66.

[21] Hargittai, Martians of science, 66.

[22] W. Laqueur, Generation Exodus: The Fate of Young Jewish Refugees from Nazi Germany (London, 2000) 155.

could not endure a long war in the Pacific because they lacked oil and iron resources, so the sooner the war with the Americans commenced, the better.[23] However, well before the attack on the American air force base the possibility of intervening in the war between the allied and axis forces was discussed by the political and military leadership of the United States. From the start of these discussions, the possibilities of new technological weapons were considered.[24]

Policy

This discussion started in 1939, when Hungarian-Jewish physicists Leo Szilard and Eugene Wigner drafted a letter that was to be sent to President Roosevelt through Einstein.[25] In this letter the physicists warned the US administration of the possibility that Nazi scientists could use large amounts of uranium (obtained through Belgian Congo) to set up nuclear chain reactions, which could possibly be used to construct 'extremely powerful bombs of a new type.'[26] This was probably the first time that the option of constructing a nuclear weapon was discussed inside the Oval Office.

Even though Roosevelt established a committee to investigate the possibility of constructing an atomic bomb by using uranium, the subject did not receive a lot of attention in the period between 1939 and 1941. This changed when Roosevelt established the *Office of Scientific Research and Development* in June 1941. The OSRD was a division lead by scientific director and presidential advisor Vannevar Bush that was to engage in research focussing on the possibilities of using uranium for military goals.[27] Inspired by a report by the British *Military Application of Uranium Detonation Committee* on the possibility of constructing an uranium bomb ('The committee considers that the scheme for a uranium bomb is practicable and likely to lead to decisive results in the war'[28]), Bush presented the relevant information to president Roosevelt, who asked for policy consideration by a small group of advisors.[29] As the historian Richard Rhodes remarks, it is interesting to notice that this small group consisted of politicians and military officers. None of the members involved were scientists.[30] However, all of them were aware of the daunting concerns that accompanied the program. 'If such an explosive were made, it would be thousands of times more powerful than existing explosives,

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[23] Rhodes, The making of the atomic bomb, 390 – 392.

[24] M.P. Leffler, The emergence of an American grand strategy, 1945–1952, in: Leffler, Westad, The Cambridge history of the cold war (Cambridge, 2010), 67 – 89, 78 – 79.

[25] A. Einstein, Albert Einstein to F.D. Roosevelt letter, in: C.C. Kelly, The Manhattan Project; the birth of the atomic bomb in the words of its creators, eyewitnesses, and historians (New York, 2007), 42 – 44, 42.

[26] Einstein, Albert Einstein to F.D. Roosevelt letter, 43.

[27] Rhodes, The making of the atomic bomb, 365.

[28] The *Military Application of Uranium Detonation Committee* report, in: C.C. Kelly, The Manhattan Project; the birth of the atomic bomb in the words of its creators, eyewitnesses, and historians (New York, 2007), 51 - 56.

[29] Rhodes, The making of the atomic bomb, 378.

[30] Ibidem, 378.

and its use might be determining', Bush remarked to Roosevelt in July 1941.[31] The outcome of this policy process was the establishment of the Manhattan Project, a project under the guidance of scientific director J. Robert Oppenheimer and executive director colonel Leslie Groves.[32]

Scientists

Even before the decision for a location was made (which primarily was to become the desert of Los Alamos, New Mexico), Oppenheimer started to meet with scientists he respected for their contributions in the field of nuclear physics.[33] It is interesting to notice that many of the men he held meetings with, were scientists that had fled Weimar Germany almost a decade earlier. Among them were the physicists Teller, Bethe, von Kármán, von Neumann and Szilard. Teller and Bethe would soon have dominant positions in the Project. Teller had already worked on the idea of constructing a hydrogen bomb (although Oppenheimer convinced him that an atomic bomb should be constructed first); Bethe was the author of three studies on nuclear physics that came to be known as the 'Bethe Bible' at the Manhattan Project site.[34] It is not hard to imagine that the physicists at the Manhattan Project were intrinsically motivated by the chance of doing state of the art research. But for those who escaped the European continent some years earlier it was also a chance to take part in a war to re-conquer their homeland. Bethe once stated that he was in it to oppose Nazism: 'After the fall of France, I was desperate to do something – to make some contribution to the war effort.'[35]

According to Hargittai, the same goes for the Jewish-Hungarian physicists: 'All were dedicated to democracy and were on the conservative side, with the exception of the leftist liberal Szilard.'[36] As we will see in the forthcoming chapters, the background of the physicists involved in the Manhattan Project influenced their stance on social affairs more than once.

Destroyer of worlds

The fact that (some) of the physicists involved with the construction of the atomic bomb were motivated by their aversion to Nazism does not mean that no ethical discussions took place during the three years that the scientists spent working on the Project. One of the strongest vocalists of the ethical dimensions of the Manhattan Project was the Polish-born British physicist Jozef Rotblat. When it became clear by late 1944 that the German nuclear bomb

[31] Leffler, The emergence of an American grand strategy, 80.

[32] Rhodes, The making of the atomic bomb, 447 - 448, 424 – 425.

[33] Rhodes, The making of the atomic bomb, 415.

[34] Ibidem, 415.

[35] Ibidem, 415.

[36] Hargittai, Martians of science, ix.

project had come to a halt in 1942, Rotblat decided to leave the Manhattan Project.[37] In an essay in which he reflected on his colleagues in the scientific community at Los Alamos, a disillusioned Rotblad described that the 'scientists with social conscience were a minority' and that 'the majority were not bothered by moral scruples.'[38]

Perhaps Rotblad's observations were a bit too pessimistic, considering the fact that various scientists involved in the project organized themselves and voiced their concerns about the bomb. A clear example of this is the report of the *Committee on political and social problems,* chaired by Noble Laureate James Franck, who expressed their disapproval of military use of the bomb. The report, sent to *The scientific panel of the interim committee* on June 11, 1945, stated that: 'If the United States would be the first to release these new means of indiscriminate destruction upon mankind, she would sacrifice public support throughout the world, precipitate the race of armaments, and prejudice the possibility of reaching an international agreement on the future control of such weapons.'[39]

The resignation of Rotblad and the committee led by Franck show that at least some of the scientists involved in the Project felt responsible for the outcome of the decision making process. The director of the metallurgical laboratory at the University of Chicago, A.H. Compton, often served as a mediator between scientists and the army in these matters, and wrote a memorandum to the assistant of project-director Groves on June 4, 1945, urging for a better understanding of the position of the scientists involved:

> 'The scientists will be held responsible, both by the public and by their own consciences, for having faced the world with the existence of the new powers. The fact that control has been taken out of their hands makes it necessary for them to plead the need for careful consideration and wise action to someone with authority to act.'[40]

The debate about the ethical implications of the construction of the bomb increased after the first successful testing of the bomb, after which Oppenheimer famously remarked that he had become 'Death, the destroyer of worlds,'[41] and following the first military use of the nuclear bombs on Hiroshima and Nagasaki in August 1945. Szilard, one of the first to mention the

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[37] C.C. Kelly, The Trinity test, in: C.C. Kelly, The Manhattan Project; the birth of the atomic bomb in the words of its creators, eyewitnesses, and historians (New York, 2007), 277 – 279, 277.

[38] J. Rotblad, Leaving the bomb project, in: C.C. Kelly, The Manhattan Project; the birth of the atomic bomb in the words of its creators, eyewitnesses, and historians (New York, 2007), 279 – 282, 280 – 281.

[39] The Franck Report, in: C.C. Kelly, The Manhattan Project; the birth of the atomic bomb in the words of its creators, eyewitnesses, and historians (New York, 2007), 288 – 290, 288.

[40] The Compton memorandum, in: C.C. Kelly, The Manhattan Project; the birth of the atomic bomb in the words of its creators, eyewitnesses, and historians (New York, 2007), 287 – 288, 287.

[41] K. Bird, M.J. Sherwin, American Prometheus; the triumph and tragedy of J. Robert Oppenheimer (New York, 2006), 309.

idea of an atomic bomb to President Roosevelt in 1939, 'felt a full measure of guilt for the development of such terrible weapons of war'.[42] The two positions of Bohr and von Neumann, which will be discussed in the forthcoming chapters, also illustrated the responsibility scientists felt for the correct deployment of the newly created pieces of weaponry.

1.3 'Wizard war': operations research and nuclear strategy

The developments in the desert of Los Alamos were not the only connections between science, the scientific community and the war. In his memoires, Churchill once described the Second World War as the *wizard war*, due to the prominent role of intelligence agencies and new technology, such as radar, nuclear research and Asdic (Sonar).[43] Although technology has always played a prominent role in the history of warfare, just like intelligence agencies existed ever since the French minister of police Joseph Fouché (1759 – 1820) organized professional research after his political opponents, Churchill's nickname for the Second World War is an appropriate one. M. Fortun and S.S. Schweber even describe the dominant role of science in warfare in the 1940s as a 'revolution':

> 'The revolution was brought about by the plethora of novel devices and instruments that were developed principally by physicists: oscilloscopes; microwave generators (magnetrons, klystrons) and receivers; rockets; the myriad of new vacuum tubes; novel electronic circuitry; computers; nuclear reactors; the many new particle detectors. Many of these devices had been introduced before the war, but in a relatively primitive state and on a piecemeal basis. It is the scale on which these devices and instruments become available that refurbishes the stage.'[44]

From this we can derive that scientific progress was not just one factor that influenced the outcome of the Second World War and that shaped the course of events in the Cold War, but that it was a social and cultural background as well, against which we should see all developments during the early Cold War.

This means that scientific reasoning and scientific methods were more and more influencing the outlook on warfare, organisations, and human behaviour during the 1940s and 1950s. Due to this development, the relationship between scientists, society and the state changed rapidly.[45] As historian E.P. Rau remarks, this newly established relationship between 'the scientist and the soldier was not without tension.'[46] We have already seen this above with the

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[42] Rhodes, The making of the atomic bomb, 749.

[43] P.K. Alkon, Winston Churchill's Imagination (Lewisburg, 2006), 155.

[44] M. Fortun, S.S. Sweber, Scientists and the Legacy of World War II: The Case of Operations Research (OR), in: Social Studies of Science November 1993 vol. 23 no. 4, 595 – 642, 598.

[45] E.P. Rau, Combat science: the emergence of Operational Research in World War II, in: Endeavour, vol 29, Issue 4, Dec 2005, 156 – 161, 156.

[46] Rau, Combat science, 156.

Manhattan Project. This evolving relationship between science and political and military organisations is also illustrated well by two other developments that influenced the structure of warfare and strategy during the Cold War; the rise of the field of operations research and the professionalization of nuclear strategy, both conducted at the RAND Corporation.

Operations research

According to Rau, Churchill's pet name for the Second World War is more than just a clever analogy. 'World War II became known as the "wizard war" because the cycles of developing countermeasures and counter- countermeasures to the weapons deployed by all sides drove rapid technological change.'[47] The main strategic asset during the war was no longer the advantage of brute force or larger stockpiles of weaponry, 'but also of tactics, training and the protocols required to maintain equipment.'[48] This led to the development of a new field of applied mathematics. One of its purposes was to manage, influence and project the results of competing systems.[49] The field was called *operations research* or *system analysis*.

The use of operations research in wartime started in the late 1930s and early 1940s. British and American military commanders were looking for ways to efficiently employ personnel and resources. This led to the deployment of civilians with a keen eye for mathematical solutions for efficiency related problems.[50] Sections of 'OR' civil scientists worked at Navy and Army Air Force bases, trying to solve problems regarding military activities. For example, teams of scientists would determine the most efficient way to patrol the airspace for hostile intruders with a limited number of aeroplanes. [51]

E.C. Williams, a junior scientific officer at the British Air Ministry in 1937, remarked that there were four main lines of research:

> 'The original work concerned equipment or weapons evaluation and redesign for better performance with its human operators; the analysis of specific operations to improve the tactics, and tactical experiments; the prediction of the outcome of future operations either in the tactical or strategic field with the object of influencing policy; and last but not least the study of the efficiency of organizations which wielded the equipment and weapons in battle.'[52]

According to historian M.W. Kirby, this was a highly successful enterprise: 'There can be no doubting the profound impact on the military mind of the contribution of civilian scientists in

[47] Rau, Combat science, 156.

[48] Ibidem, 156.

[49] Ibidem, 156.

[50] M.W. Kirby, Operations Research Trajectories: The Anglo-American Experience from the 1940s to the 1990s, in: Operations Research, vol 48, September/October 2000, 661-670, 662.

[51] Kirby, Operations Research Trajectories, 662.

[52] Fortun, Sweber, Scientists and the Legacy of World War II, 601.

enhancing the combat effectiveness of an entire military command at a critical stage in the war.'[53]

After the Second World War had ended, the US Government established the *National Research Council Committee on Operations Research*, 'to explore the potential peacetime use and expansion of *OR*.'[54] Rau describes the usability of mathematics to a number of fields:

> 'Wartime research into air defence has contributed to information theory and cybernetics; antisubmarine operations research anticipated simulation and war-gaming; and the contribution of operations research to strategic bombing was reflected in subsequent urban planning and development theories.'[55]

This growing popularity of operations research by the allied military staff in the Second World War is an important development. First, because it shows that military (and political) leaders were willing to take advise from scientists and to trust the results of their research. Second, their trust was rewarded by measurable results that saved crew, material or gas. Third, the changing character of the relationship between science and the military led to a cultural shift; gradually it became more accepted for military personnel and scientists to work together on government projects. While the state had always relied on science to conduct warfare, the relationship between the two had probably never been this close. The promises of scientific research were so impressive, that military and political leaders were looking more and more for some sort of 'general theory' of warfare.[56] When we analyse the receptions of both von Neumann and Bohr, this is an important fact to bear in mind.

Nuclear strategy at the RAND Corporation

The nuclear weapons developed at the Manhattan Project and the new field of operations research were dominant subjects on the agenda of the *RAND Corporation*, a think-tank that was founded on March 1, 1946.[57] During the Second World War, Air Force general H.H. Arnold asked his scientific advisor Theodore von Kármán, one of the physicists of Hungarian-Jewish decent that had fled Nazi-Germany a decade earlier, to write a report that provided options to employ scientists in peace time for military purposes.[58] Kármán came up with the concept of 'a university without students and with the Air Force as its only client.'[59] At the same time, Douglas Aircraft test pilot and airplane designer F.R. Collbohm was sent to

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[53] Kirby, Operations Research Trajectories, 662.

[54] R.E. Rider, Operations Research and Game Theory; early connections, in: E.R. Weintraub (ed.), Toward a history of game theory (Durham, 1992), 225 – 241, 225 – 226.

[55] Rau, Combat science, 160.

[56] P. Ericsson, The politics of game theory; mathematics and cold war culture (Dissertation at the University of Winconsin-Madison, 2006), 106.

[57] A. Abella, Soldiers of reason; the RAND Corporation and the rise of the American empire (Boston, 2008), 14.

[58] Abella, Soldiers of reason, 11.

[59] Ibidem, 11.

Washington DC to lobby for the founding of an organization that had to conduct military research.[60] In the fall of 1945, Arnold and Collbohm met and *Project Research And Development* (RAND) was established.[61]

RAND's organizational structure was unclear at best: it was provided with a starting budget of 10,000,000 dollars out of the Air Force budget, but it was housed in Douglas buildings during its first few years.[62] The director was Collbohm.[63] In 1948, 'Project RAND' was disconnected from the Douglas Company. 'The RAND Corporation' took residence in Santa Monica, California, and, according to their mission statement, conducted research to 'further and promote scientific, educational, and charitable purposes, all for the public welfare and security of the United States of America.'[64]

For years, the Air Force would be RAND's only client.[65] According to historian W. Poundstone, this provided the researchers at RAND with a large degree of freedom: 'RAND's scientists were permitted to study any issue that interested them, with the Air Force footing the bill, regardless of whether the Air Force had any interest in the subject.'[66] However, in turn, the Air Force could pose research questions to the scholars. These questions differed in depth and range, but most of them had a specific military character and touched upon subjects such as the impact of bombs, the optimal placement of anti-aircraft guns or the size of naval convoys.[67]

RAND's scholars

The scholars employed at RAND soon established reputations for themselves. Their nicknames in the national press ranged from the 'defence intellectuals'[68] and 'RANDsters'[69] to 'pipe-smoking, trees-full-of-owls-types'[70] working at 'the American academy of death and destruction.'[71] Labels such as these probably came with the research subjects the scholars at RAND were occupied with, combined with the mystery that surrounded the institute from the

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[60] W. Poundstone, Prisoner's dilemma; John von Neumann, game theory, and the puzzle of the bomb (New York, 1992), 85.

[61] Poundstone, Prisoner's dilemma, 85.

[62] Ibidem, 86.

[63] Ibidem, 86.

[64] RAND mission statement, online at: http://www.rand.org/about/history.html, last consulted at December 30th, 2012.

[65] Poundstone, Prisoner's dilemma, 87.

[66] Poundstone, Prisoner's dilemma, 87.

[67] Abella, Soldiers of reason, 17.

[68] Poundstone, Prisoner's dilemma, 83.

[69] Ibidem, 83.

[70] Ibidem, 84.

[71] Ibidem, 84.

start. For example, until 1950 it was not allowed for RAND employees to be listed in the Santa Monica phonebook.[72] RAND, however, was aiming for the top researchers in basically every field. Soon after the establishment of the project, RAND was hiring 'not only mathematicians and engineers, but astronomers, psychologists, logicians, historians, sociologists, aerodynamicists, statisticians, chemists, economists, and even computer scientists.'[73] As we will see later, a large share of these scholars consisted of social scientists and economists who conducted research in game theory.[74] Among the researchers hired by RAND were mathematicians, such as John von Neumann, John Forbes Nash and George Danzig, economists such as Kenneth Joseph Arrow and Gary Stanly Becker, political thinkers such as Henry Alfred Kissinger and Herman Kahn, and physicists such as Edward Teller, Samuel Cohen and Harold Brode.[75] [76] By 1960, RAND employed some '500 full-time researchers and about 300 outside consultants.'[77]

Nuclear strategy at RAND

RAND's fine nose for scouting talent resulted in an impressive production of position papers, research reports and books. According to historian and journalist A. Abella, one of the factors causing this productive atmosphere was the 'collegial competition:'[78]

> 'RANDites were […] always trying to outdo each other in all fields. Essays and working papers were circulated among colleagues for comments, which were always copious and controversial. New projects were examined by so-called murder boards, regularly scheduled departmental meetings where RANDites took brutal pleasure in shooting down shaky ideas. [..] At RAND parties, they tried to outdo one another in their appreciation of fine food, wine and music.'[79]

Perhaps it was due to this competitive atmosphere that some of the publications of RAND scholars could become leading documents in Cold War warfare and Cold War strategy in the first decades after the Second World War. One of the first developments in which RAND scholars played an important role was the construction of intercontinental ballistic missiles.[80] These long-range missiles that could carry a nuclear load were co-designed by RAND physicist Bruno Augenstein. RAND-director Collbohm then took the sketches to the

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[72] J.F. Brodie, Learning secrecy in the early Cold War: The RAND Corporation, in: Diplomatic history, vol 35, Issue 4, Sept 2011, 643–670, 649.

