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Essay review

Getting even with Heisenberg ☆

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P. L. Rose, *Heisenberg and the Nazi Atomic Bomb Project: A Study in German Culture*, University of California Press, Berkeley, 1998, xx + 352 pp. $35, £21.95, ISBN 0-7923-3794-8, hbk.

> Aber es ist ein wichtiger Unterschied zwischen allem, was vor 1933 geschah, und dem, was dann kam: Alles frühere zog an uns vorbei und über uns hin, es beschäftigte uns und regte uns auf, und den einen oder andern tötete es oder ließ ihn verarmen; aber keinen stellte es vor letzte Gewissensentscheidungen. Ein innerster Lebensbezirk blieb unberührt. Man machte Erfahrungen, man bildete Überzeugungen: Aber man blieb, was man war. Keiner, der, willig oder widerstrebend, in die Maschine des Dritten Reichs geraten ist, kann das ehrlich von sich sagen. (Sebastian Haffner)[1]

1. Introduction

Werner Heisenberg (1901–1976) is probably best known for his discovery of the uncertainty relations in quantum mechanics and their physical interpretation (1927). En route to quantum mechanics itself, he had the decisive insight that quantum-mechanical variables do not commute (1925). This formed the basis for the creation of matrix mechanics immediately afterwards by Born and Jordan, appearing in

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[1] "However, there is an important distinction between what happened prior to 1933 and what came afterwards: the earlier events went by and went over our heads, they concerned us and excited us, and they killed some and left others the poorer; but they never compelled us to deal with final questions of conscience. An inner sphere of life remained unaffected. One had experiences, and shaped convictions: but one remained the same person. No one who, either willingly or resistive, got entangled in the machinery of the Third Reich can honestly maintain this" (Haffner, 2000, 12; Landsman trans.).

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mature form in the 'Dreimännerarbeit' with Heisenberg.[2] This was one of the two paths along which modern quantum mechanics was discovered.

Some of his other achievements in theoretical physics deserve to be mentioned. Barely 20 years of age, and well before the introduction of electron spin, Heisenberg made the revolutionary proposal to allow half-integral quantum numbers in the context of the Zeeman effect (1921). He made various other significant contributions in the period 1920–1925 that led to the establishment of quantum mechanics, and once the new theory had arrived, he was the first to derive a number of important consequences. He was awarded the 1932 Nobel Prize 'for the creation of quantum mechanics, the application of which has led, among other things, to the discovery of the allotropic forms of hydrogen' (official citation). Similarly, Heisenberg provided the quantum-mechanical explanation of the occurrence of para- and ortho-helium (1926). His explanation of ferromagnetism (1928) stands out, too, but his most important work of the period is the foundation of quantum field theory with Pauli (1929). A few years later, he became one of the founders of theoretical nuclear physics with a detailed proposal concerning the interactions between protons and neutrons in a nucleus.[3]

Heisenberg had certain other ideas that were somewhat off focus when he proposed them, but which, in later developments by others, turned out to be influential. This applies to his suggestion to replace quantum field theory by an S-matrix (1942) (an idea that came to dominate elementary particle physics in the sixties), to his proposal of a minimal length (1936) (which, much later, found its correct incarnation in lattice field theory, as well as in quantum gravity), to his description of superconductivity as a phase transition in the late forties (eventually leading to the modern idea of spontaneous symmetry breaking), to his idea of a unified field theory of elementary particle physics (1958) (derided at the time, but now, in an entirely different version, seen as the basic link between high- and low-energy physics), and, finally, to his ideas on conformal symmetry in quantum field theory (a structure that caused an unprecedented boom in the high-energy physics of the eighties—cf. Nahm (2000)).

Apart from his own scientific record, Heisenberg trained a number of physicists that later became of world class, such as Bloch, Peierls, and Weisskopf. In summary, Heisenberg was one of the greatest theoretical physicists of the twentieth century, comparable with Einstein and Bohr. See Mott and Peierls (1977), Mehra and Rechenberg (1982), Hendry (1984), Pais (1986), and Cassidy (1992) for further details about his scientific career.

There is similarly uniform evidence about the exemplary sides of Heisenberg's character and behaviour. For example, such different observers as the English army officers who dealt with him during his internment at Farm Hall immediately after the

[2] The so-called 'Heisenberg commutation relations' $QP - PQ = i\hbar$ were actually found by Born and Jordan, and independently by Dirac.

[3] At the time, neither Heisenberg's correct identification of the composition of the atomic nucleus, nor his idea that nuclear forces can be described by quantum mechanics, was obvious at all.

war (see below), and his wife, agree that he was very friendly, and the latter stresses that many people appreciated his great personal warmth.[4] As a student, he gave evening lectures on astronomy, as well as on Mozart's operas, to generally uneducated people who were personally unknown to him. At the other end of the spectrum, he usually went out of his way to help his own students and collaborators, both in peacetime and during the war, sometimes at risk to himself. Thus a number of them avoided almost certain death at the front by being enlisted by Heisenberg for his nuclear research program. In between, he did his best during the war to prevent the German occupying forces from robbing certain physics laboratories and, in the case of the University of Leiden and of Bohr's institute in Copenhagen, he was mostly successful in doing so.

During the Nazi era, Heisenberg never joined the NSDAP or any of its affiliated organizations.[5] He was among few not to sign a manifesto of University professors in support of Hitler. Shortly after the announcement of his Nobel Prize in 1932, which made him a famous figure in Germany, he refused to take part in a national rally in his home town of Leipzig in honour of Hitler, at great peril to himself.[6] He was a member and occasional host of the Wednesday Society, a club for the German elite, many of whose members took part in the failed assassination attempt on Hitler on 20 July 1944, to be executed themselves in the aftermath.