[73] Abella, Soldiers of reason, 17.

[74] Poundstone, Prisoner's dilemma, 94.

[75] A list of (former) employees is available online at: http://www.rand.org/about/history/nobel.html, last consulted at December 30th, 2012.

[76] Abella, Soldiers of reason, 94.

[77] Poundstone, Prisoner's dilemma, 92.

[78] Abella, Soldiers of reason, 34.

[79] Ibidem, 34 – 35.

[80] Poundstone, Prisoner's dilemma, 90 – 91.

Pentagon, where a development program was put together (we will read about this missile project as well when we come to von Neumann's contributions to the Cold War).[81]

RAND's major strategic contribution to the nuclear policy of the United States was a 1954 report that investigated a question submitted by the Air Force about the most efficient way to spread overseas military bases.[82] According to RAND scholars, this was the wrong question to ask, remarks Poundstone:

> 'According to the study, overseas bases were not cost-effective and were sitting ducks for a Soviet surprise attack. Instead, the report suggested building more domestic bases and a strategy of "second-strike" capability. This was defined as the ability of the United States to launch a counterattack on the Soviet Union even in the aftermath of a Soviet first strike that killed most Americans. Second-strike capability has been a cornerstone of Pentagon thought ever since.'[83]

Not long after the rapport was released in 1954, secretary of state J.F. Dulles addressed the Council on Foreign Relations, announcing a doctrine of massive retaliation. From historian L. Menand's description of the new doctrine, we see the similarity between the two strategies.

> 'Dulles explained that the United States could not afford to be prepared to meet Soviet aggression piecemeal—to have soldiers ready to fight in every place threatened by Communist expansion. The Soviets had a bigger army, and they threatened in too many places. The solution was to make it clear that the American response to Soviet aggression anywhere would be a nuclear attack, at a time and place of America's choosing. It was a first-strike policy: if provoked, the United States would be the first to use the bomb. An overwhelming nuclear arsenal therefore acted as a deterrent on Soviet aggression.'[84]

Of course, there is a difference between what Menand calls 'first-strike policy' and Poundstone's 'second-strike capability'. However, one and the same principle was underlying these different strategies. Both lines of thinking rely on the argument that the United States should not invest in expensive military bases or standing armies overseas. Instead, they should equip their home bases with sufficient long-range weaponry, so that any provocation or attack from the side of the Soviets could be answered with force. This, in their view, was the best guarantee for Soviet restraint. This line of reasoning was motivated by game theory that was developed by, among others, Von Neumann during the Second World War. As we will see later in this study, von Neumann's ideas about game theory were very influential at

[81] Poundstone, Prisoner's dilemma, 91.

[82] Ibidem, 92.

[83] Ibidem, 92.

[84] L. Menand, Fat man; Herman Kahn and the nuclear age, online at: http://www.newyorker.com/archive/2005/06/27/050627crbo_books, last consulted at December 30th, 2012.

the institute. Because of this, game theory and rational choice analysis became the dominant paradigms in which strategic problems were discussed.

1.4 'A permanent state of Cold War'

Three years before the British journalist and author George Orwell would publish his well-know novel *1984,* the left-wing weekly *Tribune* printed his essay *You and the atomic bomb*. The date of the issue was October 19, 1945, some three months after the Hiroshima and Nagasaki bombings. In the essay, Orwell used the term 'Cold War' to describe the international balance of power that had emerged after the successful dropping of the first atomic bomb. Orwell was one of the first authors who understood the ideological and strategic implications of this new piece of weaponry. As he remarked in his essay, the most important aspect of the atomic bomb was its ideological implication: 'the kind of worldview, the kind of beliefs, and the social structure that would probably prevail in a state which was at once *unconquerable* and in a permanent state of "Cold War" with its neighbours.'[85]

According to Orwell, the central question to be asked was how difficult the manufacturing of an atomic bomb exactly was. If it was an easy process altogether, the existence of atomic weaponry could strengthen the position of the individual against the centralized state, which is, of course, a theme that returned three years later in *1984*. However, a difficult and highly technical manufacturing process would have different implications for the future of international relations: 'If, as seems to be the case, it is a rare and costly object as difficult to produce as a battleship, it is likelier to put an end to large-scale wars at the cost of prolonging indefinitely a "peace that is no peace."'[86]

In hindsight, it is clear that Orwell made a generally solid prediction of the state of affairs to come. Not long after the publication of his essay, the Cold War scenario he described became reality by two scientific and military developments that pushed the United States and the Soviet Union towards an arms race, without military contact: 'A peace that is no peace.'

A Soviet bomb

Fourteen days after the bombing of Hiroshima on the sixth of August, a committee was formed by the Kremlin to construct atomic weapons for the Soviet Union.[87] This was not the first time that the thought of building nuclear weapons had appeared to Soviet leaders. Already in 1942, Soviet officials received secret reports about developments on nuclear weapons in Great Britain, the United States and Germany.[88] During this year, Soviet officials

[85] G. Orwell, You and the Atomic Bomb, online at: http://orwell.ru/library/articles/ABomb/english/e_abomb, last consulted at December 30th, 2012.

[86] Orwell, You and the atomic bomb

[87] V.M. Zubok, A Failed Empire: The Soviet Union in the Cold War from Stalin to Gorbachev (North Caroline, 2007), 27.

[88] D. Holloway, 'Stalin and the bomb', in: M. Leffler, S. Painter, Origins of the Cold War; an international history (London 1994), 98.

met with scientists to discuss the possibility of constructing a Soviet bomb.[89] However, the efforts were small compared to the Manhattan Project.[90] In late 1943 and 1944, fifty to one hundred scientists were doing preliminary research in a laboratory led by the Russian physicist Igor Kurchatov.[91] It would take until the summer of 1946 before these activities accelerated. As historian D. Holloway remarks, the Soviets capitalized on the fact that many German scientists were willing to cooperate with them after the end of the Second World War: 'The war provided the Soviet Union with a major infusion of foreign technology, mainly in the form of captured German scientists, technicians, equipment, and production plants.'[92] When the first Soviet nuclear bomb, RDS-1, exploded in Kazakhstan on August 29th, 1949, the era of the western nuclear monopoly was over.

Bad moon rising

When President Harry S. Truman spoke to the American people, live from the Oval Office on September 23th 1949, he realized his words would have a tremendous impact all over the globe: 'I believe the American people, to the fullest extent consistent with national security, are entitled to be informed of all developments in the field of atomic energy. That is my reason for making public the following information. We have evidence that within recent weeks an atomic explosion occurred in the U.S.S.R.'[93]

Immediately after these opening words, Truman wanted to lower the feelings of anxiety most people must have felt at that time. He reminded them that the development of a Soviet nuclear bomb did not come as a surprise. The government's scientific advisors always predicted the fact that other nations could develop nuclear weapons as well:

> 'Nearly 4 years ago I pointed out that scientific opinion appears to be practically unanimous that the essential theoretical knowledge upon which the discovery is based is already widely known. There is also substantial agreement that foreign research can come abreast of our present theoretical knowledge in time.'[94]

However, the development of the first Soviet bomb sparked a public debate in the United States about the arms race, nuclear war and international control. Many Americans felt that they had lost their strategic lead.[95] International arms control was one of the topics discussed in the media and among the public. However, Truman, in response, decided to consolidate the United States' reputation as a super power by taking three steps. First, more atomic bombs

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[89] Holloway, Stalin and the bomb, 98.

[90] Ibidem, 99.

[91] Ibidem, 99.

[92] D. Holloway, The Soviet Union and the Arms Race (Yale, 1983), 22.

[93] President Truman's Statement Announcing the First Soviet A-Bomb, September 23, 1949, online at: http://www.atomicarchive.com/Docs/Hydrogen/SovietAB.shtml, last consulted December 30th, 2012

[94] President Truman's Statement Announcing the First Soviet A-Bomb, September 23, 1949

[95] Kennedy-Pipe, The origins of the cold war, 91.

had to be built to make sure that the United States had a quantitative advantage over the Soviets. Second, the hydrogen bomb, a successor of the atomic bomb that was many times as explosive as its predecessor, must be developed so that the United States would regain their qualitative advantage. And thirdly, more funding should become available to confront the Russians with 'conventional' military options, such as a better-equipped Army and Navy.[96] As we have seen above, this last option was discouraged in 1954 when scholars of the RAND Corporation advised the Eisenhower administration to invest in second-strike-capabilities instead of 'ground'-forces.

Teller's H-bomb

A subject that was debated intensely after the first successful test of the Soviet bomb in high levels of the United States military and political organisation, was the question whether the United States should develop '*The Super*'[97]; the 'hydrogen' bomb that relied on nuclear fusion instead of nuclear fission, causing it to be thousands of times more powerful than the bombs used in August of 1945.[98] From 1942 to 1949, discussions about the hydrogen bomb took place at the Manhattan Project and at the Atomic Energy Commission, a committee founded by Congress to oversee atomic energy developments in peacetime. In most discussions, Teller would play a prominent role as a protagonist of building the super.[99] Over the years, he regularly published reports on various methods to construct a hydrogen bomb.[100]

The discussion, however, was not only about the physical and technological possibilities of constructing a hydrogen bomb. Ethical and strategic considerations were heavily debated as well. Not all members of the military, political and scientific advisors were convinced of the added value of a hydrogen bomb. Henry DeWolf Smyth, a commissioner of the Atomic Energy Commission, remarked that the military value of the super was unclear and that international negotiations of arms control had a better chance for success when the United States made clear 'that it did not intend to develop the super.'[101] Lewis Strauss, another commissioner, strongly disagreed with DeWolf Smyth and advocated the development of the hydrogen bomb. In a letter to Truman in November 1949, he stated his case[102]:
'I believe that the United States must be completely armed as any possible enemy. From this, it follows that I believe it unwise to renounce, unilaterally, any weapon which an enemy can reasonably be expected to possess. I recommend that the President direct the Atomic Energy Commission to proceed with the development of the thermonuclear bomb, at highest priority, subject only to the judgment of the Department of Defence as to its value as a weapon, and of

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[96] Kennedy-Pipe, The origins of the cold war, 92.

[97] H. York, The advisors; Oppenheimer, Teller & the superbomb (San Francisco, 1979), 42.

[98] York, The advisors, 2 – 9.

[99] G.A. Goncharov, American and Soviet H-bomb development programmes: historical background, in: Physics - Uspekhi vol 39, October 1996, 1033 – 1044, 1034 – 1035.

[100] Ibidem, 1034 – 1035.

[101] York, The advisors, 58.

[102] Ibidem, 58.

the advice of the Department of State as to the diplomatic consequences of its unilateral renunciation or its possession.'[103]

Within three years after Truman decided to confront the Soviets with a more powerful nuclear weapon than the recently developed regular atomic bombs, the first hydrogen bomb was detonated at the Eniwetok atoll in the Pacific Ocean in November 1952.[104] The fact that scientific developments followed each other closely in the arms race is well illustrated by the fact that the Soviet Union's First Secretary Nikita Khrushchev announced in a speech August 8th, 1953 that the Soviet Union had constructed their own hydrogen bomb, which had been successfully tested one week later in Central Asia.[105]

Hawks and doves

In 1949, and again in 1952 – 1953, it became clear that a new status quo had come into existence. The relation between the United States and the Soviet Union was best described as 'a permanent state of Cold War', just as Orwell forecasted some six years earlier. This new state of affairs in international relations triggered a debate between two dominant schools of international political thought. From then on, the future of the world and the international state of affairs was at stake in a fierce debate between *hawks* and *doves.* Hawks generally argued in favour of heavy investments in (nuclear) military technology. They had a typical *no holds barred* attitude when it came to confrontations with the Soviets. As scholar N. Thompson describes, hawks believed that 'the best way to avoid a nuclear clash was to prepare to win one.'[106] Doves, on the other hand, believed peace should have a chance. Hawks in the military and political environment of the Pentagon and the White House outnumbered them, but this did not stop the doves from arguing that the international diplomatic stance of the United States should not (solely) depend on nuclear weapons.[107] The debate about the role of nuclear weapons in the new world order took place within this political-philosophical framework. As we will see later on in this study, the ideas of Bohr and von Neumann can be located in the *Hawk-Dove-spectrum* as well.

[103] As cited in York, The advisors, 58 – 59.

[104] York, The advisors, 5.

[105] Zubok, A Failed Empire, 96 – 97.

[106] N. Thompson, The Hawk and the dove: Paul Nitze, George Kennan, and the history of the Cold War (New York, 2009) 3.

[107] Thompson, The hawk and the dove, 4.

Chapter two
Niels Bohr

'At the same time as this development holds out such great promises for the improvement of human welfare it has, in placing formidable means of destruction in the hands of man, presented our whole civilization with a most serious challenge.'[1]

- Niels Bohr, *Open Letter to the United Nations* (1950)

When Niels Bohr wrote his open letter to the United Nations in June 1950, the atomic bomb had been on his mind for more than seven years. Bohr had first heard about the Manhattan Project in the late summer of 1943, and it did not take him long to grasp the implications of the development of this nuclear weapon. Within months, Bohr had meetings with officials, among whom Prime Minister Churchill and President Roosevelt, to talk about his views concerning stability in the new world order.

In this chapter, we will analyse Bohr's ideas about nuclear deterrence, arms control and transparency and the degree to which these were connected to his scientific thought. First, a short biographical sketch of Bohr's early life is offered, after which we will describe Bohr's contributions to the field of atomic theory and quantum mechanics, in which, as we will see, the concept of 'complementarity' takes a central place. After this, the role of Bohr in the coming about of the atomic bomb is discussed. Lastly, Bohr's ideas about diplomacy are described. In this part, we will also make clear to what extent these political and social ideas are connected to Bohr's scientific thought in general and to the notion of complementarity in particular.

2.1 Biography

When Niels Hendrik David Bohr was born on the 7th of October 1885, he inherited two distinguishing traits from his parents that would have an important impact on his life. From his father Christian Bohr (1855 – 1911), a university professor in physiology, the young Niels inherited the talent for scholarly research and an outstanding ability to teach.[2] From his mother, the Jewish Ellen Adler (1860 – 1930), he inherited his Jewish line of ancestry.[3] As we will see later in this study, Bohr became an outstanding researcher and an inspiring teacher for his students. Also, his Jewish decent influenced the course of events later in his life, when Nazi-Germany invaded Denmark and Bohr had to flee the continent.

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[1] Bohr, Open Letter to the United Nations.

[2] Pais, Niels Bohr's time, 35 – 36.

[3] Ibidem, 39.

The milieu in which Bohr was born can be characterized as 'upper middle-class intelligentsia'. Nothing prevented him and his brother Harald to pursue their goals in life.[4] In 1891, Bohr started to attend school in Gammelholm, near the centre of Copenhagen, where he would stay until he completed his *Studenterexamen*, allowing him to attend university classes.[5] It was in the autumn of 1903 that Bohr started taking up courses at Copenhagen University. The young Danish student majored in physics and did minors in astronomy, chemistry and mathematics.[6]

During his studies, Bohr developed an interest in the world that was broader than the physical sciences. In *Niels Bohr's Time*, physicist and Bohr-biographer A. Pais describes how Bohr tried to satisfy his curiosity in this period by joining a philosophical society:

> 'He was […] one of a circle of twelve students from a variety of disciplines who would regularly meet to discuss philosophical topics. Their group, called *Ekliptika*, later became an old boys' network. Members, along with their later professions, included Harald, who had become a student in 1904; Viggo Brondal, professor in romance philology; Einar Cohn, distinguished economist; Kai Henriksen, section director of the Zoology Museum; Paul Norlund, director of the National Museum, and Niels Erik Norlund, director of the Institute for Geodesy, future brothers-law-of Niels; Edgar Rubin, professor and founder of modern psychology in Denmark; Peter Skov, ambassador to various countries, including the Soviet Union; and Vilhelm Slomann, director of the Museum of Industrial Arts.'[7]

What the composition of *Ekliptika* shows is that Bohr, from his days as a student onwards, chose to surround him with intellectuals from outside the realm of physics. This was typical for the aspiring physicist. Reaching the end of his period in school, Bohr took an interest in philosophy and read the works of philosophers such as the Dane Søren Kierkegaard and German idealist writers such as Friedrich von Schiller.[8] While most of the descriptions of the lives of great physicists focus on their ties in the physics community, it is useful to keep in mind that Bohr was a person who was interested in a broad range of issues.

In 1911, Bohr defended his university dissertation, which was a study on the electron theory of metals.[9] Shortly after his graduation ceremony, he travelled to the United Kingdom, where he took residence at J.J. Thomson's Cavendish Laboratory at Cambridge University. At this time, many aspiring scientists from Denmark spent time abroad, often financed by a grant

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[4] F.J. Folse, The philosophy of Niels Bohr; the framework of complementarity (Amsterdam, 1985), 31.

[5] Pais, Niels Bohr's time, 48.

[6] Ibidem, 98.

[7] Pais, Niels Bohr's time, 99-100.

[8] Rhodes, The making of the atomic bomb, 60.