Although Heisenberg himself did not take part in the assassination plot, his personal courage was nonetheless extraordinary. He risked his life a number of times in an avoidable way. For example, just before the war he could easily have emigrated to the US with his family but, in deciding to stay in Germany, he knowingly risked being sent to the front as a soldier, war looking unavoidable. During the end of the war, he could have awaited arrest by Allied forces with little danger, but, instead, he endeavoured on a reckless and almost deadly bicycle tour through Germany to see his family. The lack of safety measures during his nuclear reactor experiments is notable, and he was almost killed when his reactor did, indeed, explode.

Finally, throughout his life Heisenberg exhibited a remarkable sense of responsibility.[7] Starting with his leadership of the 'Gruppe Heisenberg,' a

[4] Heisenberg's wife did not encounter her husband uncritically; see Section 2.5 below. It would perhaps have been foolish for Heisenberg not to be friendly to the English officers, but his pose seemed natural to them, and they trusted him. This was by no means the case with all internees. See Frank (1993) and Bernstein (1996).

[5] Of the German nuclear physicists, 56% were party members and 72% were affiliated to some Nazi organization. For example, Weizsäcker was a member of the National Socialist Dozentenbund (University Teachers League). See Walker (1989) and Hentschel (1996). Note that throughout this paper the reference 'Weizsäcker' is to Carl Friedrich von Weizsäcker (1912–).

[6] Heidegger, of course, was prominently present.

[7] The book under review actually takes the opposite view (e.g., p. 19), for the reason that Heisenberg left the decision to build nuclear weapons to politicians. However, this seems to ignore all other evidence, and, even in this example, it is not clear which other choices Heisenberg had. In fact, Weizsäcker emphasizes that Heisenberg (and he) tried to gain control of the nuclear project as much as possible; see Weizsäcker and van der Waerden (1977).

pathfinders youth squad, in his late teens, through his pivotal role in opposition to the 'deutsche Physik' movement of Lenard and Stark in the late thirties,[8] his acceptance of the directorship of the Kaiser-Wilhelm-Institute for Physics in Berlin–Dahlem in 1943 at the request of others, and culminating in his central role in the rebuilding of German science after the war,[9] Heisenberg led the German (theoretical) physics community from the front; although, like any genuine scientist, he would undoubtedly have preferred to sit at his desk contemplating the laws of physics.

With Weizsäcker, Heisenberg was the driving force behind the Göttingen Manifesto of 1957, which called for the Federal German Government to abandon its plans for developing its own nuclear weapons (predating the later anti-nuclear peace movement).[10] His efforts after the war towards international scientific cooperation stand out, including his important role in the establishment of the CERN particle accelerator centre in Geneva in the fifties. During his presidency of the Alexander-von-Humboldt-Stiftung from 1953–1975, he successfully implemented his ideal that scientists should form an international family with lifelong ties.

The enigma of Heisenberg is that there was another side to his life. His decision to stay in Germany during the Nazi era led him to enter a Faustian pact with a government of whose criminal nature he was well aware from the start,[11] and which, as was also known to Heisenberg (at least to some extent), gradually stepped up its demonic behaviour, initiating unspeakable war crimes and crimes against humanity that culminated in the Holocaust.

Heisenberg did not resign in protest when his Jewish colleagues were expelled from their university posts; in fact, he aided this policy by helping to fill the vacancies left by these expulsions, and he even blamed non-Jewish scientists such as Weyl and Schrödinger for leaving Germany voluntarily in 1933.[12] In 1938, Heisenberg contributed to a Festschrift in honour of his former teacher Sommerfeld, in full knowledge of the fact that only papers from 'Aryans' would be included.

Following his verbal abuse by representatives of the deutsche Physik movement—culminating in the infamous article in the SS newspaper 'Das Schwarze Korps' in 1937 characterizing Heisenberg as a 'white Jew'—he approached none other than Himmler for support. Himmler in turn involved Heydrich, and after a lengthy investigation by the SS, which he underwent voluntarily, even (unsuccessfully) attempting to meet Himmler personally on a number of occasions, Heisenberg was eventually cleared of all 'charges'.[13] With Heisenberg's scientific honour, but

[8] Cf. Hentschel and Hentschel (1996) or Walker (1995).

[9] See Heisenberg (1969), Heisenberg (1980), Cassidy (1992), and especially Hermann (1977).

[10] See Heisenberg (1980) and Hermann (1977). Of course, in his enthusiasm for nuclear energy, Heisenberg was out of phase with this movement.

[11] As stressed by his wife in Heisenberg (1980).

[12] Though Austrian, Schrödinger held a professorship in Berlin at the time. See Cassidy (1992) and Rose's book.

[13] See Heisenberg (1980), Cassidy (1992), Walker (1995), Hentschel (1996), and Rose's book.

most probably not his life at stake, this episode is sometimes contrasted with his lukewarm response to a plea by Goudsmit in 1943 for help in saving his parents from deportation and almost certain death in a concentration camp. Short of approaching Himmler this time, or indeed any German authority in Germany or Holland, Heisenberg merely sent a letter of support to Goudsmit's colleague, Coster. As pointed out by Goudsmit (1976) himself, though, it is doubtful that any action by Heisenberg would have been effective in this case.

Between 1941 and 1944, Heisenberg travelled to a number of occupied countries (viz., Hungary, Denmark, Holland, and Poland) in an official capacity as a sort of German cultural ambassador, wining and dining with the German occupation authorities.[14] Evenings held at local German Cultural Institutes, intended to encourage citizens whose country was occupied, and whose Jewish population was being deported to death camps, to come and admire Germany, typically included a talk by Heisenberg on physics or philosophy, and some classical music by a German composer. The famous Bohr–Heisenberg encounter in 1941 took place in such a context. It should be mentioned that Heisenberg also used such trips as a vehicle for helping colleagues abroad.

The trip most compromising to Heisenberg's reputation must be the one to Cracow in 1943. There he visited his former schoolmate and 'Duzfreund' Hans Frank, the Governor of occupied Poland.[15] In a different context, Heisenberg's wife mentions that her husband was well aware of the mass liquidations in Poland (Heisenberg, 1980, p. 64), and his biographer notes that Heisenberg must have known about the gruesome liquidation of the Jewish ghettos in Cracow and Warsaw shortly before his trip (cf. Cassidy, 1992, p. 467). In Cracow, Heisenberg accepted the Copernicus prize from Frank for his scientific achievement.

In September 1939, Heisenberg joined the German nuclear research team ('Uranverein', Uranium Club) by military order. This team had been assembled by Kurt Diebner (see below) on behalf of the Heereswaffenamt, Army Ordnance Office (HWA), following suggestions by the physical chemist and explosives expert Paul Harteck (1902–1985) and others that Germany should investigate the possible relevance of nuclear energy to the war effort. Heisenberg seemed quite keen to obey this order, as he started his research as the team's chief theoretical physicist with undeniable zeal.

His first report, *The possibility of technical energy production from Uranium fission*,[16] laid the theoretical foundations for all subsequent research in Germany on that topic. Also, by present standards,[17] the report correctly foresaw that a nuclear reactor could be built in two qualitatively different ways, each posing its own difficulties: One should either use enriched Uranium and an easily obtained moderator such as ordinary water, or one could work with natural Uranium at the

[14] Cf. Walker (1989, 1992, 1995), Cassidy (1992), and Rose's book.

[15] Frank was tried and hanged at Nürnberg in 1946 for war crimes and crimes against humanity. See the protocol *Das Urteil von Nürnberg 1946*, dtv dokumente (München: DTV, 1961, pp. 197–201).

[16] G-39, reprinted in Heisenberg (1989).

[17] Cf. the comments by Wirtz in Heisenberg (1989).

cost of using heavy water or extremely pure graphite as a moderator. The paper, in addition, contained a number of mistakes, concerning both reactor theory and bomb design, about which it made a few remarks.[18]

For various reasons, the use of graphite as a moderator was not pursued,[19] so the German team saw two options left. Various isotope separation projects, as well as a number of methods to produce heavy water, were pursued, principally by Harteck; Heisenberg played no role in these.

Heisenberg supervised a series of reactor experiments, served as a theoretical consultant in general, and otherwise carried on his normal university work, including research on elementary particle physics and other fundamental physics. There can be little doubt that Heisenberg was aware of the use of slave labour in Uranium mines and processing factories (as was routine throughout German industry). For example, the Uranium plates that were needed in Heisenberg's own specific reactor design were manufactured by 2000 female inmates of the Sachsenhausen concentration camp (Glover, 1999, p. 91). During air raids, Heisenberg refused entry to local citizens seeking shelter in the bunker in Berlin–Dahlem where he and his team tried to build a nuclear reactor.

In July 1942, Heisenberg was appointed Director of the Kaiser-Wilhelm-Institute for Physics in Berlin–Dahlem, where part of the nuclear research program had already been running under his supervision for some time. This was followed in February 1943 by his installment as a Professor of Theoretical Physics at the University of Berlin, a highly prestigious chair, and by his election as a member of the Prussian Academy of Sciences[20] in April of the same year. These appointments, approved by the highest Party and Government offices, made Heisenberg the physicist with the highest official credentials in Germany during the war. A cover story of the Nazi journal *Das Reich* featured Heisenberg as a 'deutsche Volksführer.'

The outcome of the project, which in its later years was interrupted by heavy Allied bombing and sabotage of Germany's supply of heavy water from Norway, was that no bomb was built, but that a nuclear reactor running at criticality was almost achieved during the last days of the war.

Ten of the German nuclear physicists, including Heisenberg,[21] were interned by the Allies between May and December 1945, spending the last six months at a country estate, Farm Hall, near Cambridge in England. Their conversations were secretly recorded, and, following a petition by scholars, were made public in

[18] These errors are spelled out in detail in the book under review; see below.

[19] Fermi used graphite in his first successful nuclear pile experiment in Chicago. According to Heisenberg, an erroneous judgement by Bothe, a later Nobel laureate, stopped the Germans from taking this route. See Heisenberg (1969) and Irving (1967). This version has been criticized by Walker (1989) and by the book under review.

[20] Einstein had resigned from the Academy in disgust in 1933, just before he would have been expelled.

[21] The others were Diebner and Harteck, who had been the two other main figures of the project, Gerlach, who had been put in charge in the final year, the younger project members Bagge, Korsching, Weizsäcker, and Wirtz, and finally Hahn and Laue, who both had had little or nothing to do with it.

1992.[22] At Farm Hall, the internees produced a statement[23] whose main point was that 'it was the view of the researchers that the resources for the production of a bomb were not available in the context of the technical possibilities prevailing in Germany'.

It is clear from the Farm Hall transcripts, as well as from interviews by Goudsmit during the Alsos mission, that immediately after the end of the war in Europe, Heisenberg and his German colleagues believed that their knowledge about nuclear technology and its possible military uses was superior to that of the Allied scientists. This belief was shattered by the BBC News at 9 p.m. on August 6, 1945, which he and the nine other internees heard at Farm Hall.[24]

Heisenberg never apologized for his behaviour during the Third Reich. He later suggested on various occasions, usually in a somewhat ambiguous manner leaving the conclusion to the reader, that he had actually actively withheld the bomb from the Nazi leaders.[25] This line was defended much more enthusiastically by Weizsäcker.[26] At the same time, Heisenberg's published writings on the nuclear project emphasized the fact that its goal had been the 'technical utilization of atomic energy' (Heisenberg, 1947).[27]

All this leads to a number of intriguing questions, which various people, including Heisenberg himself, have tried to answer after the war. Why did the Germans, with at least two actual and three future Nobel prize winners in their circles,[28] and considerable Government support, fail to build an atomic bomb? How can we understand Heisenberg's actions between 1933 and 1945, and his later lack of self-criticism?