[9] Folse, The philosophy of Niels Bohr, 33.

from the Danish Carlsberg Foundation.[10] Thomson had discovered the electron in 1897, earning him the Nobel Prize in physics in 1906. After this, he worked on the structure of the atom, making the Cavendish lab one of the obvious places for the young Bohr to gain some experience in research at a renowned laboratory.[11] Bohr stayed at the Cavendish for nearly a year, working on Thomson's atomic models. Late in 1911, Bohr met Ernest Rutherford, an atomic physicist from New Zealand, who had recently settled in Manchester. Rutherford had published a paper on the structure of the atom in *The Philosophical Magazine* in May 1911, claiming it be 'much superior to J.J.'s', with which he meant 'superior to Thomson's models'.[12] Bohr arranged a transfer to Manchester in January 1912, departing from Cambridge in April. The official reason for Bohr's early departure from Cambridge was that he wanted to familiarize himself with radioactivity at Rutherford's lab. However, historian of science M. Jammer ascribes Bohr's leaving to 'a disagreement with Thomson concerning the latter's [..] model of the atom.'[13]

In Manchester, Bohr started out following a course in radioactivity, after which he was appointed to work in Rutherford's laboratory 'on the absorption of α-particles in aluminium.'[14] According to Pais, Bohr was not that interested in the issue and wondered in silence 'how much would come out of his problem.'[15] In a 1962 interview with historian of science T.S. Kuhn, Bohr recalled how he finally told Rutherford that he would rather focus on the theoretical side of the issue:

> 'A few weeks later I said to Rutherford that it would not work to go on making experiments and that I would better like to concentrate on the theoretical things. […] From then on, I worked at home.. And then I actually didn't see the others too much because I just worked there…You see, there was not so much to talk about. I knew how Rutherford looked at the atom, you see, and there was really not very much to talk about…'[16]

As soon as Bohr traded the experimental research at Rutherford's lab in for a theoretical approach, he became occupied with questions evolving around Rutherford's discovery of the atomic nucleus. According to Bohr scholar H.J. Folse, Bohr realized at the time that the Rutherfold nucleus had to be 'the cornerstone for building any model of the atom', but that it was nonetheless hard to construct a stable model.[17] Bohr's stay at the Manchester lab was too short to come to conclusions on these matters. In July 1912, he left the United Kingdom and

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[10] Folse, The philosophy of Niels Bohr, 33. Also in: Pais, Niels Bohr's Time, 117.

[11] Folse, The philosophy of Niels Bohr, 33. Also in: Pais, Niels Bohr's time, 117.

[12] Pais, Niels Bohr's time, 123-124.

[13] M. Jammer, The conceptual development of quantum mechanics (New York, 1966), 69.

[14] Pais, Niels Bohr's time, 125.

[15] Ibidem, 125.

[16] Ibidem, 125 – 126.

[17] Folse, The philosophy of Niels Bohr, 33 – 34.

returned to his family in Denmark.[18] As we will see in the following paragraph, the foundations of what was to become the 'Bohr atom' had at this point already been vested in his mind.

2.2 Bohr's science

It did not take Bohr long to sort out his thoughts on the atomic nucleus and the correct structure of the atom. Within a year after his return from the United Kingdom, Bohr published three papers about atomic theory in *The Philosophical Magazine.*[19] In this paragraph, we will look at some contributions of Bohr to this field. Also, we will shortly discuss his role in the debate on quantum mechanics and his philosophical views on complementarity that originated from this debate.

The Bohr Atom

What did Bohr's contribution to atomic theory, as published in *The Philosophical Magazine* in the second half of 1913, imply?[20] To grasp the importance of these three papers, we must briefly look at the leading thoughts about the atom that had existed up until then. In ancient Greek philosophy of nature an 'atom' (ἄτομος) was known to be the smallest kind of particle; one that could not be cut in parts itself. But this reading of the term had lost its meaning well before Bohr entered the field. 'It was clear', so writes Folse, 'that the 'atoms', which were the fundamental units of the chemical elements, were not in fact elementary in the sense of having no internal structure.' [21] When chemistry became a mature science during the course of the nineteenth century, the nature of small particles provided scientists still with many questions. Folse: 'The various properties of the chemical elements exhibited patterns that called out for an explanation, and that explanation was generally understood to require describing the structure of the chemical atoms.'[22]

So, in short, before Bohr entered the field the question at hand in modern atomic theory was what the internal structure of the atom exactly was. Thomson, who we saw before as one of Bohr's professors at the Cavendish lab and as the discoverer of the electron, tried to offer an explanation[23] by constructing a model based on the assumption that negatively charged electrons are compensated by 'a positive charge uniformly smeared out over a sphere of fixed radius.'[24] Unfortunately, his model ultimately failed to account for the atom's stability.[25]

[18] Pais, Niels Bohr's time, 128.

[19] Folse, The philosophy of Niels Bohr, 34.

[20] Ibidem, 34.

[21] Folse, The philosophy of Niels Bohr, 57.

[22] Ibidem, 57.

[23] Pais, Niels Bohr's time, 118.

[24] Ibidem, 118.

[25] Ibidem, 119.

The main problem underlying the stability of the model was caused by Thomson's starting point: he stayed within what we would call today the framework of classical physics.[26] This is where Bohr comes in. The young Danish theorist was prepared to look beyond the boundaries of the classical framework to offer a stable model for the structure of the atom.[27]

Bohr could not have done so without a physical constant that was formulated some thirteen years earlier, when the German physicist Max Planck struggled to solve a problem called the ultraviolet catastrophe. In short, the problem was that following classical physics, the energy that is emitted from a heated black body should be continuous and infinite, but this is obviously not possible. In his attempts to put together a formula that would save the phenomena, Planck decided to change the way energy was distributed. Instead of continuous energy values, the energy in Planck's formula took the shape of finite elements.[28] There has been much debate about the question if Planck was fully aware of what he was doing, but the fact of the matter was that he had introduced the energy quantum. Later, Einstein would apply Planck's ideas about finite elements of energy to the problem of the photoelectric effect and proposed the idea of a light particle, the 'light quantum'.[29]

This development went through Bohr's mind when struggling with the atomic model. As Bohr wrote in a paper dating from July 13th, 1913:

> 'Whatever the alteration in the laws of motion of the electrons may be, it seems necessary to introduce in the laws in question a quantity foreign to the classical electrodynamics, i.e., Planck's constant, or as it often is called the elementary quantum of action.'[30]

It is safe to say that the atomic model that Bohr produced in 1913 was the result of a synthesis of Rutherford's nucleus-based atom and Planck's quantum conception.[31] Bohr's model of the atom consisted of a small core, the nucleus. Electrons circled in orbits around this nucleus.[32] The revolutionary aspect of this was that Bohr avoided the potential instability of the model by assuming that electrons only radiate if they jump from one fixed and stable orbit to another.[33]

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26 Pais, Niels Bohr's time, 119.

27 Folse, The philosophy of Niels Bohr, 64.

28 Rhodes, The making of the atomic bomb, 70.

29 Ibidem, 71.

30 N. Bohr, On the Constitution of Atoms and Molecules, Philosophical Magazine Series 6, 26: 151, 1 — 25.

31 Jammer, The conceptual development of quantum mechanics, 69.

32 H. Kragh, K.H. Nielsen, Spreading the gospel: The Bohr atom popularised, Centre for Science Studies, Aarhus University, Aarhus, Denmark, 6-7.

33 Kragh, Nielsen, Spreading the gospel, 6-7.

Bohr's contributions to the field of atomic theory in 1913 earned him a reputation as one of the leading minds in contemporary physics. Shortly after the publication of his three papers on the structure of atoms, the First World War broke out, making physics a second-rate priority in most European countries. Shortly after the war, however, Bohr was awarded the 1922 Nobel Prize in physics for his 'services in the investigation of the structure of atoms and of the radiation emanating from them.'[34] From then on, Bohr's voice carried weight in any scientific or public debate he became involved in.

Uncertainty

The success of the Bohr atom did not mean that the debate about particles at microscopic scales was over. Atomic theory struggled with inconsistencies and it was still a problem to separate the fields of classical physics and quantum physics in a logical way.[35] Problems as these tormented the entire field of sub-atomic physics. It would take until Werner Heisenberg and Erwin Schödinger formulated consistent theories in the midst of the 1920's, before the uneasiness about atomic theory slowly faded.[36]

The fundamental problem during the years between 1913 and 1926 was that physics seemed to have lost its coherent language. As Jammer points out, 'terms like 'place', 'velocity', 'orbit' continued to play an important part in the representation of the formalism although their very rejection lay at the foundation of the whole development [of quantum theory, ccb.].'[37] The world of sub-atomic particles no longer fitted everyday language. Words and sentences fell short. Space-time descriptions that were intuitively right were seemingly not applicable to the sub-atomic domain.[38] Werner Heisenberg, Bohr's talented 26-year-old assistant, managed to formulate an important breakthrough. Instead of adapting the language of physics to the new insights and the results of experiments, Heisenberg decided to change the ambition of physics altogether, as writes Jammer:

> 'It would be impossible to construct an independent appropriate conceptual apparatus (in the sense of a descriptive language) which would give an adequate intuitive interpretation of the abstract formalism, since all our conceptualizations are inseparably connected with spatiotemporal ideas, as Heisenberg saw no other alternative than to retain the classical intuitive notions but to restrict their applicability.'[39]

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[34] The Nobel Prize in physics 1922, online at: http://www.nobelprize.org/nobel_prizes/physics/laureates/1922/, last consulted December 30th, 2012.

[35] Folse, The philosophy of Niels Bohr, 65.

[36] Folse, The philosophy of Niels Bohr, 65.

[37] Jammer, The conceptual development of quantum mechanics, 324.

[38] Ibidem, 325.

[39] Ibidem, 325.

In the end, the result of Heisenberg's considerations was the uncertainty principle; the postulate that it was not possible to measure a particle's momentum and position at the same time.[40] Or, as Rhodes describes it with stylistic simplicity, in the sub-atomic world 'one measurement always made the other measurement uncertain.'[41]

The rise of complementarity

It has been said that Heisenberg's uncertainty principle triggered Bohr to develop his concept of complementarity. However, Jammer points out this is incorrect from 'both historical and conceptual points of view.'[42] Rhodes also discusses Bohr's reaction to Heisenberg's work and concludes that Bohr, after putting pressure on Heisenberg to make some last minute changes, could live with the publication of Heisenberg's paper on uncertainty.[43] According to Jammer, it is more probable that the publication of Heisenberg's paper 'prompted Bohr to give his thoughts on complementarity a consistent and final formulation'[44]. In other words: Bohr was already working on complementarity well before Heisenberg told him about his ideas on uncertainty.

This final formulation of the concept of complementarity was made public in September 1927, when Bohr gave a lecture entitled *The quantum postulate and the recent development of atomic theory* at the International Congress of Physics in Como, Italy, to mark the occasion of the hundredth anniversary of Allessandro Volta.[45]

With the Como lecture, Bohr wanted to attack the conceptual problems that had appeared in quantum theory over the past years. His closest colleagues were already aware of the fact that Bohr was aiming to solve these problems. In May 1927, Heisenberg wrote to Wolfgang Pauli, an Austrian theoretical physicist, that Bohr 'wants to write a general paper on the 'conceptual basis' of the quantum theory.'[46]

What thoughts did Bohr exactly bring forward in his lecture? The problems Bohr sketched in the opening part were far from new to his audience: Classical physical ideas were fundamentally limited when applied to atomic phenomena. It was especially troublesome to interpret data from experiments, because, after all, 'our interpretation of the experimental material rests essentially upon the classical concepts.'[47] These concepts were not made to fit the atomic world, where observation, space, time, and causality were not self-evident.

[40] Jammer, The conceptual development of quantum mechanics, 326.

[41] Rhodes, The making of the atomic bomb, 130.

[42] Jammer, The conceptual development of quantum mechanics, 345.

[43] Rhodes, The making of the atomic bomb, 131.

[44] Jammer, The conceptual development of quantum mechanics, 345.

[45] Ibidem, 345 – 351., The Como lecture was published in *Nature* in 1927. From now on, I will refer to the printed article when I discuss the Como lecture.

[46] Pais, Niels Bohr's time, 309.

[47] N. Bohr, Como lecture, 1927.

Because of the quantum postulate, Bohr argued, it is clear that 'any observation of atomic phenomena will involve an interaction with the agency of observation.'[48] Because 'the definition of the state of a physical system […] claims the elimination of all external disturbances […] any observation will be impossible and, above all, the concepts of space and time lose their immediate sense.'[49] But if we permit some of these interactions with the system in order to measure, so states Bohr, 'an unambiguous definition of the state of the system is naturally no longer possible and there can be no question of causality in the ordinary sense of the word.'[50] Bohr used a problem concerning the nature of light to illustrate this:

> '[Light's] propagation in space and time is adequately expressed by the electromagnetic theory. Especially the interference phenomena *in valuo* and the optical properties of material media are completely governed by the wave theory superposition principle. Nevertheless, the conservation of energy and momentum during the interaction between radiation and matter, as evident in the photo-electric and Compton effect, finds its adequate expression just in the light quantum idea put forward by Einstein.'[51]

According to Bohr, we must look at these two analyses of the nature of light as attempts at 'an interpretation of experimental evidence in which the limitation of the classical concepts is expressed in complementary ways.'[52] In other words: because our classical language fails us, we express our interpretation of our observation in two different ways, by the lack of one solid expression.

Bohr proposed a solution for the mutually exclusive views: We should simply not look at them as being mutually exclusive. Rather, we should see them as different, but equally valid ways of looking at the atomic domain that 'complement' each other.[53] Both are different sides to the same coin of reality. An object in the sub-atomic world simply expresses itself to the spectator according to the question the spectator asked (i.e. what measuring methods the spectator used). Bohr: 'The very nature of the quantum theory thus forces us to regard the space-time co-ordination and the claim of causality, the union of which characterizes the classical theories, as complementary but exclusive features of the description, symbolizing the idealization of observation and definition respectively.'[54] In other words, because our words and our language originate from 'our ordinary perception', we must 'adapt our modes of

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[48] N. Bohr, Como lecture, 1927.

[49] Ibidem

[50] Ibidem

[51] Ibidem

[52] Ibidem

[53] Rhodes, The making of the atomic bomb, 131.

[54] Bohr, Como lecture, 1927.

perception to the gradually deepening knowledge of the laws of Nature.' After all, remarks Bohr, this is exactly what Einstein did as well with his theory of relativity.[55]

The introduction of the concept certainly stirred the debate, both scientifically as well as in the hotel's dining room after the Como-lecture, but the direct impact of 'complementarity' as a tool in physics was limited. As the Hungarian physicist Eugene Wigner remarked, Bohr's 'lecture will not induce any one of us to change his own meaning about quantum mechanics.'[56]

Complementarity as philosophy

While complementarity was not an instant success in the physics community, Bohr did not abandon the concept. Over the years, he refined his thoughts about complementarity by debating, among others, Einstein. For example, at Solvay congresses, Bohr and Einstein debated each other by coming up with thought experiments about the nature of physical reality.[57] During his career, Bohr remained a proponent of complementarity in quantum physics, even when the field had reached such a degree of specialization that its potential use diminished.[58] However, for the purpose of this study, it is more important to notice that Folse remarks that Bohr, from 1929 onwards, looked for ways to apply complementarity and its epistemological lessons in fields beyond physics.[59] While one would expect that Bohr's reputation as an outstanding physicist gained him good will from scientists from other fields, the opposite was the case, so writes Folse:

> 'His fame as an atomic physicist in a sense stood in his way, for it was virtually only in application to quantum theory that everyone investigated complementarity at all, and even then only in the restricted application of dealing with complementary 'wave pictures' and 'particle pictures' in particular experimental situations.'[60]

This did not stop Bohr from looking for alternative applications for complementarity. Pais even uses a term, 'complementarism', for the attempts Bohr made to spread complementarity to psychology, biology and anthropology.[61] Let us focus on one of these attempts: biology.

A clear example of Bohr's attempts to apply the concept of complementarity to the field of biology is the *Light and Life* lecture he held in August 1932 at the International Congress of

[55] Bohr, Como lecture, 1927.

[56] Pais, Niels Bohr's time, 315.

[57] Folse, The philosophy of Niels Bohr, 143.

[58] Ibidem, 142.

[59] Ibidem, 142.

[60] Folse, The philosophy of Niels Bohr, 168.

[61] Pais, Niels Bohr's time, 439.

Light Therapy in Copenhagen.[62] In the lecture, Bohr compared the problems that surrounded the concept of 'life' with the problems in quantum theory. I quote this at length, because it is a perfect illustration of Bohr's analysis of biology by using complementarity:

> 'If we were able to push the analysis of the mechanism of living organisms as far as that of atomic phenomena, we should scarcely find any features differing from the properties of inorganic matter […] however […] the conditions holding for biological and physical researches are not directly comparable, since the necessity of keeping the object of investigation alive imposes a restriction on the former which finds no counterpart in the latter […] On this view, the existence of life must be considered as an elementary fact that cannot be explained, but must be taken as a starting point in biology, in a similar way as the quantum of action, which appears as an irrational element from the point of view of classical mechanical physics, taken together with the existence of elementary particles forms the foundation of atomic physics. The asserted impossibility of a physical or chemical explanation of the function peculiar to life would in this sense be analogous to the insufficiency of the mechanical analysis for the understanding of the stability of atoms.'[63]

What we see here is that Bohr applies complementarity to the field of biology by adapting it to fit the specific problems of the field (the existence of life), making it an approach with a somewhat holistic character.[64] If we want to grasp the mystery of life in biological research, we must accept the fact that there are elementary facts that we have to accept, just as the quantum of action is such an 'elementary fact' in physics. After all: if we examine a living animal at the smallest possible scale, we can only see the building blocks of life. But real life shows itself only when we look at the living animal from a different (larger) perspective. Just as in quantum physics, the object changes its appearance according to the view of the spectator. And instead of seeing these counter-intuitive facts as mutually exclusive, we must accept that both are different sides of reality.

What this example makes clear is that complementarity for Bohr was no longer merely a conceptual tool in the field of quantum physics, but a philosophical stance on issues beyond the field of physics. As we will see later in this study, Bohr also applied complementarity to political and social affairs during the course of the Second World War and the Cold War.

2.3 Bohr and the bomb

In the remaining parts of this chapter, I will give a description of Bohr's role at the Manhattan project and his work in diplomatic affairs. I have decided to do this in two separate paragraphs. Of course, it is to some extent artificial to draw a line between Bohr's time at the Manhattan project and his diplomatic activities. After all, at the Manhattan Project, Bohr was

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[62] J. Faye, Niels Bohr; his heritage and legacy (Dordrecht, 1991), 158.