Heisenberg (1947) gave his own public answer to the first question, namely that 'the project could not have succeeded under German war conditions (…) To obtain the necessary support, the experts would have been obliged to promise early results, knowing that these promises could not be kept. Faced with this situation, the experts did not attempt to advocate with the supreme command a great industrial effort for the production of atomic bombs.' As pointed out in Hentschel (1996), Heisenberg said something different in private at Farm Hall: 'We wouldn't have had the moral courage to recommend to the government in the Spring of 1942 that they should employ 120,000 men just to build that thing up.'[29]

[22] See, for example, Frank (1993) or Bernstein (1996). Some excerpts had already been published in Groves (1962, Chap. 24).

[23] The statement is reprinted in Frank (1993) and in Bernstein (1996).

[24] 'HEISENBERG: Well, how have they actually done it? I find it is a disgrace if we, the professors who have worked on it, cannot at least work out how they did it.' Quoted from the Farm Hall transcripts in Groves (1962, p. 338); see also Bernstein (1996, p. 178).

[25] See Rose's book, Chap. 1–3, and Section 2.4 below.

[26] Cf. Rose, Chaps. 2 and 20, Bernstein (1996), Prologue, and footnote 66 below.

[27] It should be mentioned that already during the war it was foreseen that nuclear reactors could power submarines, and in fact Heisenberg himself mentioned this possibility to the military. Hence the 'technical utilization of atomic energy' is not necessarily peaceful. Cf. Hentschel (2000).

[28] Namely: Laue, Heisenberg and Hahn, Bothe, Jensen, respectively.

[29] First quoted in Groves (1962, p. 335); see also Bernstein (1996, p. 129).

2. Some older literature

To put Rose's book in perspective, we need to take a brief look at six previous texts on the German wartime nuclear project and Heisenberg's role in it. Some of these are classics, while others have been included to achieve some balance between the Anglo-Saxon and German points of view.[30] A good account of Heisenberg's life as a whole has been written by Cassidy (1992),[31] who devotes much attention to Heisenberg's behaviour during the Nazi era. For an encyclopedic overview of physics in Nazi Germany, see Hentschel (1996).

2.1. Goudsmit

'Alsos'[32] was a scientific intelligence mission that followed the Allied troops in the wake of their invasion of Europe. Its initial purpose was to 'learn as soon as we could what the Germans might be able to do if they exerted every possible effort to produce an atomic weapon' (Groves, 1962, p. 186). After it had become clear that nothing was to be feared, its goal became to keep whatever scientists and scientific equipment that would be of any military value out of the hands of the Russian (and French) troops. Reporting directly to Groves in the US, its military commander in Europe was Boris Pash, and its scientific head was Sam Goudsmit (1902–1978). The internment of Heisenberg and other German nuclear physicists at Farm Hall in 1945 was part of the Alsos work. On top of the secondary goal just mentioned, another purpose of Farm Hall was to prepare the German scientists for reintegration into the zones of Germany that, after the war, were occupied by the UK or by the US.

Goudsmit wrote three popular articles and a famous book (Goudsmit, 1947) about the Alsos mission, which served as a point of reference for all later assessments of the German wartime nuclear program, and in particular of Heisenberg's role in it. This book polarized the discussion about Heisenberg, in that most later authors either largely agree to, or else oppose Goudsmit's conclusions. These were that the German bomb project had not achieved even the basics of understanding nuclear weapons, and that it had failed because of the totalitarian climate in Germany, complacency, the interference of politicians in the affairs of science (particularly of 'utterly incompetent' key men in administrative positions), the deterioration of interest in pure science and its lack of prestige, the anti-semitism doctrine of the

[30] The heroic portrait of Heisenberg in Jungk (1958) has now been discarded even by its author, although this picture has lived on in Hermann (1977) and in Powers (1993). The latter, negatively received by all scholarly critics, is cited in the German Brockhaus Encyclopedia, as well as in Meyers Taschen Lexikon, as one of its two references on Heisenberg (the other is Cassidy, 1992). In the *New York Review of Books* of February 8, 2001, Powers states his main motivation: 'At the heart of it, in my view, is an anomaly—why (…) not only was there no German atomic bomb, but there had not even been a big effort to build one.' In fact, there is no such anomaly (cf. Section 3.2 below), obviating the need for incredible scenarios such as that of Powers. As a spy story, Powers (1993) is counterbalanced by Kramish (1986), which enjoys a better reputation.

[31] See also the interesting review by Rudolf Peierls in the *New York Review of Books* of 23 April 1992.

[32] Greek for 'grove', as in 'General Leslie Groves', the military leader of the Manhattan Project.

Nazis that led to the exile of notable scientists, the lack of vision of the German scientists, and, finally, because of the role of hero worship. This last point specifically refers to Heisenberg, who is portrayed as holding competent (if not excellent) research groups, such as those of Ardenne and Diebner, in contempt. At the same time, Heisenberg's own erroneous judgements and decisions, of which there were many according to Goudsmit, were hardly openly questioned by the other German researchers. Heisenberg is portrayed as a man of ideals, and as a fierce nationalist who had put his support for any German cause ahead of his dislike of the Nazis.

Given the severity of the issue, and also taking into account that both of Goudsmit's Jewish parents had been killed at Auschwitz, *Alsos* is amazingly light in tone, and full of irony and self-mockery.[33] It was written partly with a political agenda related to the situation of science in the US (analysed in Walker, 1989), and partly under the influence of Goudsmit's ongoing argument with Heisenberg concerning the German nuclear project.[34] A remarkable aspect of *Alsos* is that Heisenberg seemed far more worried about accusations that he had not understood bomb physics than about criticism of his general behaviour during the Nazi era.

Alsos contained a number of factual errors,[35] all contributing to Goudsmit's general conclusion that the German program had been a flop. But Goudsmit was willing to correct most of these in public at Heisenberg's insistence. Since we now know that Heisenberg's own account after the war contained factual and other errors as well, it needs to be emphasized that the latter never showed the slightest tendency to correct his stance, either in private or in public. More generally, it appears that Heisenberg simply did not understand how his courageous behaviour during the Nazi era, which he contrasted with the treason of emigration, could possibly be the subject of controversy. In this light, Goudsmit's (1976) obituary of Heisenberg is particularly magnanimous.[36]

One feature of Goudsmit's book stands out, and that is the enormous importance he attaches to Heisenberg's role in the German nuclear project. This is practically the only point on which he agrees with Heisenberg (1969) himself; the book under review takes the same stance. Other authors, such as Irving (1967), Bagge, Diebner, and Jay (1957), and in particularly Walker (1989), sketch a different picture that seems more realistic; see below.

[33] Walker's (1990) characterization of *Alsos* as a 'heroic' account seems to ignore this aspect.

[34] See Heisenberg (1980), Walker (1989, 1990), Cassidy (1992), Bernstein (1996), and especially the book under review for a detailed discussion of their debate.

[35] The main ones are that Goudsmit did not realize that the Germans had understood the role of Plutonium, and that they knew about the crucial role of fast neutrons in atomic bomb physics.

[36] There is evidence that Goudsmit had a change of heart. Heisenberg (1980) mentions that, long after their debate, Goudsmit apologized to Heisenberg in private, and Martin Heisenberg (a son of Werner and Elizabeth) wrote in a letter to the *New York Review of Books* (16 January 1992) that, in 1978, Goudsmit had apologized to his (Martin's) brother Jochen, distancing himself from what he had written about his father.

2.2. Bagge and Diebner

Kurt Diebner (1905–1964) was an experimental physicist who played a central role in the German nuclear project. During the war he was the principal scientific administrator of the project, simultaneously holding the positions of military adviser to the HWA on nuclear physics, director of the Nuclear Research Council (Kernforschungsrat), and managing director of the Kaiser Wilhelm Institute for Physics. Furthermore, he ran his own nuclear reactor experiments, usually in competition with Heisenberg. Diebner was a Nazi party member, and was apparently held in contempt by Heisenberg. Most of his ideas on reactor design, however, were much better than Heisenberg's.

Erich Bagge (1912) was a theoretical physicist who had written his thesis with Heisenberg, but who later became closely associated with Diebner, politically as well as scientifically. He was a member of both the Nazi party and the Dozentenbund. During his internment at Farm Hall, he kept an interesting diary, which is reprinted in Bagge, Diebner, and Jay (1957).

In this book, Bagge and Diebner state their views on the German nuclear project. They claim that the crucial error was the HWA's requirement in December 1941 that something of immediate military use should emerge from the nuclear research project within 9 months. Following the physicists' clarification that this would be impossible, the consequent transfer of authority from the HWA to the Reichsforschungsrat (National Research Council, RFR), and the appointment of the technical physicist Abraham Esau as the man in charge, then sealed the fate of a possible German nuclear bomb, despite the fact that almost simultaneously the RFR was put under Göring's supervision.

Speer had nothing to do with these decisions; he became involved with the project only in the Spring of 1942.[37] Indeed, there is no mention by Bagge and Diebner of Heisenberg's encounter with Speer in June 1942, which according to Heisenberg himself had been the pivotal meeting leading to Speer's (and not the HWA's) decision to assign a relatively low profile to the nuclear project. The latter reading, of course, squares with Heisenberg's perception that he himself was the main figure in the project, alone entitled to influence the cardinal decision to step up the project to industrial proportions.[38]

By quoting from the Proceedings of the key HWA meeting on nuclear energy in February 1942, *Energiegewinnung aus Uran*,[39] Bagge and Diebner prove that Goudsmit had been wrong in his statements that the Germans had failed to recognize that a bomb could be made from Plutonium, a point that had earlier been made by Heisenberg in his correspondence with Goudsmit.

As to the subsequent attempts to at least build a reactor at criticality, Bagge and Diebner mainly blame the repeated Allied attacks on the Norske Hydro factory at

[37] See Speer (1970, pp. 226–227), for his version.

[38] As Bagge and Diebner point out, the decision to launch the Manhattan Project on its huge scale in the US was made almost on the same day as the HWA's decision not to step up its German counterpart.

[39] See Walker (1989, Chap. 2), and Rose's book, Chap. 11, for a discussion of this document.

Rjukan, the only source of heavy water for the German project, for their failure. The disagreements in reactor design between Heisenberg's group and Diebner's can only be inferred between the lines, and with hindsight.

2.3. Irving

David Irving is undoubtedly the most colourful and controversial author on the German nuclear project. Currently infamous as a Holocaust-denier and speaker at neo-Nazi rallies, regularly sueing or being sued for libel,[40] he innocently started out as a factory worker in Germany[41] to perfect his mastery of the language. He then became an amateur historian,[42] publishing a large number of books about various aspects of the Third Reich, some of which became bestsellers. For an Anglo-Saxon author, his books are distinguished by his efforts to sketch the German perspective. This feature positively stands out in his first book on the destruction of Dresden, and also in his study of the German nuclear project discussed below. Thus he was eventually led to try and see what Hitler's personal point of view had been. His initial conclusion was that Hitler had never ordered the extermination of the Jews, developing into his current stance that the Holocaust actually did not take place (cf. Evans, 2001). This naturally has caused enormous offense, but Irving (1967) predates these developments, and seems largely unobjectionable.