[63] As quoted in Faye, Niels Bohr, 158.

[64] Faye, Niels Bohr, 159.

already thinking about the post-war years and met with officials to discuss his ideas about arms control and transparency.[65] Nevertheless, for matters of structure, we will look at his role at the Manhattan project and his role in international affairs from separate points of view.

Now then, where does a history of Bohr and the atomic bomb begin? It is somewhat arbitrary to choose an appropriate starting point for the history of Bohr and the atomic bomb. One could start in the midst of the 1930's, when (Jewish) physicists, who fled Germany, and later Austria, found a safe place to stay at Bohr's Institute for Theoretical Physics in Copenhagen.[66] One could start in January 1939, when Lise Meitner and Otto Robert Frisch were convinced by Bohr to publish their interpretation of experiments that showed a new process called fission (which would lay the foundations for the possibility of constructing an atomic bomb in the future).[67] Or one could start on October 20th, 1939, when Bohr was elected as the President of the Royal Danish Academy for Sciences and Letters, a mere three weeks before the German armies invaded Denmark.[68] Finally, and this is perhaps the best way to start a history of Bohr and the atomic bomb, one could start with the famous meeting Bohr had with his former assistant, Werner Heisenberg, in Nazi-occupied Denmark in September 1941.

The Heisenberg meeting

In 1927, Heisenberg left his position as an assistant to Bohr to become professor of theoretical physics at the University of Leipzig.[69] He was awarded the Nobel Prize in physics in 1933.[70] Heisenberg did not leave Germany in the 1930s, when the Nazi's came to power. There has been much debate about his motivations for staying in Germany. It has been suggested that Heisenberg had national socialist sympathies, while other scholars mention that he tried to find scholarships for Jewish colleagues in safer countries. It has also been suggested, that Heisenberg was an 'apolitical' figure who had figured that his chance to live a successful life was best when he stayed in Germany.[71] Heisenberg became part of the Nazi-regime in 1939, when he began to work at a nuclear project belonging to the German military. During the first years of the war, Heisenberg worked on nuclear fission in order to construct an atomic weapon.[72]

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[65] Pais, Niels Bohr's time, 497- 498.

[66] R. Oppenheimer, Niels Bohr and atomic weapons, in: The New York review of books, 1964, online at: http://www.nybooks.com/articles/archives/1964/dec/17/niels-bohr-and-atomic-weapons/?pagination=false, last consulted December 30th, 2012.

[67] Pais, Niels Bohr's time, 454.

[68] Pais, Niels Bohr's time, 464.

[69] C. Carson, Heisenberg in the atomic age (New York, 2010), 21.

[70] The Nobel Prize in physics 1931, online at: http://www.nobelprize.org/nobel_prizes/physics/laureates/1932/ , last consulted December 30th, 2012.

[71] Pais, Niels Bohr's time, 484 – 485.

[72] Carson, Heisenberg in the atomic age, 22 – 23.

In the autumn of 1941, Heisenberg visited Nazi-occupied Denmark to give a lecture at an astrophysics meeting in Copenhagen. While prominent physicists from Denmark were invited, including Bohr and others from the Institute for Theoretical Physics, none of them attended the lecture.[73] Heisenberg and Bohr did meet in private, however, at the Institute. During his visit to Copenhagen, Heisenberg had repeatedly mentioned that it was important that Germany should win the war, leaving his conversation partners baffled or even offended.[74] However, the progress of the war was not the main topic of the private conversation Bohr and Heisenberg had. Opinions differ on what was discussed exactly, but as various scholars have noted, both Bohr and Heisenberg were troubled by the outcome.[75] Heisenberg recalled years after the meeting that he had asked Bohr whether physicists have a moral duty to work on the 'practical exploitation of atomic energy.'[76] Bohr's son Aage recalls that Heisenberg brought the subject to military applications of nuclear energy, which is, of course, a slightly different topic. According to Rhodes, Heisenberg unintendedly revealed to Bohr that an atomic bomb could be made, be it with a 'terrific technical effort'.[77] Bohr was at that time still convinced that an atomic bomb was beyond reach for the near future. In a lecture in December 1939, he had expressed his scepticism, when he said that chain reactions could occur in uranium but that they would remain 'too short and rare for there to be any question of an explosion.'[78] Nevertheless, Bohr reacted 'frightened' and 'shocked'[79] to Heisenberg's confessions and cut off the conversation before he could get into details.[80] Heisenberg later remarked that, in hindsight, he considered it possible that Bohr did not get the last part about the technical difficulties fully. It is possible that because of this, Bohr was under the impression that the Germans were making serious headway with the development of an atomic weapon.[81]

Bohr finding out about the bomb

It would take until 1943 before Bohr became involved with the allied attempts to construct an atomic weapon. As we have seen in the previous chapter about the Manhattan Project, the British and the Americans installed committees from 1941 onwards to conduct nuclear research and construct an atomic weapon. Bohr had fled to England in late September 1943, when it was no longer safe for Jews to live in Denmark. Here he became acquainted with the allied nuclear efforts. As F. Aaserud, the director of the Niels Bohr Archive, writes about this period:

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[73] Pais, Niels Bohr's time, 483.

[74] Ibidem, 483.

[75] Carson, Heisenberg in the atomic age, 436 – 437.

[76] Carson, Heisenberg in the atomic age, 437.

[77] Rhodes, The making of the atomic bomb, 384.

[78] Pais, Niels Bohr's time, 462.

[79] Rhodes, The making of the atomic bomb, 384.

[80] D.C. Cassidy, A historical perspective on Copenhagen, in: Physics Today, July 2000, 28 – 32, 32.

[81] Rhodes, The making of the atomic bomb, 384.

> 'He was briefed immediately about the development of the atomic bomb and seems to have been convinced immediately of the project's feasibility. He agreed to help in the project while at the same time developing his own thoughts about the post-war implications of the bomb and what could and should be done about it.'[82]

Bohr was offered an appointment as a scientific advisor to the British project. He declined, having the conviction that his connections with American scientists made a 'joint appointment' more valuable.[83] In November, Bohr travelled to New York, were he was given the pseudonym Nicholas Baker. Though he never became a permanent resident at the Los Alamos site, he made several visits to the laboratory.[84] As Oppenheimer later recalled, Bohr's presence at the project was widely appreciated. As we have seen in the previous chapter, scientists at Los Alamos discussed their role in the war from time to time and their share in the construction of such powerful weapons seriously troubled some of them. According to Oppenheimer, Bohr enlightened these discussions:

> 'Bohr spoke with contempt of Hitler, who with a few hundred tanks and planes had tried to enslave Europe for a millennium. He said nothing like that would ever happen again; and his own high hope that the outcome would be good, and that in this the role of objectivity, the cooperation which he had experienced among scientists would play a helpful part; all this, all of us wanted very much to believe.'[85]

Austrian physicist Victor Weisskopf reflected on Bohr's role in the many discussions: 'Every great and deep difficulty bears in itself its own solution… This we learned from him.'[86] As we will see later in this study, the role Bohr played at the Los Alamos site was closely connected to his political views, in which complementarity played a distinctive role. In fact, even Weisskopf's remarks already illustrate the connection with complementarity. Except for some intermediate trips to the United Kingdom, Bohr stayed in the United States until after the Hiroshima and Nagasaki bombings of August 1945. He returned to Denmark on August the 25th, being re-elected as president of the Royal Danish Academy for Sciences and Letters in September.[87]

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[82] F. Aaserud, Niels Bohr's political crusade during World War II, date and location of publication unknown, 305.

[83] Pais, Niels Bohr's time, 496.

[84] Ibidem, 497.

[85] Rhodes, The making of the atomic bomb, 524.

[86] Rhodes, The making of the atomic bomb, 524 – 525.

[87] Pais, Niels Bohr's time, 504.

2.4 Diplomacy

As we have already seen in the previous paragraphs, Bohr's role at Los Alamos was not a mere technical one. With the physicists at Los Alamos, Bohr discussed their moral obligations and reflected on the ethical dilemmas their work at the project brought along. Also, Bohr held meetings and wrote letters to political officials during the war and thereafter. 'From the very start,' concludes Pais, 'Bohr's thoughts were less concerned with the current war effort, however, than with the enormous changes the new weapons would create in the post-war world.'[88]

In this last part of the chapter on Bohr, we will discuss some of his key contributions to the debate about nuclear weapons. We will do this in three parts. First, we will discuss the meetings Bohr held and the memoranda and letters Bohr exchanged with political leaders and high officials in the United States and Great Britain. Second, we will discuss the articles Bohr wrote and published on atomic weapons and nuclear deterrence. Thirdly, we will look into the reception (and the possible influence) of Bohr's ideas about nuclear deterrence and arms control. This means that we focus on the substance of Bohr's meetings, letters and articles in the first two parts, and focus more on the result of his efforts in the third part. After these analyses, we will draw some preliminary conclusions about the role of complementarity in Bohr's diplomatic and political thought.

2.4.1. Behind the scenes

More than a year before the first atomic bomb was used in wartime, Bohr held meetings and exchanged letters with some of the key players in the political scene. While it is impossible to discuss all of the correspondence that dealt with the atomic bomb and arms control, some documents and two meetings are of great importance to grasp Bohr's ideas about the new international situation and the reaction these ideas invoked. These will be discussed below.

The Anderson Letter

One of the earliest documents in which Bohr elaborated on his ideas about international arms control is a letter, written in February 1944, to Sir John Anderson, a British government official who had been responsible for the British Tube Alloys project since 1941.[89] Bohr wrote the letter shortly after visiting the Los Alamos site (codenamed 'Y') for three weeks to inform Anderson about his first impressions of the American project. The content of the letter was the result of numerous discussions Bohr had with Lord Halifax, the British ambassador to the United States.[90] In a technical sense, Bohr was impressed by the scientific and organizational efforts. The progress Bohr had seen and the results of the experiments at 'Y'

[88] Pais, Niels Bohr's time, 498.

[89] F. Aaserud, Introduction, in: F. Aaserud (ed.), Niels Bohr collected works volume two; the political arena (1934 – 1961), 3 – 85, 15.

[90] Aaserud, Introduction, 19.

had convinced him that 'no doubt [was] left as to the realizability of the project.'[91] The fact that an atomic weapon was within reach urged Bohr to include his opinions on diplomatic topics as well in the letter to Anderson:

> 'I know that the question of control has already been considered within your committee, but the more I have learned and thought about the possible development in this new field of science and technique, the more I am convinced that no kind of customary measures will suffice for this purpose and that no real safety can be achieved without a universal agreement based on mutual confidence.'[92]

Bohr proceeded by informing Anderson about the measures that were necessary in his view:

> 'An effective control would in fact not only involve intricate technical and administrative problems, but would also demand such concessions regarding exchange of information, and openness about industrial efforts including militarily preparations, as would hardly be conceivable unless at the same time all partners were assured of a compensating guarantee of common security against dangers of unprecedented acuteness.'[93]

According to Bohr, these unprecedented dangers were not necessarily a negative development in the history of diplomacy. In fact, the development of the bomb might as well trigger a new phase in international affairs:

> 'The main point of the argument is that the impending realization of the project would not only seem to necessitate, but should also, due to the urgency of confidence, facilitate, a new approach to the problem of international relationship.'[94]

After receiving Bohr's letter, Anderson discussed its content with Halifax and both men concluded that it was best to let Bohr explain his views directly to President Roosevelt, considering that any shift in foreign policy that would come near to the one Bohr was advocating had to be dealt with at the highest security level.[95] Eventually, Bohr would meet Prime Minister Churchill on the 16th of May 1944 and President Roosevelt on the 25th of August 1944. In both cases, Bohr sent a letter to the statesmen afterwards, thanking them for their time and once again emphasizing his main arguments. We will discuss these letters later in this paragraph, because they give a clear view of what was discussed in these confidential

[91] N. Bohr, Letter to Anderson, 16 February 1944, in: F. Aaserud (ed.), Niels Bohr collected works volume two; the political arena (1934 – 1961), 86 – 88, 86.

[92] Bohr, Letter to Anderson, 87.

[93] Ibidem, 87 – 88.

[94] Ibidem, 88.

[95] Aaserud, Introduction, 19.

meetings. First, however, we will analyse a memo Bohr wrote in March 1944. The memo can be seen as the first extended version of Bohr's ideas about arms control. Perhaps he wrote it to straighten his thoughts on the subject, preparing for the important meetings to come. Because Bohr discussed the document with Halifax in April 1944, we will label it *The Halifax Memo*.[96]

The Halifax Memo

Bohr had worked for several weeks on the Halifax memo, presumably right from the moment when he sent the February letter to Anderson.[97] The memo is headlined *Confidential comments on the project of exploiting the latest discoveries in atomic physics for industry and warfare* and consists of three parts. The first part, *Foundations of the project*, is a short description of the coming about of the scientific and engineering efforts of the United States and Great Britain to develop an atomic weapon and it stresses the fact that the successful development of an atomic weapon is 'one of the greatest triumphs of science and technique' that will 'deeply influence the future of mankind.'[98]

In the second part, *General implications of the project*, Bohr touches upon the paradoxical nature of the project. As we have seen before, Bohr thinks that atomic energy can be expected to 'revolutionize industry and transportation' and it 'promises results of perhaps equal importance for human welfare.'[99] However, if world leaders do not pay serious attention to the problem of international control, the dangers this new form of energy brings along will outweigh its benefits.[100] In this part, Bohr uses some paragraphs from the February letter to Anderson, but he also adds some new considerations, both on the role of scientists and on the great promise the atomic weapon offers to 'a peaceful international collaboration:'

> 'The ultimate form of the control arrangement must, of course, largely depend on the future development and at any stage, advice of scientists and technicians will surely be needed. The main point of the argument is, however, that the accomplishment of the project would not only seem to necessitate, but should also, due to the urgency of mutual confidence, facilitate, a new approach to the problem of international relationship. Far from being a hindrance to the free development of national communities or to the rivalry between nations as regards human progress, a universal agreement of the kind indicated should just offer a solid foundation for such endeavours in eliminating the menace of a suppression

[96] Aaserud, Introduction, 22.

[97] Ibidem, 22.

[98] N. Bohr, Memo, 2 April 1944, in: F. Aaserud (ed.), Niels Bohr collected works volume two; the political arena (1934 – 1961), 90 – 95, 92.

[99] Bohr, Memo 2 April 1944, 92.

[100] Ibidem, 92.

> by materially superior powers and thus securing a lasting peaceful international collaboration.'[101]

What we see here is that Bohr emphasizes the possibility of peaceful international collaboration between nations in a stronger sense than he did in the February letter to Anderson. In the letter, Bohr mentioned the possible new approach to international relationships, but he did not speak about peaceful collaboration. Presumably, Bohr's ideas evolved a bit further between February and April 1944.

In the third part of the memo, *Possibilities of the momentary situation*, Bohr elaborated further on this possibility. If Great Britain and the United States would take 'an early initiative' towards openness and 'harmonious collaboration', the international community would be grateful, so thinks Bohr:

> 'Many reasons would also seem to justify the conviction that a proper approach, with the object of establishing common security from ominous menaces without excluding any nation from participating in the promising industrial development which the accomplishment of the project entails, will be welcomed with sincerity and be responded with a loyal cooperation on the effectuation of the necessary far reaching control measures. […] Every nation will at that moment find itself united in the deliverance from sombre anxieties and in pride and admiration for the gigantic scientific and engineering effort which as a contribution to the common cause will rank with the most heroic and successful military undertakings.'[102]

Bohr ends the memo with a reference to the scientific community. Personal connections between scientists from the eastern and the western hemisphere might 'be of help in establishing preliminary and non-committing contact.'[103]

At this point, it is important to mention that Bohr was acquainted with Peter Kapitza, a prominent Soviet physicist and Nobel laureate, who had offered him to come to the Soviet Union to take part in atomic research right after Bohr discussed his memorandum with Halifax. According to historian Aaserud, Bohr always consulted Anderson in his correspondence with Kapitza.[104] However, as we will see in the fourth chapter, Churchill and Roosevelt distrusted Bohr because he advocated international contacts between scientists and corresponded with Kapitza at the same time.

[101] Bohr, Memo 2 April 1944, 93.

[102] Bohr, Memo 2 April 1944, 94.

[103] Ibidem, 95.

[104] Aaserud, Introduction, 24.

The Churchill-meeting
Not long after discussing the memorandum with Halifax, Bohr was invited to meet Prime Minister Churchill. As we have described in the introductory remarks of this study, the meeting proved a fiasco. Churchill distrusted Bohr's plea for openness and transparency and was, presumably, more occupied with D-day, which was approaching soon.[105] However, a few days after the meeting, Bohr wrote Churchill a letter, in which he – again – advocated the need for control and the possibilities for peace it might bring:

> 'These circumstances obviously have an important bearing on the question of an eventual competition about the formidable weapon, and on the problem of establishing an effective control, and might therefore perhaps influence the judgment of the statesmen as to how the present favourable situation can best be turned to lasting advantage for the cause of freedom and world security.'[106]

Again, the line of Bohr's thought was clear: while the bomb posed unimaginable threats to the safety of our entire civilization, it might as well be the solution that was needed for problems in international diplomacy. As we will see below, the notion of complementarity played a role in Bohr's analysis: an object presented itself to the world according to the point of view of the observer. One could look at the atomic bomb as a threat and as an opportunity.

The Roosevelt-meeting
Shortly after the failed Churchill-meeting, Halifax and Felix Frankfurter, an associate justice of the Supreme Court and friend of Bohr, informed President Roosevelt about the meeting.[107] Roosevelt told Frankfurter that he wanted to meet Bohr, asking him to request a memorandum from Bohr that he could read as an introduction.[108] Bohr sent the memo on the 3rd of July 1944.

Because this document has a close resemblance with the Halifax memo and the Churchill letter, I will not analyse it at length. As with the earlier documents, Bohr started this memo with an explanation of the scientific developments that had led to the construction of the atomic bomb. After this, Bohr emphasized the need for openness and international control, just as he did in the Halifax memo and the letter to Churchill. As we will see below, large parts of his Open Letter to the United Nations in 1950 were extracted from the Roosevelt memorandum.