The Virus House[43] was the first full study of the German Uranium project. It is based on thousands of documents, many of which were unearthed by Irving himself (who made them available to the public in microfilm), as well as on interviews and correspondence with all main actors (except Diebner, who died in 1964). The entire book is a pleasure to read; the chapters on the sabotage of the Norske Hydro plant have the quality of a thriller. From it, one obtains a reasonably accurate overview of the project from the discovery of nuclear fission up to the internment of the ten scientists at Farm Hall (to his openly stated dismay, Irving was given no access to the Farm Hall transcripts; see Irving, 1967, p. 276).

Irving does not fall into the trap of putting Heisenberg at the centre stage; in fact, his unsung hero is Harteck, who, Irving assures, 'given the funds, the men, and the materials, could certainly have produced an atomic bomb for Germany' (Irving, 1967, p. 265). Irving sees the German nuclear scientists' failure to 'fire Speer's imagination with the possibilities of nuclear fission' (Irving, 1967, p. 267) as their greatest shortcoming. The slow pace of the project is blamed, firstly, on the fact that the project was directed by scientists (and not by the military, as in America): 'In

[40] For the latest state of affairs, the reader may consult Evans (2001) or the numerous internet sites devoted to Irving.

[41] See Lukacs (1998) for this and other information on Irving used below.

[42] Academic historians regard him as an amateur or as a journalist. Irving himself emphasizes the fact that he does not consult history books written by professionals for his own research, relying instead on interviews conducted by himself and on unpublished documents. It should be noted that his use of such sources has been severely criticized.

[43] The title refers to the name of the nuclear physics laboratory in Berlin–Dahlem, intended to scare people off.

short, the behaviour of the German scientific leaders demonstrated that during war, science cannot be safely left to scientists.' (Irving, 1967, p. 270); and, secondly, on the emphasis on theory, the latter point with direct reference to Heisenberg. Interestingly, we have Heisenberg's reaction to Irving's book. In an interview with Ermenc (1989), he says that 'Irving's book is a very good book in the sense that it gives all the facts or practically all the facts. But it has one deficiency. When he tries to determine motives he does not do very well because he cannot think himself into the atmosphere of a totalitarian country making war.'

In some respects, Irving indeed follows Heisenberg's version of events, such as in his emphasis of Bothe's graphite measurement, the subsequent decision to continue with heavy water as a moderator, and also in his acceptance of Heisenberg's claims, contra Goudsmit, that he had fully understood the principles of the atomic bomb. Rose (pp. 53–54) provides a detailed list of factual errors in *The Virus House*, but his portrayal of Irving as Heisenberg's man puts little weight on Irving's discarding any suggestion by the Germans to the effect that they did not make the bomb because they did not want it. In fact, he writes that 'there is no indication that at any stage in the logical process of development the scientists' scruples would have become powerful enough to overcome their natural curiosity to see what came next.' (Irving, 1967, p. 268). Indeed, what makes Irving (1967) particularly realistic is the absence of a moral dimension, both in the author and in his subjects.

2.4. *Werner Heisenberg*

Heisenberg (1969) is a peculiar type of autobiography, consisting mainly of conversations between the author and some of his friends on the principal themes that occupied Heisenberg. The author adds the disclaimer that he reports these conversations as they *might* have taken place. *Der Teil und das Ganze* (*Physics and Beyond*) is a masterpiece. All conversations are fascinating, and one would like to live such a rich life of physics, philosophy, politics, and responsibility oneself.

Unfortunately, there is overwhelming evidence that certain crucial passages in the book reflect Heisenberg's opinions as he had developed them much after the described events. In other words, he described conversations the way he would have wanted them to have taken place, rather than as they were.[44] For example, he repeatedly states that he saw National Socialism as a catastrophe right from the beginning, which could only lead to the destruction of Germany. He recalls a conversation in 1939 with Fermi, Goudsmit, and other colleagues of his in the US, in which Heisenberg claims to have expressed no doubt whatsoever that Germany would lose the upcoming war. This conversation was remembered quite differently by the others present (such as Laura Fermi); cf. Rose's book for a detailed discussion of this (pp. 267–268) and similar occasions (Chap. 19).

[44] This is not to say that Heisenberg did not write down what he remembered. The claim is that his remembrance of things past was highly coloured by later events and insights. This point was already made by Mott and Peierls (1977).

Heisenberg does not mention his foreign trips during the war (except the one to Copenhagen in 1941), but many of the physicists he visited (such as Kramers, Casimir, and Bohr's associate Rozental) recall quite clearly that, until 1943, Heisenberg not only expected a German victory, but even saw this as the best possible outcome in the given circumstances.[45] This point is discussed in Walker (1989), Cassidy (1992), and also in detail in Rose's book. Heisenberg's only ally in his version seems to be his wife; see below.

On a different note, Heisenberg's portrayal of his early interest in philosophical questions, as well as their relevance and even determining role for much of his research in theoretical physics, has been called into question as well; see Cassidy (1992) for the first, and Beller (1999) for the second point. The truth seems to be that Heisenberg was primarily a pragmatist,[46] who added philosophical considerations usually with hindsight, or just for political convenience.

Against this background, Heisenberg's account of the Uranium project can only be expected to be a mixture of fact and fiction, which is indeed what it seems to be. It is, in any case, impossible to acquire a proper idea of the project from the book. Key players, such as Diebner and Harteck, are not mentioned once; one obtains the impression that the project consisted of Heisenberg and his own collaborators Weizsäcker, Wirtz, and the Döpel couple, with credit to Hahn for his discovery of fission. Heisenberg sees the Government's decision[47] in June 1942 as the key event that determined the fate of the project. However, nowhere does he say that he would have refused to build such weapons if it had been possible. In other writings, Heisenberg actually stated repeatedly that he was glad the turn of events spared him and his colleagues the moral decision.