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[105] Aaserud, Introduction, 26.

[106] N. Bohr, Letter to Churchill 22 May 1944, in: F. Aaserud (ed.), Niels Bohr collected works volume two; the political arena (1934 – 1961), 96 – 98, 97.

[107] Aaserud, Introduction, 30.

[108] Ibidem, 30.

From Bohr's personal notes, it becomes clear that Bohr met Roosevelt in the Oval Office on the 25th of August.'[109] Aage Bohr, Niels Bohr's son, mentions in his *War Years* that Bohr was optimistic and satisfied when he came from the meeting. All in all, Bohr was confident that Roosevelt had understood his views about arms control well.[110]

In a fairly short follow-up letter to Roosevelt, dating the 7th of September 1944, Bohr expressed his gratitude for being allowed the chance to explain his views to the President. As we have seen before, Bohr used the opportunity of the 'thank-you-note' to remind the President of the most important parts of his plea:

> 'It is from the point of view of proper timing that I venture to suggest that the technical factors of the situation make the present moment most favourable for considerations of the question of control by the friendly governments most concerned, lest opportunities be forfeited of forestalling a fateful competition about the new weapon and of turning the great triumph of science and engineering to lasting benefit for the common cause.'[111]

As we will see below, Bohr would soon become disappointed in the results of his meeting with Roosevelt. However, for now it is important to point out that with this letter to Roosevelt, Bohr's behind the scenes mission with the world's political leaders had reached its peak. As we know, in the months after Bohr's diplomatic contacts with Roosevelt and Churchill, the bomb was further developed at Los Alamos, and finally used against the Japanese in August 1945.

2.4.2 Public debate

So far, Bohr played an active role trying to influence policy behind the scenes. He discussed his views in letters and conversations with the leaders and high officials of the American and British governments and armed forces. After the first bombs were used in August 1945, Bohr also tried to stir the debate on these issues in public. However, the amount of writings that deal with atomic weapons and nuclear deterrence specifically is rather limited. Therefore, I will focus on two publications of Bohr in this section: The 'S*cience and civilization'* article Bohr published in *the New York Times* in August 1945 and the Open Letter Bohr sent to the United Nations in June 1950.

Science and civilization

After the Hiroshima and Nagasaki bombings, the need for secrecy and backdoor diplomacy vanished for Bohr.[112] According to Aaserud, Bohr 'was anxious to express his views on [the

[109] Aaserud, Introduction, 34.

[110] Ibidem, 35.

[111] N. Bohr, Letter to Roosevelt 7 September 1944, in: F. Aaserud (ed.), Niels Bohr collected works volume two; the political arena (1934 – 1961), 109 – 111, 110.

[112] Aaserud, Introduction, 49.

bomb's] implication in public. He hoped thus to contribute to a broader understanding of the new perspectives presented by the revolutionary technological advance and of the far-reaching measures called for.'[113]

Bohr's first publication about the atomic bomb and the new international balance of powers was an article entitled *Science and civilization* in *the New York Times* of August 11, 1945. In it, Bohr started by addressing the paradoxical nature of modern physics:

> 'While the increasing mastery of the forces of nature has contributed so prolifically to human welfare, and holds out even greater promises, it is evident that the formidable power of destruction which come within reach of man may become a mortal menace unless human society can adjust itself to the exigencies of the situation.'[114]

Just as Bohr advocated in his letters and memoranda, the devastating forces of the atomic weapons and the dangers they unleashed upon civilization must be met by cooperation and transparency:

> 'Against the new destructive powers no defence may be possible and the issue centres on world-wide cooperation to prevent any use of the new sources of energy which does not serve mankind as a whole.'[115]

The only way to achieve effective international control, Bohr argued, is free international access to information and 'the abolition of barriers hitherto considered necessary to safeguard national interests but now standing in the way of common security against unprecedented dangers.'[116] If the nations of the world would succeed in this, the atomic bomb might have not been such a bad development at all, Bohr argues:

> 'The extent of the contribution which an agreement about this vital matter would make to the removal of obstacles to mutual confidence and to the promotion of a harmonious relationship between nations can hardly be exaggerated.'[117]

In his *Times*-article, Bohr expressed more or less the same views as he did in his letters and memoranda for Roosevelt and Churchill. Not long after the publication of this article in the Times, Bohr was asked to write an article with comparable substance for *Science*, which

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[113] Aaserud, Introduction, 49.

[114] N. Bohr, Science and civilization, The Times 11 August 1945, in: F. Aaserud (ed.), Niels Bohr collected works volume two; the political arena (1934 – 1961), 121 – 124, 123.

[115] Bohr, Science and civilization, 124.

[116] Ibidem, 124.

[117] Ibidem, 124.

appeared in October 1945. It would take until June 1950, however, before Bohr addressed the organization that, according to him, could make a real difference: the United Nations.

Open Letter to the United Nations

During the first years after the Second World War, Bohr never published the reports and memoranda he had sent to Churchill, Roosevelt and other high officials. He kept corresponding and discussing the possibility of an open world and international arms control with friends from the political sphere, next to his spare publications in the *New York Times* and *Science*.

At certain moments during this period, it seemed as if Bohr's plea for openness and transparency was heard in the political leadership of the United States. For example, in June 1946, United States representative to the United Nations Bernard Baruch proposed the establishment of an international Atomic Development Authority, the so-called *Baruch Plan*.[118] For the purposes of this study, it stretches too far to go over the exact proposals Baruch made, but it is of great interest to notice that Bohr was mentioned in talks between Secretary of State J.F. Byrnes and Baruch. According to Aaserud, Bohr was tipped as 'the ideal type' to be in the board of directors of the Autority that was to be founded.[119] While the plan was the result of a long-winded diplomatic process between the Americans, the British and the Soviets, the Soviets did not accept its premises and priorities. As it turned out, the Soviet ambitions for constructing an atomic bomb themselves could not be contained.

The rejection of the Baruch Plan had severe diplomatic consequences. In 1950, acquaintances of Bohr who worked at the State Department informed him that the 'political climate in Washington was not conducive to initiating an official offer of openness on the part of the United States government.'[120] Clearly, these remarks were also connected to the recent coming about of the Soviet bomb in 1949. This was when Bohr realized he had to change his course if he wanted to spread his ideas.

The result of this was the *Open Letter* Bohr sent to the United Nations on June 9, 1950.[121] Already in the first paragraph, it is clear that Bohr had not changed his thoughts on the paradox of atomic energy:

> 'At the same time as this development holds out such great promises for the improvement of human welfare it has, in placing formidable means of destruction

[118] The Baruch Plan, online at: http://www.atomicarchive.com/Docs/Deterrence/BaruchPlan.shtml, last consulted February 8th, 2013.

[119] Aaserud, Introduction, 68.

[120] Ibidem, 78.

[121] Ibidem, 79.

in the hands of man, presented our whole civilization with a most serious challenge.'[122]

After describing his own role at the Manhattan Project and his contacts with political and military leaders, Bohr presented his views about the many possibilities the new situation offered:

> 'It appeared to me that the very necessity of a concerted effort to forestall such ominous threats to civilization would offer quite unique opportunities to bridge international divergences. Above all, early consultations between the nations allied in the war about the best ways jointly to obtain future security might contribute decisively to that atmosphere of mutual confidence which would be essential for co-operation on the many other matters of common concern.'[123]

Just as we have seen before, when Bohr presented his views to Roosevelt and Churchill, Bohr is convinced that in the darkness of the situation hope is to be found. Perhaps, so Bohr argues, the development of the atomic bomb could be the start of a ground-breaking new start for humanity:

> 'Moreover, the very novelty of the situation should offer a unique opportunity of appealing to an unprejudiced attitude, and it would even appear that an understanding about this vital matter might contribute most favourably towards the settlement of other problems where history and traditions have fostered divergent viewpoints.'[124]

Bohr proceeded by proposing diplomatic steps that should be taken by the countries that have obtained nuclear technology. The steps he mentioned are similar to those he urged Roosevelt and Churchill to consider some six years earlier: a free flow of information through the world community, including military information and international arms control. What Bohr argued for is, in short, a truly 'open world'.[125] Though this might seem naïve, Bohr was aware of the difficulties his approach brought along. This, however, should not stop the nations of the world to work together in peace, because the stakes were simply too high:

> 'The consideration in this memorandum may appear utopian, and the difficulties of surveying complications of non-conventional procedures may explain the hesitations of governments in demonstrating adherence to the course of full mutual openness. Nevertheless, such a course should be in the deepest interest of all nations, irrespective of differences in social and economic organization, and

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[122] Bohr, Open letter to the United Nations

[123] Ibidem

[124] Ibidem

[125] Ibidem

> the hopes and aspirations for which it was attempted to give expression in the memorandum are no doubt shared by people all over the world.'[126]

Bohr closes his Open Letter by stating that the current 'deadlock' between nations can only be removed when 'all supporters of international co-operation' work towards the same goal: 'The efforts of all supporters of international co-operation, individuals as well as nations, will be needed to create in all countries an opinion to voice, with ever increasing clarity and strength, the demand for an open world.'[127]

2.4.3 The reception of Bohr's ideas about nuclear deterrence and arms control

How did the military and political leaders react to the ideas that Bohr brought forward in his conversations, letters, memoranda, and essays? In this paragraph, we will shortly analyse the results of Bohr's efforts that have been described above.

At first, positive signs were appearing. Right after Bohr's flight to Britain, he was informed about the project and he was offered an appointment as a scientific advisor to the British project. Although Bohr declined, for reasons we have mentioned elsewhere, this certainly shows the amount of trust that was vested in him.[128] In the months following his arrival in Britain and his travels to the United States, Bohr met regularly with influential figures, varying from high-ranking public officials such as Anderson, Frankfurther and Halifax to political leaders such as Churchill and Roosevelt. It seems that most political and diplomatic leaders were interested in Bohr, both as a person and as a scientist. Diplomats, among them Anderson and Halifax, helped Bohr to transform his ideas into a 'practical political course of action'. However, at this time, we already see that the diplomatic figures struggle with the a-political character of Bohr's proposals. A clear example is the letter that Halifax sent to Anderson about his conversation with Bohr: 'These scientists find it very difficult to make their thought precise on political problems, and […] I have had a lot of work with Bohr to get any clear idea of how his thought worked.'[129]

The tables turned definitely, however, when Bohr was given the opportunity to explain his views to Churchill. Anderson introduced some of Bohr's ideas to him in a letter dating 21st of March 1944. In it, he explained Bohr's ideas about informing the Russians about the Manhattan Project and the possibility of 'collaborating' with the Russians in international arms control programs. Churchill circled the word 'collaborate' and wrote 'on no account' on the page.[130] As we have already seen in the introduction of this study, the meeting that Churchill granted Bohr in May 1944 to explain his views proved a fiasco for Bohr.

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[126] Bohr, Open letter to the United Nations

[127] Ibidem

[128] Pais, Niels Bohr's time, 496.

[129] Aaserud, Introduction, 19.

[130] Ibidem, 21.

The meeting Bohr had with Roosevelt on August the 26th went apparently well. Roosevelt was said to be open and interested and promised to discuss the matter with Churchill.[131] The result of the discussion between Roosevelt and Churchill did not turn out the way Bohr had hoped for. In the meeting at Roosevelts apartment at Hyde Park on September 18th, both leaders agreed that no international agreements should be reached about the atomic bomb.[132] Things got worse when Churchill and Roosevelt discussed Bohr's contacts with Kapitza, the Soviet physicist. After the conversation with Roosevelt, Churchill wrote to his scientific advisor Lord Cherwell:

> 'The President and I are much worried about Professor Bohr. How did he come into this business? He is a great advocate of publicity. He says he is in close correspondence with a Russian professor, an old friend of his in Russia, to whom he has written about the matter and may be writing still. The Russian professor has urged him to go to Russia in order to discuss matters. What is all this about? It seems to me that Bohr ought to be confined or at any rate made to see that he is very near the edge of mortal crimes.'[133]

Not only had Bohr failed to succeed in convincing Churchill and Roosevelt of his idealistic road to peace as regarding the content of his views, he was now distrusted, and, as it turns out in the next sentence of Churchill's letter, even disliked;

> 'I had not visualized any of this before, though I did not like the man when you showed him to me, with his hair all over his head, at Downing Street. Let me have by return your views about this man. I do not like it all.'[134]

While Bohr kept his contacts with high officials and scientists, his advice played no serious role in either the Roosevelt, the Truman administration or the Eisenhower administration. As we saw above, acquaintances of Bohr informed him in 1950 that the cold war was becoming more intense. Plans for 'global openness' were no longer discussed.'[135] This is when Bohr decided it was time to discuss his views at the highest possible platform, according to him: the United Nations.

2.4.4 Preliminary conclusions: The role of complementarity in Bohr's political thought

What can be said about Bohr's ideas about nuclear deterrence and arms control in general and how were these ideas connected to his scientific thought? In this paragraph, I will formulate some preliminary conclusions about the role of complementarity in Bohr's political thought. A more thorough discussion of Bohhr's ideas about the bomb and the interaction between

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[131] Aaserud, Introduction, 36.

[132] Ibidem, 37.

[133] Pais, Niels Bohr's time, 502.

[134] Ibidem, 502.

[135] Aaserud, Introduction, 78

Bohr and military and political leaders will take place in chapter four. But for now, we will summarize what we have seen above.

The concept of complementarity played a distinctive role in Bohr's perspective on quantum physics and in his outlook on the world in general. Complementarity helped him in an epistemological way to deal with the apparent internal inconsistencies of quantum mechanics in the late 1920s. In the years following his Como lecture, Bohr tried to expand the use of complementarity to other fields, such as biology. It is safe to say that Bohr, while trying to apply complementarily to other domains in science, was using the concept in a social sense as well.

To establish connections between the concept of complementarity, which originated in physics, and Bohr's analyses of the atomic bomb, we have to acknowledge that it is necessary to adopt a liberal interpretation of 'complementarity'. Of course, it is impossible to simply 'pick up' the concept of complementarity that originated in 1927 and apply it to Bohr's political thinking in 1943 – 1950. But, as some scholars have stated in the past, this is not so problematic as it seems. After all, Bohr himself kept adjusting the concept to fit the topics he was occupied with at a particular moment.[136]

Therefore, concerning the role of complementarity in Bohr's political thought on the atomic bomb, three preliminary conclusions can be drawn. First, we have seen that Bohr used the concept of complementarity when he discussed the moral implications of the work of the many scientists at the Manhattan Project. As the reader will recall, Austrian physicist Weisskopf reflected on Bohr's role in the many discussions by stating that the biggest lessons they learned from Bohr was that 'every great and deep difficulty bears in itself its own solution.'[137] As we now know, this was quite characteristic for Bohr's complementary way of analysing the situation: if one changes the perspective on an object (or on a situation) the nature of the object will change.

Second, Bohr used the concept of complementarity in the same way when he discussed nuclear issues with world leaders such as Churchill and Roosevelt. For example, in a letter he sent to Churchill after their meeting, Bohr addressed the question how the challenges that the nuclear weapons brought forward could be 'turned to lasting advantage for the cause of freedom and world security.' Lastly, in Bohr's publications after the first use of the atomic bomb in August 1945, complementarity played a role as well. In his New York Times article, Bohr addresses the public for the first time on these matters. Already from the start, he remarks that physics brought enormous advantages to the well being of mankind, but, at the same time, poses incredible treats. Later in his piece, he turns this argument around: the treats posed by the bomb, could be turned around for the better of all mankind.

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[136] A clear overview of Bohr's attempts to adapt the concept of complementarity to fit various situations can be found in Katsumori, Niels Bohr's complementarity (2005).

[137] Rhodes, The making of the atomic bom, 524 – 525.

C h a p t e r   t h r e e
John von Neumann

'The problems of the future of humanity can not be resolved by a single prescription, but only in reliance on day-to-day opportunistic measures, and reliance on the human qualities required: patience, flexibility, intelligence.'

John von Neumann, *Can We Survive Technology?* (1955)

When the Hungarian-Jewish mathematician John von Neumann wrote the article *Can we survive technology?* in *Fortune Magazine* in 1955, he had spent nearly twenty years as a consultant for the American military. Originally, von Neumann's input was appreciated because he was an expert on explosions, earning him a job at the Manhattan Project. However, during the early years of the Cold War, von Neumann established a reputation as an expert on 'war games', based on his ground-breaking work on the foundations of game theory in the late 1920's.[1] As an advisor on nuclear and military policy, von Neumann worked at the previously mentioned RAND institute and played an influential role in the decision-making process on foreign policy during the Eisenhower administrations.

In this chapter, we will analyse von Neumann's ideas about nuclear deterrence and arms control. First, a biographical sketch of von Neumann's early life is offered, after which we will describe von Neumann's scientific contributions. Scientifically, von Neumann was a Jack-of-all-trades. This means that we have to focus on his contributions to the field of game theory and ignore his many contributions in other fields, such as many other branches of mathematics and quantum mechanics. After this, the role of von Neumann at Los Alamos is discussed. Lastly, von Neumann's ideas about diplomacy and politics are described. In this part, we will also make clear to what extent these political ideas are connected to von Neumann's ideas about game theory.

3.1 Biography

It has been said that Budapest, Hungary, in which John von Neumann was born in 1903 was one of the most vibrant and intellectually stimulating capitals of the world.[2] At the time, Hungary and Austria were part of the dual monarchy Austria-Hungary. While Vienna was its official capital, Hungary was living through a period that has been described as an intellectual, cultural and economic renaissance.[3] It was in this intellectual climate that von

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[1] For a short overview of John von Neumann's life, see the obituary at the Institute for Advanced Study's website at http://www.ias.edu/people/vonneumann/legacy, last consulted December 30th 2012.

[2] Macrea, John von Neumann, 31.

[3] Ibidem, 31.

Neumann attended the Lutheran Gymnasium from 1914 onwards.[4] At high school, his mathematical talent manifested itself and he was given extra university teaching in set theory and the theory of measurement before graduating his secondary education.[5]

During von Neumann's high school years, Hungary went through the First World War (1914 – 1918). A communist regime came to power in 1919, soon succeeded by a right wing government that shortly after taking office introduced anti-Semitic laws.[6] Von Neumann never emphasized the fact that he was Jewish (sources say he was an atheist, formally becoming a Catholic when he married in 1930), but the events must have made an impression on the young von Neumann.[7] However, it is hard to retrieve to what extent he was influenced precisely by the state of affairs.