In his report on the conversation with Fermi mentioned above, he quite clearly describes the Allied case as morally superior to the Nazi one. However, a few chapters later he changes this judgement by drawing a parallel between the German scientists' inability to stop what happened in the German concentration camps with the (perceived) inability of the Allied scientists to prevent the bombing of Hiroshima and Nagasaki (cf. Heisenberg, 1969, p. 231). As analysed in detail by Rose, who is infuriated by it, this symmetry argument came up in a different version in later writings of both Heisenberg and Weizsäcker, in which it is stated that, at the end of the day, the German scientists had merely worked on the peaceful use of nuclear energy, whereas their Allied colleagues had built atomic bombs. In this light, Heisenberg (1969) contains a remarkable passage, already noted by Mott and Peierls (1977), viz., 'The fact that in wartime no attempt was made in Germany to construct atomic bombs although the knowledge of the principles existed, probably had a favourable effect on these negotiations'.[48]

[45] As less desirable alternatives, he saw a Russian victory and subsequent dominance of Europe, or an Allied victory, imposing hatred against the German people and possibly destroying Germany.

[46] Speaking of which: in Ermenc (1989) Heisenberg declares that he took part in the Uranium Club in order to obtain research funding.

[47] Which he attributes to Speer, as we know from later writings.

[48] These negotiations concerned the reintroduction of nuclear research in postwar Western Germany. See Heisenberg (1969, p. 256) for the original German text.

2.5. Elisabeth Heisenberg

Not long after an affair with a sister of Weizsäcker, forbidden by her father, and during a deep depression caused by his loneliness in conjunction with the political situation, Heisenberg met Elisabeth Schumacher[49] in January 1937 at a musical evening where he performed. They got married in April. She was 13 years younger than him, they had seven children, and stayed together until his death (see Cassidy, 1992 for further details).

Her biography of her husband (Heisenberg, 1980) is as fascinating as his own account, but stands out because of its honesty. The serious points where she factually disagrees with other sources all occur when she directly relies on testimony by her husband.[50] For example, she sides with Heisenberg's version of his perception of Nazism and the outcome of the war (see above).[51] Another serious example is where she approvingly quotes her husband's statement to Irving that the scientists had kept it to themselves that nuclear reactors would produce Plutonium.[52] This view propagated, not only into Heisenberg (1989), but also into other German texts, such as Hermann (1977).[53] As a matter of fact, the Plutonium idea is repeatedly mentioned in *Energiegewinnung aus Uran* (see footnote 39), and this is because, in reality, Heisenberg informed a military audience at least twice in 1942 of this possibility in an unambiguous way.[54] Indeed, one of these occasions is mentioned quite openly by Heisenberg (1947) himself.

The cultural propaganda trips are mentioned only in passing, and without revealing their actual political purpose. On painful matters of interpretation, she predictably comes to the defense of her husband. For example, in the context of the Göttingen Manifesto of 1957, she writes: 'Dieses Manifest war, genau besehen, die konsequente Weiterführung der Haltung, die die verantwortungsbewussten Physiker

[49] Her brother was the economist E. F. Schumacher who wrote the famous book *Small is Beautiful*.

[50] Although her account of the Heisenberg–Bohr encounter of 1941 seems even more distorted than her husband's, claiming that Heisenberg wanted to signal to Bohr that Germany would not and could not build an atomic bomb. Heisenberg (1969) more modestly claims he intended to discuss with Bohr the moral aspects of working on nuclear energy in times of war. See Frayn (1998) for a recent dramatized perspective on this meeting as well as Cassidy (2000).

[51] Cf. Heisenberg (1980, pp. 81–83). The foreigners, she simply says, had all misunderstood Heisenberg. Another possible explanation is that Heisenberg did not always share his inner thoughts with his wife during the Nazi era; cf. Heisenberg (1980, pp. 79–80).

[52] See Heisenberg (1980, p. 91). One of the most important breakthroughs in the quest for atomic bombs was the insight that, in a nuclear reactor, some of the U_{238} is eventually transformed into Plutonium, which is even more fissionable by fast neutrons than U_{235}, and may therefore be used as the basic ingredient of a bomb. This obviates the need for the separation of Uranium isotopes beyond the small enrichment of natural Uranium that is necessary to build most reactor types. The Allies and the Germans reached this insight independently. The bomb used to destroy Hiroshima was made from U_{235}, but the one dropped on Nagasaki, like most subsequent atomic bombs, consisted of Plutonium.

[53] Whose author, in addition, wrote a fair number of admiring encyclopedia and handbook entries on Heisenberg.

[54] This is pointed out in a fair number of books, including Irving's (!), Walker (1989), Bernstein (1996), and also Rose's book. The reader may verify this for him or herself by looking at p. 520 of Heisenberg (1989), or at p. 299 of Hentschel (1996).

auch während des Krieges eingehalten hatten; damals war sie aus dem Widerstand gegen eine unmoralische, verbrecherische Regierung entstanden (…)',[55] showing that she accepts his own idea that he had actively resisted the Nazi state.[56] At the same time, she mercilessly exposes his obstinate character, and openly reveals the fundamentally undemocratic nature of their marriage, in which Heisenberg took all key decisions by himself, usually putting (his) physics—and even the German Uranium project—ahead of family interests.

From her book, read in conjunction with the biography by Cassidy (1992), one acquires a full understanding of Heisenberg's character, and of his controversial behaviour during the Third Reich. His almost irrational love of Germany, with its countryside and its music,[57] carried more weight for him than all the atrocities of the Nazis. Throughout the war, Elisabeth Heisenberg confides, her husband continued to believe in the 'secret existence' of the Germany he had known and loved. His extreme patriotism made him regard those who did leave voluntarily as cowards or even traitors. The positive side of this was his conviction that one should not bring oneself into safety whilst leaving others behind who relied on one's protection and support. As a related point, Weizsäcker (1977) mentions that Heisenberg simply wanted to be with his people (i.e., the Germans) in these times of duress.