Von Neumann graduated in 1921, after which he was pressured by his family to take up chemical engineering courses at the universities of Berlin and Zurich.[8] This, however, was not in line with von Neumann's ambition of becoming a mathematician. Von Neumann-biographer N. Macrae describes the solution von Neumann came up with:

> 'Before leaving to become a chemical engineer […], he enrolled at Budapest University as a candidate for an advanced doctoral degree in mathematics. […] He planned to carry on his undergraduate and graduate education simultaneously, in two distinct disciplines and in three cities several hundreds of miles apart. To cap this cheek, the schoolboy's project for a Ph.D thesis was to attempt axiomatization of Georg Cantor's set theory. […] The seventeen-year-old seemed to suggest that he would try to jog up Everest in gym shoes, although only on a part-time gig.'[9]

During his first years in college, von Neumann already published papers on Cantor's set theory and ordinal numbers.[10] It was also during these first years that von Neumann finished a first draft of his doctoral dissertation in mathematics, before even attending any courses at Budapest University.[11] With these extraordinary achievements in mind, it is no surprise that von Neumann's career as a student was over before it begun. He graduated in Zurich in 1926, aged twenty-one, and received his PhD with the highest honours from Budapest shortly thereafter.[12]

[4] Macrea, John von Neumann, 61 – 67.

[5] Ibidem, 70.

[6] Ibidem, 78.

[7] Ibidem, 43.

[8] Ibidem, 86.

[9] Ibidem, 86 – 87.

[10] Ibidem, 94 – 95.

[11] Hargittai, Martians of science, 58.

[12] Macrea, John von Neumann, 98.

Göttingen, Berlin, Princeton

After his years as a college student, von Neumann shortly settled in Göttingen, where he took an interest in the young field of quantum mechanics and its still unfinished translation to mathematical language.[13] Working as a *Privatdozent* in Berlin and Hamburg between 1927 and 1929, von Neumann published thirty-two papers in mathematics, often related to problems dealing with physics.[14] According to Hargittai, von Neumann was satisfied with his life and work in Germany and may well have spent the rest of his life there if it was not for the political turmoil of the 1930s.[15]

In the fall of 1929, von Neumann was invited to come to Princeton. At the end of the 1920's, American mathematicians such as Oswald Veblen wanted to modernize American mathematics and the invitations to von Neumann and Eugene Wigner were part of this quest.[16] In 1933, Princeton's Institute for Advanced Study was founded and von Neumann was appointed as one of its professors in the same year, giving him the opportunity to spend six months in the United States and six months in Europe.[17] After Hitler's rise to power, von Neumann finally terminated his academic appointments in Germany. In 1937, he was naturalized as an American citizen. The United States, the place he fell in love with on the day of his arrival[18], had become his new home.[19]

Soon after his naturalization, Von Neumann took exams to become a lieutenant in the United States Army, but was declined for being over the age of 35.[20] The reason why Von Neumann wanted to join the army was that this was the best way to gain access to explosion statistics, a field he was interested in.[21] Because of the rejection, Von Neumann could direct all his attention to his work at the Institute for Advanced Study. Von Neumann's productivity at the Institute was impressive. Between 1933 and 1942, he published thirty-six papers.[22] As we will see in the following paragraph, these dealt with a variety of topics, including quantum physics, rational behaviour theory in economics (which laid the foundations for the new science of game theory) and mathematics. At Princeton, Von Neumann's productivity and wit earned him the status of a 'demigod', who had studied humans and learned to imitate them perfectly.[23]

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[13] Hargittai, Martians of science, 59.

[14] Ibidem, 59.

[15] Ibidem, 59.

[16] Ibidem, 81.

[17] Ibidem, 81.

[18] Ibidem, 81.

[19] Ibidem, 82.

[20] Ibidem, 122.

[21] Macrea, John von Neumann, 190

[22] Hargittai, Martians of science, 82.

[23] Rhodes, The making of the atomic bomb, 109.

3.2 Von Neumann's science

When Von Neumann was appointed professor at Princeton's new Institute for Advanced Study in 1933, the physics community was still debating the problems arising from quantum mechanics. The question of how to model the sub-atomic universe was still highly accurate. At the same time, comparable problems rose in a different field of science. Economics, the science of measuring and predicting human behaviour, such as the consumption and production in a society, evolved from a historical, descriptive activity into a more mathematical-oriented science.[24] Just like many physicists, economists of the 1930's struggled with the question how to transform the theories and ideas into mathematical sound formulas. As can be expected, Von Neumann instantly felt attracted to these mathematical problems.

Games in the 1920's

One could start the history of game theory in seventeenth century France with Pascal's and Fermat's work on probability and chance.[25] Or one could start with the Prussian military game *Kriegspiel*, a game played on a map of the border-area between France and Belgium, which was frequently played at military academies in eighteenth century Germany.[26] I have chosen, however, to start the history of games in the modern age, unfortunately ignoring the very first building blocks of the field. This is a choice for matters of space, but, as we will see below, there are also a few substantive reasons to let the history of game theory commence in the early twentieth century.

It was in 1928, well before he left for Princeton, that von Neumann published a paper entitled *Zur Theorie der Gesellschaftspiele* in the journal *Mathematische Annalen*. In it, von Neumann set out to formulate mathematical solutions to questions concerning parlor games; games in which there are two players with diametrically opposed interests. These are the so-called zero sum games. The question von Neumann tried to answer was whether there is a defining strategy to play such a game, considering that one player's loss is the other player's gain.[27]

To illustrate the problem von Neumann was trying to solve, let us imagine a game in which both players, Karl and Alexis, have opposing interests. One player's loss is the other player's gain. To keep the game simple, we assume both Karl and Alexis only have two options. Karl could play move 1 (we call this option K1) or play move 2 (which we call option K2). Alexis, on its turn, could play move 1 (which we will call option A1) or play move 2 (option A2). Both have to make their move simultaneously, so it is not possible to wait and see what their opponent's move will be. To make the game look like a real 'game scenario' in the everyday

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[24] E.R. Weintraub, Introduction, in: E.R. Weintraub (ed.), Toward a history of game theory (Durham, 1992), 3-14, 3.

[25] S.J. Heims, John von Neumann and Norbert Wiener; from mathematics to the technologies of life and death (Cambridge, 1980), 79 – 80.

[26] Poundstone, Prisoner's dilemma, 37.

[27] Heims, John von Neumann and Norbert Wiener, 83 – 84, 85.

world, we can ascribe imaginary pay-offs to their moves. For example, let us assume that if Karl and Alexis both play option 1 (K1 & A1), this works out a lot better for Karl than for Alexis for some reason. And let us assume that if Karl plays K1, but Alexis plays option A2, this works out better for Alexis. If Karl plays option K2 and Alexis plays option A1, Alexis is scoring more points, and, finally, if Karl plays option K2, while Alexis plays option A2, Karl is doing better. Again, these pay-offs are fully arbitrary and they only serve to ascribe points to moves, just like moves have pay-offs in the real world (imagine any war game, for example). Please note that the pay-off for both players is transparent: each player knows what is at stake for himself and his opponent. If we put these moves and pay-offs in a matrix, the game looks as follows:

	Alexis A1	Alexis A2
Karl K1	+5	-2
Karl K2	-2	+2

In this game[28], the outcomes in the table are seen from the perspective of Karl. When we switch plusses and minuses, we see the game from Alexis' perspective. If we assume that both players wish to minimalize their losses and maximize their gain, it is safe to say that Karl would play option K1. After all, no matter what Alexis plays, Karl's losses never fall below option K2, while his possible gain is higher (If both play option 1 (K1 & A1), Karl gains 5 points. If Karl plays K1 and Alexis plays A2, Karl looses two points. But this is still a lot better than when Karl plays option K2: If Alexis plays A1 Karl looses two points. If Alexis plays A2, Karl is only gaining two points.). If we look at the game from Alexis's perspective, it is safe to say he would play A2 (If both play option 2 Alexis looses two points. If Alexis plays A2 and Karl plays K1, Alexis gains two points. But these options are still better than playing A1, because then Alexis' worst-case scenario is -5 instead of -2, while there is not more to gain).

But then a problem arises. Because both players have all the information necessary to make their next move, their choices are influenced by their predictions of the other player's behaviour. Alexis predicted that Karl would play K1, which is why he picked A2. This minimized his losses and maximized his gain (+2) if Karl keeps playing K1. At the same time, Karl could predict Alexis' behaviour as well, which is why he would not like to play K1 all the time, despite the fact that this option is potentially gaining him the most. The problem that soon arises, then, is that it is quite difficult to make rational decisions in these zero-sum games. Both players will end up in endless circles of estimation and prediction. The point at

[28] There are numerous games like this displayed online, serving as examples of game theory and the minimax theorem. While I have made this game up myself, it is a variation on a game example Poundstone uses at page 57 from *Prisoner's dilemma*. Also, I have drawn inspiration from an online game-situation, displayed for example at http://en.wikipedia.org/wiki/Minimax_theorem#Minimax_theorem

which both players are adjusting their moves based on their expectations of their opponent's move, orthodox probability theory falls short.[29]

This is the dilemma von Neumann was thinking about. The solution to this problem was the minimax theorem, which von Neumann proved in his 1928 article. Just as in our imaginary game, von Neumann started out with modest zero sum games. He used 'Paper, rock, scissors' and 'matching pennies' as examples. Most of von Neumann's considerations about these games are loaded with functional calculus and topology[30], which makes them too complex to discuss in detail. What is interesting for the topic of this study, though, is the solution he offers. The way out of Karl's and Alexis' dilemma is the use of *mixed strategies*. Instead of endlessly hoping that Alexis would be foolish enough to play A1, Karl should change his choices in a random order from K1 to K2. Like Karl, Alexis should do the same. Depending on the pay-off, Karl and Alexis can thus calculate the amount of times they should opt for option 1 or 2. According to von Neumann, mathematics shows both players the way to the perfect equilibrium in which their losses are minimized and their gains are maximized.

Because von Neumann had proven that it was mathematically possible to formulate such a perfect strategy, the minimax theorem guarantees that 'every finite, zero-sum, two-person game has optimal mixed strategies.'[31] Again, the formal elaboration of the theorem is mathematically too complex to be discussed here. What matters about von Neumann's theorem for the development of game theory is that he offered a rational and mathematical solution to games in which players have opposing interests: the possibility of calculating an optimal mixed strategy.

This minimax theorem (named after the wish to minimize the maximum pay off of the opponent) was revolutionary, because in older mathematical works on probability and chance, the opponent's considerations were missing. S.J. Heims elaborates on this difference between Von Neumann's strategy and the historical works:

> 'One crucial aspect of modern game theory missing from Pascal's wager is the presence of a competitor, an intelligent opponent. Modern game theory is remarkable in that in its description of a game, for example the game of checkers, all possible moves of the opponent are taken into consideration in making one's own move. Competitive games, whether athletic games or board games, mimic the competitive elements of social reality.'[32]

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[29] Poundstone, Prisoner's dilemma, 50.

[30] R.J. Leonard, From parlor games to social science: Von Neumann, Morgenstern, and the creation of game theory 1928-1944, in: Journal of Economic Literature, Vol. 33, No. 2 (Jun 1995), 730-761, 734.

[31] Wolfram Mathworld offers a description online at: http://mathworld.wolfram.com/MinimaxTheorem.html, last consulted December 30th, 2012.

[32] Heims, John von Neumann and Norbert Wiener, 81.

In this factor, one can clearly see the added value of the modern field of game theory for economical, political and military considerations. Below, we will pay attention to the implementation of game theoretical thinking in these fields.

Games in the 1940's

After von Neumann's 1928 paper on the theory of zero sum games, the development of game theory as a field of science stagnated. Scholar S.J. Heims remarks that the only development of some interest during the 1930's was the adoption of the minimax theorem by scholars outside the field of game theory, such as the statistician A. Wald. Wald used von Neumann's theorem to develop statistical decision theory, which was a different branch of mathematics.[33]

From this perspective, it is no surprise that when von Neumann decided to once again direct his attention to game theory, the field was more or less the same as he had left it behind, some fifteen years earlier. Together with Princeton-based economist Oskar Morgenstern, born in Germany and raised in Vienna, von Neumann published *Theory of games and economic behaviour* in 1944. The collaboration between the mathematician and the economist is interesting. Scholars of the history of game theory have elaborated endlessly about questions concerning the nature of their professional relationship, arguing about what the contribution of Morgenstern exactly was to the numerous theorems and game-scenario's von Neumann produced in the drafts.[34] The debate led some scholars to argue that Morgenstern's biggest contribution to the field of economics *was* John von Neumann (and the previously mentioned statistician A. Wald, who is not relevant for our story at the moment). As economist M. Shubik once stated: 'It was Morgenstern's ability both to see the relevance of the work of these two great mathematicians [Von Neumann and Wald, ccb.] and to persist in getting them to work on problems of economic significance.'[35] Indeed, Morgenstern has once described himself as the catalytic factor in the history of the book.[36]

The collaboration between von Neumann and Morgenstern was fruitful indeed. They started working together in 1941, two years after they had first met at a party at Princeton (where, by the way, Niels Bohr was present as well).[37] In the fall of 1940, the idea rose to work on a paper together, explaining the nature of von Neumann's 1928 article to an audience of economists.[38] Soon, both men dropped the idea of writing a paper and started working on

[33] Heims, John von Neumann and Norbert Wiener, 95.

[34] For an account of this debate, see A. Schotter, Oskar Morgenstern's contribution to the development of the Theory of Games, in: E.R. Weintraub (ed.), Toward a history of game theory (Durham, 1992), 95 – 112.

[35] U. Rellstab, New insights into the collaboration between John von Neumann and Oskar Morgenstern on the Theory of Games and Economic Behavior, in: E.R. Weintraub (ed.), Toward a history of game theory (Durham, 1992), 77 – 94, 77 – 78.

[36] Rellstab, New insights, 78.

[37] P. Mirowski, What were von Neumann and Morgenstern trying to accomplish? in: E.R. Weintraub (ed.), Toward a history of game theory (Durham, 1992), 113 – 150, 121.

[38] Rellstab, New insights, 80.

separate chapters discussing well-defined parts of game theory and problems in economics. In April 1943, Morgenstern delivered the 600-page manuscript for *Theory of games and economic behaviour* to the publisher at Princeton.[39] When the book was published in 1944, the New York Times covered the news with a front-page review.

What did von Neumann and Morgenstern set out to do in *Theory of games and economic behaviour*? The main goal of the book was to transform the science of economics. Both von Neumann and Morgenstern 'shared [the] conviction that probability theory must be comprehensively incorporated into economic theory at a fundamental level.'[40] Both men were curious about human behaviour and rationality and wished to axiomatize nineteenth century economics into a more formalized science. Intrinsically, they were driven by the wish 'to know as much as possible about the behaviour of the individual and about the simplest forms of exchange.'[41]

Individually, Morgenstern, as an economist, had just witnessed the great recession of the 1930's and must have concluded that the (neo-) classical theories of economic thought did not explain the recent events in a satisfying way. For von Neumann, working on these topics gave him a chance to finally use his theoretical work from 1928 for practical purposes. At this point, it is worth mentioning that von Neumann had taken an interest in economics in the late 1920's. He borrowed textbooks on economics from colleagues, 'galloping' through them, and reporting about his opinion about them to his colleagues the day after.[42] This led to a lecture at a Princeton mathematics seminar in 1932, which was called *On certain equations of economics and a generalization of Brouwer's fixed-point theorem.* Von Neumann held the lecture without any notes and it was timed at half an hour. When he was invited to repeat the lecture at a seminar in Vienna in 1936, he was unable to attend. To make up for his absence, he send the organisation a nine-page text, which was later published and appreciated by some as the 'greatest paper in mathematical economics'.[43] From this perspective, von Neumann's decision to contribute to the field of economics again in the 1940's was not such a curious move after all.

For the purpose of this study, it is not necessary to discuss all the new ideas that are in *Theory of games and economic behaviour* in comparison to von Neumann's 1928 article. Nonetheless, it is useful to describe some of the key characteristics of the book. In each part of the book, von Neumann and Morgenstern routinely first discuss the theory of a set of games (the theory of zero sum two person games, for example), which rely heavily on von Neumann's earlier work. After this, they work out examples of these games in the form of economic problems. It is interesting to notice that von Neumann and Morgenstern tried to

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[39] Rellstab, New insights, 92.

[40] Mirowski, What were von Neumann and Morgenstern trying to accomplish?, 135.

[41] Ibidem, 136.

[42] Macrea, John von Neumann, 251.

[43] Macrea, John von Neumann, 247 - 248.

formulate explanations and theorems for situations in which three or more players are involved (n-person games), leading up to zero sum > 6 person games, while von Neumann's 1928 article mainly discussed zero sum games between two players. Needless to say, the theory of games becomes more complex with each added person. The main reason for this is the factor of coalition building: two weak players could outnumber one strong player, for example.[44] But where does this stop? When truly analysing a country's economy, one should formulate a matrix consisting of variables true to the amount of citizens (and even then ignoring the fact that most economies have an open, international character). Von Neumann and Morgenstern realized this as well. Next to these problematic n person games, they addressed other types of games as well, such as non-zero sum games.[45] These are more mathematically complex than two player zero sum games. Because of this, von Neumann and Morgenstern acknowledged in their opening remarks that their book was just the start of the project of game theory: 'Here we can approach only the simple questions. However, these questions are of a fundamental character.'[46] After 1944, there was no time to elaborate on the 'not so simple'-questions. Von Neumann's war efforts were taking more of his time.[47]

Despite von Neumann's and Morgenstern's aspirations to 'solve' the methodological problems in the study of economics, game theory was not an instant success in this particular field. As historian of economics R.J. Leonard remarks, textbooks on economics placed topics concerning games, such as the Nash equilibrium, in the section dedicated to 'other topics' for decades.[48] This started to change in the 1980's. Yet the true measure of the success of game theoretical thinking in the midst of the twentieth century can be found in other disciplines. Game theory became a major factor in political science and military science. Experts in both fields became interested in its possibilities. The popularity of the theory rose so quickly that some scholars even wondered what was happening. [49] On this, we will elaborate below. First, we will look at the activities von Neumann undertook in the desert of Los Alamos.

3.3 Von Neumann and the bomb

Just as we have done when analysing Bohr's contributions to the Manhattan Project and to international affairs, we will discuss von Neumann's work at the Manhattan Project independent from his diplomatic efforts. Von Neumann first entered the site of the Manhattan Project at Los Alamos in the summer of 1943. He had already done research for the National Defense Research Committee on shock waves, helping to develop and improve anti-tank

[44] Poundstone, Prisoner's dilemma, 63.

[45] A perfect example of a non zero sum game is 'the battle of the sexes'; a husband and wife have different preferences about their weekly night out, but both would still rather go out together than apart.

[46] J. von Neumann, O. Morgenstern, Theory of games and economic behavior (Princeton, 1944), xxvii.

[47] Poundstone, Prisoner's dilemma, 63 – 64.

[48] R.J Leonard, Creating a context for game theory, in: E.R. Weintraub (ed.), Toward a history of game theory (Durham, 1992), 29 – 76, 29.

[49] Heims, John von Neumann and Norbert Wiener, 95.

weapons such as the bazooka and torpedoes.[50] Besides his job at the NDRC, he was a consultant for the Navy section on mine warfare. Also, he became a member of the advisory board of the Ballistic Research Laboratory, based in Aberdeen, United Kingdom.[51] These appointments made von Neumann one of the leading scientific experts in the United States on explosions, a field in which his calculating skills were of great value because of the many variables involved.[52]

When von Neumann was directed to the research site at Los Alamos, he was spending time in Britain on behalf of his work at the Navy section on mine warfare.[53] It is interesting to note that he, unlike other top-scientists, was not invited to join the Manhattan Project on a full time basis. Also, the invitation to become a consultant to Oppenheimer was sent late in 1943 when compared to the invitations that were sent to the other scientists. Hargittai offers an explanation that tells us a bit about the working habits of Von Neumann as well:

> 'The explanation is that he was a mathematician rather than a physicist. Also, he provided immediate solutions to many immediate problems and was treasured for that in many different undertakings, whereas the development of the atomic bomb was a longer-range project. For him, it was probably also not fitting to dedicate himself to one particular project full time. But in the fall of 1943, he was already engaged at Los Alamos, in addition to his many other assignments.'[54]

Macrae estimates that von Neumann spent only approximately 30% of his time as a consultant at Los Alamos.[55] Unlike Bohr, who served as a father figure and spiritual leader for some scientists, Von Neumann's role at the Project was aimed more at solving specific problems. Because of this, not much is known about conservations von Neumann had with his colleagues on armament. His contributions to the Project, however, are numerous and diverse. At Los Alamos, von Neumann was one of the consultants to whom Oppenheimer could turn for advice on various topics.[56] Françoise Ulam, the late wife of the mathematician Stanislaw Ulam, remarked that von Neumann 'worked on the whole project, scientifically and politically, especially [later] with the hydrogen work. In fact he was unable to play the role of senior scientist or advisor without being actively engaged.'[57] This fits the general image that exists of von Neumann as an enthusiastic and intellectual whirlwind, shooting from the hip at complex problems as they arise. Perhaps this is why von Neumann had a good time as an

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[50] Rhodes, The making of the atomic bomb, 479. Also in Hargittai, Martians of science, 123.

[51] Hargittai, Martians of science, 122.

[52] Ibidem, 123.

[53] Ibidem, 124.

[54] Ibidem, 124.

[55] Macrae, John von Neumann, 215.

[56] Rhodes, The making of the atomic bomb, 479.

[57] F. Ulam, Nonmathematical reminiscences about Johnny von Neumann, in: Glimm, J., Impagliazza, J., Singer, I., (ed.) The legacy of John von Neumann (New York, 1988), 9 - 14, 12.

advisor at Los Alamos: it was the new frontier when it came to interdisciplinary scientific work. Historian Poundstone also mentions the positive attitude that von Neumann displayed at the Project site:

> 'He seems not to have suffered the pangs of conscience that afflicted so many of the scientists who had worked on the bomb. Most of the Manhattan Project scientists returned to academia, many anxious to forget the war, the bomb, and Los Alamos. Von Neumann continued as a consultant to defense agencies after the war. He came to love the country around Los Alamos so much that some said that, had he lived, he might have bought a home there.'[58]

We will come to von Neumann's deeper motivations for doing defence work later in this study, but for now we can conclude that von Neumann must have found it a stimulating environment. This shows in his productivity as well. One of the first of his contributions to the Project was a study that showed that the bomb would have the most impact when it exploded above the ground instead of on ground level.[59] Another contribution that is worth mentioning was concerned with the detonating device that was used to bring the two parts of critical mass together. After a discussion with Teller, von Neumann remarked that the compressibility of the material (iron) should be considered as well.[60] Teller, in hindsight:

> 'In my discussions with him some crude calculations were made. The calculation is indeed simple as long as you assume that the material to be accelerated is incompressible, which is the usual assumption about solid matter. In material driven by high explosives, pressures of more than 100,000 atmospheres occur.'[61]

These calculations of von Neumann played a role in determining the shape and size of the bomb. These contributions seem minor, however, when compared to von Neumann's most controversial task at the project. In the weeks before the first atomic bombs were thrown, he was key advisor to project leader General Groves when it came to selecting the right Japanese cities to bomb.[62] Von Neumann and Groves respected each other and they regularly discussed the most appropriate targets.[63] When they finally picked Hiroshima as the first city to bomb, sparing Kyoto as one of the intellectual centres of Japan, von Neumann's advice was the cornerstone of one of the most characteristic events in human history.

While most scientists left Los Alamos after the bombing of Hiroshima and Nagasaki in the summer of 1945, von Neumann kept returning to the spot. His military assignment consisted

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[58] Poundstone, Prisoner's dilemma, 69.

[59] Hargittai, Martians of science, 124.

[60] Ibidem, 124 – 125.

[61] Rhodes, The making of the atomic bomb, 480.

[62] Heims, John von Neumann and Norbert Wiener, 232.

[63] Ibidem, 193.

of making calculations of the explosions of the bombs, in order to improve their effectiveness.[64] Next to von Neumann, a few physicists remained to work at Los Alamos occasionally, among whom Teller. After Truman ordered the construction of *The Super*, their activities led eventually to the development of the hydrogen bomb, a topic we have touched upon before.[65] At this time, von Neumann was already actively engaged in consulting the government about nuclear strategy. Below, we will focus on this and the role of game theory in his activities.

3.4 Diplomacy

Up until now, we have seen examples of von Neumann's scientific and military activities. We have seen how von Neumann, as a scientific jack-of-all-trades, became increasingly popular within the different branches of the United States government and army. We have also been able to grasp some of von Neumann's ideas about the political and diplomatic domain already. Unlike most scientists at Los Alamos, von Neumann liked working in the defence sector a lot.

In this part, we will make a more thoroughly analysis of von Neumann's ideas about nuclear deterrence and arms control and the role of game theory in them. In the previous chapter, we have seen how Bohr operated to get his opinions across. He wrote letters to world leaders and discussed them with various government officials behind the scenes. When the need for secrecy vanished after the first nuclear bombings, Bohr published two articles on the subject in *Nature* and *The New York Times*. Especially after the intensification of the Cold War early in 1950, he became a public advocate of transparency and international arms control, voicing his opinions on the world stage. Therefor, making a thorough analysis of Bohr's political and diplomatic thought (and the role of complementarity in it) was relatively easy. All the relevant documents in which he expressed his views are available.

To determine the political and diplomatic ideas of von Neumann, however, a different strategy is needed. Bohr was an *outsider* who was *trying* to influence policy. Von Neumann was the opposite: an *insider* who *did* influence policy. To make matters worse, von Neumann disliked appearing in public and he seldom gave interviews.[66] Therefore, the amount of documents dealing with his political ideas is slim compared to Bohr. This has a few consequences for the remainder of this chapter. If we wish to give an account of von Neumann's political ideas, we have to rely more on secondary remarks about von Neumann as a person. Occasionally we can analyse important government decisions that were taken, based on ideas that von Neumann put forward in his advice or in his scientific papers. Furthermore, by analysing the reception of von Neumann's scientific ideas in the political and military sphere, we gain some insight in the political and military possibilities of his scientific

[64] Macrae, John von Neumann, 329.

[65] Ibidem, 331.

[66] Hargittai, Martians of science, 157.

work (which we will do in chapter four). These are the alternative strategies I will work with. While it is not ideal, we will see that it yields some interesting insights nonetheless.

In the first part of this section, we will analyse von Neumann's personal ideas about nuclear deterrence and arms control. Due to the lack of any written material by von Neumann himself, this will mainly be a description about his personal views and his way of thinking about the cold war based on remarks by people who stood close to him. In the second part, we will analyse von Neumann's role as an advisor in the Truman and Eisenhower administrations during the cold war. Third, we will investigate how von Neumann's game theory, which he peremptory formulated in *The theory of games and economic behaviour* in 1944, found its way in the United States military and government. In the last part, we will draw some preliminary conclusions about the role of game theory in von Neumann's political thought.

3.4.1. Von Neumann's political and diplomatic ideas

Before we enter the core of von Neumann's political ideas, we will investigate the ideological foundations on which his ideas were based. What drove von Neumann as a socially engaged person, in a community in which most scientists were quite reserved about their political views? Fortunately, Marina von Neumann Whitman, von Neumann's daughter (his only child), elaborated extensively on her father's ideological worldview in a lecture held at a conference by the American Mathematical Society at Hofstra University in 1988.[67] In this lecture, the personal motives that constituted his worldview are discussed. According to von Neumann Whitman, von Neumann's ideas were shaped between the 1930's and 1950's by his search for freedom and his aversion of totalitarianism. First, this drove him to the United States in the 1930's:

> 'By the beginning of the 1930's, if not even earlier, he [von Neumann, ccb.] became convinced that the lights of civilization would be snuffed out all over Europe by the spread of totalitarianism from the right. So he made an unequivocal commitment to his home in the new world and to fight to preserve and re-establish freedom from that new beachhead.'[68]

During the 1940's, von Neumann realized that war with the Soviets became inevitable as soon as the Second World War would come to a close. As his daughter pointed out, a new kind of totalitarianism was soon to threaten his new homeland:

> 'In the 1940's and 1950's, he was equally convinced that the threat to civilization now came from totalitarianism on the left, and his commitment was just as unequivocal to fighting it with whatever weapons lay at hand, scientific and

[67] M. von Neumann – Whitman, John von Neumann: a personal view, in: Glimm, J., Impagliazza, J., Singer, I., (ed.) The legacy of John von Neumann (New York, 1988), 1 – 4, 1.

[68] von Neumann – Whitman, John von Neumann, 2.

economic as well as military. It was a matter of utter indifference to him, I believe, whether the threat came from the right or from the left.'[69]

Because of this, von Neumann, unlike most other scientists at Los Alamos, did not think that using the atomic bomb was only justified when Germany was the target. According to Hargittai, von Neumann was convinced that developing the bomb was a key factor in securing the future of the United States: 'He did not think that inventing the murderous bomb was sinful and he denied that the only reason for it was to be ahead of Nazi Germany. […] He was 100% pessimistic about Russian relations. So he was preparing himself and his adopted country for the post-war conditions of the world.'[70]

This is remarkable, especially when we consider that many scientists at the time had a distinct preference for left-of-center ideologies. Hargittai elaborates on this difference between von Neumann and the rest of the scientific community: 'Von Neumann was horrified by the idea of communism, whereas many of his colleagues appeared to be left-wing and preferred to ignore the frightening news of poverty and tyranny from Soviet Russia.'[71]

It is then safe to say that von Neumann's political and diplomatic ideas were vested in the belief that the United States should do whatever it takes to preserve and protect its values when totalitarian forces would threaten them. Because of this, von Neumann was considered a true hawk in the spectrum of international affairs. Peace and stability could only be guaranteed when the opposing forces (in this case the Soviets) were absolutely certain that any aggressive move on their part would be answered with a full-blown nuclear response. One of the consequences of this impassive analysis of a possible nuclear war was that von Neumann advocated the bombing of the Soviets before they could develop enough weapons of their own: 'With the Russians it is not a question of whether but of when. [...] If you say why not bomb them tomorrow, I say why not today? If you say today at 5 o'clock, I say why not one o'clock?'[72]

Later in this study, we will see to what extent it is possible to make a connection between von Neumann's personal stance on nuclear deterrence and arms control and his ideas about game theory. But for now, we can already see that his hawkish stance on deterrence appeared to be inspired by the game theoretical elements of his scientific work. After all, if the United States would guarantee that each move on behalf of the Soviets would be met with a (near) fatal response, the pay-off of making a move would be negative from the Soviet's point of few. The Soviets would certainly hesitate to make a move with an expected result like that. This reminds us of the minimax theorem we have seen above. While we will look into this below,

[69] von Neumann – Whitman, John von Neumann, 2.

[70] Hargittai, Martians of science, 125.

[71] Ibidem, 82.

[72] This quote first appeared in Life Magazine, February 25 1957, page 96.

we will first analyse von Neumann's role as an advisor in the Truman and Eisenhower administrations.

3.4.2 Von Neumann's role as an advisor in the Truman and Eisenhower administrations

Von Neumann was not an influential figure in Washington during the first three years after the war.[73] While he played a role in the development of the hydrogen bomb in the late 1940's, he was combining scientific work with (some) consultancy-work for the army, the government and business, such as IBM. However, at the end of the Truman administration, von Neumann took up a few extra consultancy-jobs for the government and the military, becoming a consultant for the CIA and a member of the scientific advisory board of the United States Air Force, among other things.[74] Despite these new appointments, von Neumann's role during the Truman administration remained modest.

This changed when Eisenhower became President in 1953, shortly after the Soviets first detonated their hydrogen bomb. Eisenhower appointed three scientific advisors (Strauss, Quarles, Gardner) who all thought the United States had a bigger chance to win the Cold War when von Neumann was involved.[75] Next to this, Eisenhower's Secretary of State J.F. Dulles shared von Neumann's hawkish mentality when it came to restricting Soviet aggression.[76] In the first week of the Eisenhower administration, von Neumann was approached to become the chairman of the nuclear weapons panel of the scientific advisory board of the United States Air Force.[77] This is probably the place where von Neumann's largest contribution to the development of the Cold War took shape. The nuclear weapons panel, often called the von Neumann committee, was asked to advise on the possibility of constructing a missile that carried a nuclear warhead all across the world to hit a pre-determined target in the Soviet Union.[78] Macrae lists the committee's findings:

> 'After its meetings in early 1954, the von Neumann committee reported (1) that it was possible to build a rocket-powered ballistic missile that would carry a nuclear warhead across a quarter of the world and deliver it with accuracy; (2) that the Soviets might be some years ahead of America in this field; and (3) that new management techniques would be needed so that America could catch up.'[79]

Immediately after the publication of the report, new rocket-development-programmes were being started. Three intercontinental missiles were developed (the Atlas, the Titan and the Minutemen), two intermediate range missiles (the Thor and the Jupiter) and one marine

[73] Macrae, John von Neumann, 333.

[74] Ibidem, 351.

[75] Ibidem, 347.

[76] Ibidem, 356.

[77] Ibidem, 358.

[78] Ibidem, 359 – 361.

[79] Ibidem, 361.

launched missile (the Polaris), all constructed with the goal of carrying a nuclear warhead in mind.[80] The Soviets had an advantage when it came to long distance rocket science compared to the Americans. This 'missile gap' existed for only one and a half years though. Soon after the start of the missile-programmes, the gap was closed. While this may seem like a theoretical problem (after all, no missiles were launched during the cold war), the closing of the missile gap had enormous practical implications. As Macrae rightly mentions, the only reason why Kennedy could demand from Khrushchev to take his missiles away from Cuba during the Cuba Crisis in 1962 was that both political leaders knew that the United States outnumbered the Soviet Union when it came to long-range missiles.[81]

With the game theory we have seen earlier in this study in mind, one immediately recognizes the added value of having a clear and transparent advantage over one's opponent. This is why this is an appropriate point to discuss further implications of von Neumann's game theory in the nuclear strategy of the United States.

3.4.3 Reception: von Neumann's game theory in the nuclear strategy of the United States

It has been said that the only reason why game theory survived the period between the end of 1944, when von Neumann and Morgenstern published *Theory of Games and Economic Behavior,* and the 1980's, when it became a fruitful field of research in a variety of social sciences, was its connection with the United States military.[82] Indeed, a close examination of the period makes clear how soon the game theoretical thinking of *Theory of Games and Economic Behavior* found its way to the relevant actors in government and military organisations. Already in 1946, Warren Weaver, a mathematician and the head of the Applied Mathematics Panel at the previously mentioned Office of Scientific Research and Development, commented on the book and encouraged other scholars to read it as well, especially for its interesting ideas about the concept of 'utility'. Weaver thought this to be relevant, because of his search for a quantification of military success and losses, which he called 'military worth':

> 'Military worth […] is closely related to the general concept of utility in economic theory. And the reader is warmly encouraged to read the discussion of a numerical theory of utility given (on pages 15 to 29 and elsewhere) in "Theory of Games in Economic Behavior" by John von Neumann and Oskar Morgenstern. This pioneering and brilliant book is, it should be pointed out, connected in a most important way with the viewpoint here being presented, for it develops a large part of the mathematics necessary for theories of competitive processes.'[83]

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[80] Hargittai, Martians of science, 159.

[81] Macrae, John von Neumann, 364.

[82] Erickson, The politics of game theory, 95.

[83] Ibidem, 107.

As we have seen in the opening chapter of this study, von Neumann's game theory also became an instant success at the RAND Corporation, where it was used, among other things, to calculate optimal targets for strategic bombing. As a matter of fact, already before von Neumann had reached his peak as an influential consultant, former students of him applied his insights, mostly based on his 1928 article, to military dilemmas during the Second World War. An anecdote presented by Poundstone shows that already in the Second World War, game theoretical thinking was put to the test.[84] Merril Flood, a mathematician and former student of von Neumann, worked at the Air Force, where she had to prepare a study on the (non-nuclear) bombing of Japan: what would be the right target to bomb, considering the fact that the Japanese know that the Americans were most likely to aim for the highest-ranked targets? As we see, these situations have a lot in common with the game between Karl and Alexis in which they constantly try to predict each other's next move. Flood recognized the game theoretical aspects of the dilemma and used games to calculate the right targets.[85]

We have already seen that scholars at the RAND Corporation had taken an interest in the ideas of von Neumann. In the last days of 1947, Clyde Williams, at the time the director of the institute, offered von Neumann $ 200 a month for being a part-time consultant. From the letter Williams wrote it becomes clear how much they valued von Neumann:

> 'In practise I would hope that members of the Project [RAND, ccb.] with problems in your line could discuss them with you, by mail and in person. We would send you all the working papers and reports of RAND which we think would interest you, expecting you to react (with frown, hint or suggestion) when you had a reaction. In this phase, the only part of your thinking time we'd like to bid for systematically is that which you spend shaving: we'd like you to pass on to us any ideas that come to you while so engaged.'[86]

Von Neumann accepted. In a follow-up letter, Williams specified the agenda of the institute: 'We intend to make major efforts on applications of game theory. […] If you were really to pour your torrent of energy into these subjects for a while, there would probably be a handsome pay off.'[87]

While we will discuss the underlying mechanics that influenced the reception of von Neumann's game theory more thoroughly in chapter four, we can for now conclude that game theoretical thinking was already popular among military leaders during the Second World War.

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[84] Poundstone, Prisoner's dilemma, 68.

[85] Ibidem, 68.

[86] Ibidem, 94.

[87] Ibidem, 95.

3.4.4 Preliminary conclusions: The role of game theory in von Neumann's political thought

To what extent was John von Neumann's political thought intrinsically determined by his ideas about game theory? One of the first conclusions that can be drawn based on the above is that von Neumann, unlike Bohr, appears to be less occupied with the connections between his scientific ideas and his political ideas. Bohr's ideas about the atomic bomb, nuclear deterrence and arms control were the result of a continuous philosophical argument, leading all the way from his ideas about quantum mechanics to affairs of world politics. Von Neumann, however, appears to have been more straightforward in his approach to political, military and diplomatic problems. While von Neumann, just like Bohr, had an outlook on the world that was dominated by a certain mind-set (mathematics and rigorous rationality) and a practical derivative of this mind-set (which was game theory), it is hard to make a distinction between the times in which von Neumann was actively using game theory to solve a dilemma, and the times in which his approach towards a specific problem originated simply from his general outlook on the world. Of all the literature that deals with this question, Poundstone offers the best explanation:

> 'Game theory […] is about conflict among rational but distrusting beings. Von Neumann escaped revolution and terrorism in Hungary and later the rise of Nazism. […] Game theory was the brainchild of a cynic. […] It is conceivable that von Neumann's personality led him to explore game theory rather than something else. It is wrong to think that von Neumann concocted game theory as a scientific basis for his personal beliefs or politics. Game theory is a rigorously mathematical study which evolves naturally from a reasonable way of looking at conflict.'[88]

What Poundstone's explanation shows is that the game theory framework fitted the psyche of von Neumann so well that it is sometimes hard to distinguish between the von Neumann who intentionally applied game theoretical thinking to political matters and the von Neumann who just discusses politics.

These problems of demarcation also come to show when we look at the statements of scholars who discussed political affairs with von Neumann. When asked about the connection between game theory and von Neumann's political ideas, the answer of von Neumann's former acquaintances differ. In the first place, there are those who have discussed matters of war and diplomacy with von Neumann and did not notice a game theoretical perspective. For example, Herbert York, a leading scholar in nuclear arms research, once said that 'Johnny never used Theory of Games language when discussing military or political options. He gave his views in the language used in the newspapers.'[89] Others, however, do believe von Neumann used game theory in his analysis. Valentine Bargmann, a mathematician at Princeton, remembers how von Neumann discussed the end game of the Second World War with him, in which it was

[88] Poundstone, Prisoner's dilemma, 39.

[89] Macrea, John von Neumann, 263.

sure to von Neumann that Hitler's next move was to get on a plane to South America.[90] Based on the research listed above, it is not possible to determine which version of the matter is more correct, so it is best to stay with Poundstone's explanation.

What can be concluded at this point is, of course, that von Neumann's game theoretical thinking achieved success in the political and military spheres of the United States soon after, and to a certain degree even before, the publication of *The theory of games and economic behaviour*. While it is complicated to draw conclusions about von Neumann's own political ideas (and the role of game theory in them) based on the reception and application of his ideas by others, it is safe to say that von Neumann was certainly aware of the possible applications of his theories in a military sense. After all, the job he accepted at RAND and the many part-time consultancy-jobs he took were closely connected to the application of his game theoretical ideas to diplomatic affairs.

[90] Poundstone, Prisoner's dilemma, 69.

Chapter four
Analyses

'We may sum up in two sentences. Human technology has just reached new depths of murderousness. Sooner or later, we must choose between collective suicide and the intelligent use of scientific invention.'

- Albert Camus, *Combat* (August 8th, 1945)

When the French philosopher Albert Camus wrote an article about the threat of nuclear weapons in *Combat*, the newspaper of the French resistance, the second atomic bomb on the Japanese had yet to be thrown. Nuclear weapons were one of the central topics in the intellectual debate of the later 1940's. Every public intellectual of some standing was obliged to take a stance on the issue. At the same time, army leaders and politicians were eager to use scientific and philosophical ideas to optimize their strategy. This meant that there existed both a large *supply* of intellectual ideas on the topic of nuclear weapons and it also meant that the military and the government were willing to incorporate these intellectual ideas into their organization. However, the military and the government were not simply absorbing whatever scientific and intellectual contributions were available. As a matter of fact, they held certain preferences themselves. For example, we have already seen that von Neumann's ideas were met with curiosity and interest, while Bohr's were quickly dismissed. But which underlying mechanisms influenced these preferences? In this chapter, we will analyse this question and formulate some possible explanations. First, we will give a brief recapitulation of the relevant factors from chapter one. Second, we will look at the varying receptions of Bohr's and von Neumann's ideas about nuclear deterrence and arms control that we have seen in chapters two and three. Here, some possible explanations for the varying receptions will be formulated.

In search of a general theory of warfare

When analysing the reception of Bohr's and von Neumann's political ideas in the course of the late Second World War and the early cold war, it is of great importance to keep the cultural, political and scientific climate in mind. It is useful to shortly recapitulate the relevant factors of this period. When Roosevelt established the *Office of Scientific Research and Development* in June 1941, the application of scientific ideas to military and diplomatic goals was already well under way. On both sides of the war, scientists were consulted about war-efforts. We have seen successful examples of this scientific and military cooperation in radar technology and operations research. When Roosevelt decided to put some of the United States government's efforts into nuclear research, the British had already established the *Military Application of Uranium Detonation Committee* and their *Tube Alloys Project*. At the same time, German physicists such as Heisenberg were working on nuclear fission in laboratories facilitated by Hitler's administration. The role of science in warfare was so dominant during the 1940s that various scholars characterized it as a 'revolution'[1] and labelled the Second World War a 'wizzard war'.[2]

The fact that many connections between 'scientists and soldiers' existed during and after the Second World War had far-reaching consequences. For example, never had there been so many scientists involved in the United States army as from the 1940's onwards. A second effect was that in the top levels of the armed forces, there was a demand for some sort of 'general theory of warfare'.[3] After all, considering that science brought progress in fields varying from medicine to transporting, it seemed reasonable to assume that there existed an ultimate theory about warfare as well. As a result, when analysing the reception of Bohr's and von Neumann's ideas about nuclear deterrence and arms control, two important factors have to be kept in mind: (1) there was a desire from the high military command at the Navy and the Air Force to have a 'general theory' of warfare, prompted by (2) a cultural and political climate in which the value of the interaction between science and the army was at its peak.[4]

Possible explanations

As soon as Bohr had heard about the development of the atomic bomb, he directed his attention to the question of stability in the new world order. How could there be peace in an atomic world? If we sum up Bohr's view on the matter in a few sentences, it shows that just like small particles in the sub-atomic world of quantum mechanics, the bomb showed itself to the observer depending on his point of view. If one looked at the bomb as a horrifying piece of weapon, then it was such a weapon. But if one chose to look at the bomb as a chance for the world to unite against war, nationalism and oppressive government, then the bomb could be of value in this mission. We have already seen that Bohr's notion of complementarity worked its way through his political ideas. If the leaders of the allied forces were willing to show responsibility and work together with the Soviets and other nations in an international arms control program, then peace was at hand, according to Bohr.

Von Neumann, on the other hand, saw the atomic bomb as a neutral instrument. In hands of the Nazis or communists, it was a force of evil. But in the hands of the Americans, the bomb could serve as an instrument to the preservation of liberty and democracy against the oppressive forces of totalitarianism. In his view, it did not matter whether the opposing forces were German or Russian, which is why he did not have second thoughts when it turned out that the German atomic bomb project stagnated well before the Americans succeeded in the construction of a atomic bomb. As we have seen so far, von Neumann's worldview was based on impassive rationality and mathematical rigor. This made it hard to distinguish between his formal ideas about game theory and the person of John von Neumann. From his perspective, winning the Cold War was at hand as long as the United States would play off its strategic

[1] Fortun, Sweber, Scientists and the Legacy of World War II: The Case of Operations Research (OR), 598.

[2] Rau, Combat science, 156.

[3] Erickson, The politics of game theory, 106.

[4] Erickson, The politics of game theory, 106.

advantage and develop atomic weapons in superior numbers compared to the Soviets. Game theoretical analyses showed him that the road to victory was best guaranteed by making sure the Soviets were absolutely certain that the United States outnumbered and outweighed them when it came to nuclear weapons.

What are possible answers to the question why von Neumann's ideas about nuclear deterrence were met with curiosity and interest, while Bohr's ideas were dismissed before the Second World War had ended? Perhaps it is useful to first look at the actual results their theories could offer for the United States armed forces and government (and, to some extent, the British armed forces and government). If von Neumann's ideas were more popular than Bohr's, perhaps this was due to the actual results von Neumann's game theory offered to the armed forces?

Unfortunately, this seems not to be the case. Both Bohr's complementarity driven idealism and von Neumann's game theoretical worldview did not stand out for their actual results. As historian R.J. Leonard points out, the successes of von Neumann's game theory in the armed forces during the cold war 'illustrate better the *confidence* the military held in mathematics as a tool rather than the direct *usefulness* of the ideas in this context.'[5] Looking at warfare from a game theoretical perspective certainly offers some advantages (think of it for example as a framework that is useful to clarify and categorize all the possible military actions), but its mathematical pretentions did not fit the true possibilities game theory offered in the 1940's. This was mainly due to the mathematical problems that arose with non-zero sum games. As P. Ericksson, a historian of game theory, explains, non zero-sum games offered no solutions to military problems:

> 'Non-zero-sum games possessed no obviously correct solution, and any attempts to interpret different solution concepts invariably had recourse to tacit notions of fairness, trust, and communication that had little place in a technocratic theory of military decision. While a number of the military-funded mathematicians attempted the non-zero-sum game, their subsequent disciplinary trajectories […] demonstrated the instabilities engendered by these games.'[6]

The hope that game theory served a 'one size fits all' solution for military problems was in vain. Of course, Bohr's theory of complementarity, which resulted in transparency and openness, offered not much either. After all, its most practical advice was to be transparent about the nuclear weapons program towards the Soviets, which is not an attractive scenario for a country in times of war.

What did matter, however, was the fact that von Neumann's game theory offered the *promise* of a useful theory and actual results. While the applicability of the theory fell short in practice

[5] Leonard, Creating a context for game theory, 71.

[6] Erickson, The politics of game theory, 98.

(despite some counterexamples), its future possibilities interested many military and political leaders. The promise of usefulness, rather than the actual usefulness of game theory, was one of the reasons for its popularity.

To understand this, we have to return to the political and cultural climate of the times. As we have summarized above, (1) there was a wish from the high military and intellectual command at the Navy and the Air Force to have some sort of 'general theory' of warfare, prompted by (2) a cultural and political climate in which the value of the interaction between science and the army was at its peak.[7]

It occurs that von Neumann's game theory fitted in this frame perfectly. The first reason for this 'perfect fit' was the nature of game theory itself. It had all the characteristics that were needed to make it well suited for being a 'general theory of warfare'. After all, it was a science entirely made up of competition, rivalry and warfare. It seemed to be a tool that could be applied to numerous military problems that concerned strategy. As one will understand, Bohr's theory of openness and international arms control lacked such characteristics. We could say that von Neumann offered a tool, while Bohr offered merely a philosophy.

A second reason for the 'fit' between von Neumann, game theory, and the cultural and political climate in the 1940's and 1950's is that von Neumann had proven himself as a person of value in the interaction between science and the army. It is safe to say that the reputation he established as a scientific problem solver earned him respect and credit among politicians and military officials. As a consequence of this, von Neumann was making quite a name for himself during the Second World War and in the period thereafter. He was a frequent visitor at RAND, at Los Alamos and at various government offices in Washington, where he inspired scholars, mathematicians and officials with his quick thinking, his hawkish mentality and his ideas about game theory. Von Neumann was, so to speak, a man 'one had to watch'. Bohr, in his turn, was not such an inspiring figure for politicians and military commanders. As we have seen, his fellow-scientists praised Bohr at the Manhattan Project, but he did not flourish among straight forward men like Churchill. While von Neumann, with his wit and no holds barred attitude, was an interesting figure for most politicians and military officials to discuss international affairs with, Bohr was disliked because of his 'hair all over his face' and the inability to translate his ideas into clear political goals. One clearly sees the distance between the different personalities.

On top of this, it could well be argued that it was not only the difference in character between von Neumann and Bohr that influenced the reception of their ideas. Perhaps, von Neumann's ideas resonated better in the political and military climate of the 1940's and 1950's because they fitted more in with already existing views. His game theoretical analyses resulted in the plea for a strong army and a no holds barred attitude towards the Soviets. It is safe to say that these ideas went well with the ideas that already existed in high military and political command. On the other hand, Bohr did not only differ in character from the leading military

[7] Erickson, The politics of game theory, 106.

and political officials, his ideas were quite different as well. What Bohr proposed – the sharing of atomic information with the Soviets – was totally opposed to the existing views in the political and military community. If we continue this line of thought, it could also be argued that men like Churchill, and to a certain extent Roosevelt, Truman and Eisenhower, had an ideological bias as well. It is said that von Neumann casted votes for both democratic and republican presidents during his life, always lining up with the majority of the American people. This makes it hard to conceptualize the ideological similarities between von Neumann and the political and military leadership. It seems plausible, however, that men like Churchill and Eisenhower had more in common ideologically speaking than they would have with a person like Bohr. It is in the combination of these factors that the explanation for the varying receptions of Bohr's and von Neumann's ideas about nuclear deterrence and arms control should be sought.

Chapter five
Concluding remarks

'The State that separates its scholars from its warriors will have its thinking done by cowards and its fighting by fools.'

- Quote attributed to Thucydides

Why did von Neumann's ideas about nuclear deterrence resonate more strongly in the political-military leadership of the United States and the United Kingdom than Bohr's ideas about transparency and arms control? In this study, we have analysed the intellectual contribution of two scientists to two wars that held entire hemispheres in their grasp for over forty years. In doing so, we have seen how the natural sciences and diplomatic affairs relate to each other and, just as important, how natural scientists relate to political and military actors. Unfortunately, while conducting this research, I had to ignore many interesting aspects of the key players involved. For example, I have not properly mentioned von Neumann's fascinating and ground-breaking work in the 1950's on the modern computer as a consultant for IBM. Also, I had to ignore large bits of Bohr's work for the peaceful uses of atomic energy. But, nevertheless, some conclusions can be drawn about Bohr's and von Neumann's ideas about nuclear deterrence and arms control in the course of the cold war.

First, it is obvious that the military and political actors in the Second World War and the cold war were susceptible to intellectual ideas about warfare. In the previous chapters, we have already seen that there existed a widespread demand for an applicable 'general theory of warfare'. In the theories of Bohr and von Neumann, we saw two possible intellectual frameworks that could be adopted by the military and political actors. Bohr's theory, based on his ideas from the world of quantum mechanics and his notion of complementarity, did not succeed in becoming a paradigm. Von Neumann's contribution, to a large extent based on his game theoretical thinking, was widely received as the possible basis for the 'general theory of warfare' that political and military actors were hoping for.

As we have seen, actual results were not the main condition in becoming such a dominant theory. Rather, a combination of mutually reinforcing factors enabled von Neumann to become one of the leading intellectuals of the cold war, while Bohr was dismissed from having any influential positions at all. The first of these factors was the fact that game theory held the promise of being a general theory of warfare, offering future results. By its competitive nature, it was well suited for being a widely usable theory of war. The basic elements of the theory fitted the mind-set of the people who were influential in military and political decision-making. Von Neumann's ideas about nuclear deterrence doubled to a large extent with the already existing views of the military and political command. This in contrast to Bohr, whose ideas resonated badly with already existing preferences. A second possible reason was that von Neumann, unlike Bohr, had already made himself a popular figure in the political and military spheres by offering many practical and technological solutions for the war effort. Thirdly, social factors played a distinctive role. Von Neumann was the kind of scholar and the kind of person that was doing well in military circles and who was already a popular figure based on his publications during the Second World War. Bohr, on the other hand, was not the type of person who flourished among military and political leaders. Also, there might well have been an ideological bias among the political and military leaders, which could – to some extent – offer an explanation for the fact that von Neumann appealed to them more than Bohr did.

The result of a combination of these factors was that the nuclear grand strategy of the United States during the Cold War was nearer to von Neumann's no holds barred attitude than to Bohr's plea for openness. Von Neumann's game theoretical analyses of the cold war, and his impassive rational approach of military problems, contributed to the fact that the strategy of the United States in the early cold war was one of confrontation and retribution instead of international arms control, transparency and retreat. In hindsight, we can say that the military and political leaders of the United States chose *the hawk* above *the dove*. After the Cuban missile crisis, in which President Kennedy could settle for a retreat of Soviet missiles from Cuba, cold war aggression gradually subsided. The Soviet Union slowly marginalized into a failed empire; bankrupted by an arms race it could not afford.

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