But what stands out most clearly is Heisenberg's obsession with physics, German physics,[58] and his own role in it, with which he gradually started to identify himself. It is quite evident that Heisenberg assigned almost infinite weight to his role as the leader and saviour of theoretical physics in Germany, and to his vision that it was he who had to protect whatever what was left of it through the Nazi years ('Inseln des Bestandes'), with the aim of rebuilding German physics after the war continuously in his mind. Against this weight, no compromise with the Nazis could be too embarrassing to make him change his mind about his course. His occasional moments of doubt were overcome by his character as a fighter in conjunction with his stubbornness, which his wife attributes to his Westphalian origins.

Added to this is the classical 'Wir haben es nicht gewußt' argument, used after the war by countless Germans to justify their passive behaviour in the face of so many atrocities. While this may often have been sincere, in the case of Heisenberg it certainly is not, since the available reports on his foreign trips during the war, and his statements after the war, make it clear that he was well aware of the mass

[55] Heisenberg (1980, pp. 171–172).

[56] She seemed, on the whole, overly impressed by her husband, believing he had access to the highest spheres of thought. Her admiring recollection of a walk during which he told her about his latest views on harmony and symmetry in nature leaves an odd impression, given that these views were based on his 'world formula', which later turned out to be bogus. She similarly believed him when he confided to her that he had been a childhood prodigy ('Wunderkind'), which he clearly was not, despite an impressive school record. Prodigies are people like Mozart or von Neumann.

[57] Apparently, Heisenberg could not imagine that people in other countries could spend the evening 'in small private circles in which one could make music with another in the deepest mutual understanding.' Quoted by Rose, p. 266.

[58] To be distinguished from the 'deutsche Physik' of Lenard and Stark, the absurd movement mentioned before, which Heisenberg strongly and courageously opposed.

liquidations in Poland and Russia,[59] which he apparently saw as necessary by-products of war.

2.6. Walker

Walker (1989) is essentially the author's Ph.D. dissertation, which has become a standard scholarly reference on the German nuclear project. It gives a detailed description of the project from 1939 on, and, interestingly, also describes its aftermath up to 1949, including the deNazification trials many German scientists had to undergo,[60] and the post-war apologetic discussions about the project. Walker had no access to the Farm Hall transcripts in writing this book, but it is clear from his later work (Walker, 1995) that these have not modified his opinions. Apart from the nuclear project itself, Walker gives a superb treatment of Heisenberg's foreign propaganda trips during the war, amplified in Walker (1992). More generally, despite the criticism it has undergone (see below), it should be stressed that *German National Socialism and the Quest for Nuclear Power* is a very good, balanced, and instructive piece of work. It would undoubtedly form the best starting point of a reading course on the subject.

Walker's main point is that black-and-white characterizations of scientists under Hitler are invalid. Instead, he argues for a grey zone in which most scientists (and, indeed, most non-Jewish citizens altogether) in Nazi Germany moved.[61] Being mostly apolitical (as Heisenberg expressly claimed to be), they usually opposed the excesses of Nazism at least in thought, regretted the emigration and abduction of their Jewish colleagues, but otherwise collaborated and compromised with the regime to their benefit. As he forcefully says, 'to characterize the behavior of honorable men such as Hahn, Heisenberg, Laue,[62] Planck, and others as 'resistance' is to debase the term' (Walker, 1989, p. 230), but neither were they evil men who would have done everything to bring Hitler victory. Carefully distinguishing between intentions and actions, he exposes their postwar apologetics as often misguided and hypocritical.

As to the question of why the German nuclear project failed, he comes to the somewhat surprising conclusion that it had not. Instead, it 'took the course it did

[59] It may well be that Heisenberg hid such knowledge from his wife; in addition, it is not clear that during the war Heisenberg knew much about the Nazi death camps in the East, or about the behaviour of the Germans in occupied countries such as Holland, which were officially held in friendly regard ('Brudervolk'). It is likely that Heisenberg's friend Weizsäcker was much better informed through his father Ernst.

[60] These are significant also for the study of Heisenberg, who was not tried himself, but frequently provided evidence in court both about his colleagues and about Nazi or even SS officials. His evidence was usually quite generous, and played a role in the eventual clearing of most of these people. See also Cassidy (1992) and especially Rose's book, Chap. 21.

[61] See also the excellent study of Hentschel (1996), based on the same philosophy.

[62] Laue certainly should be discussed separately from the other three.

because of the cultural, economic, ideological, political, and scientific environment in which it took place' (Walker, 1989, p. 233). He reaches this point of view partly because of his justifiable and welcome emphasis on factors other than the scientists and their theories and intentions, and partly because he believes that the German scientists had done their work quite well. As to the first point, he stresses that not scientists but politicians and military men took the fundamental decisions, in which the outcome of the physics research only played a partial role. In particular, he quite rightly points out that Heisenberg's role should not be overestimated. As to the second, against Goudsmit and the Farm Hall transcripts, Walker (1989, 1995) maintains, with Heisenberg, that the German physicists had fully understood applied nuclear physics with regard to both reactors and bombs. Since Walker clearly exposes the fact (denied by the later Heisenberg) that the scientists basically told the military all they knew, it follows that the German bomb was not built because the German politicians and military officials decided that it would not be possible before the end of the war. Following Heisenberg, he then agrees that this was a fair decision; the difference is that Heisenberg emphatically saw himself as the originator of this fundamental decision (which he subsequently put into the hands of Speer), whereas Walker transfers it to the administrative level. This last point seems important, but Walker's generally positive perception of the state of German nuclear physics during the war has been criticized by Logan (1996) and by Rose (in the book under review, pp. 67–70).

This perception propagated into Walker's discussion of the Goudsmit–Heisenberg debate after the war.[63] Hence, apart from his justifiable criticism of Goudsmit's allegedly naive perception of the role of politics, the military, industry, and totalitarianism in Nazi Germany, of Goudsmit's exaggeration of Heisenberg's role, and of Goudsmit's mistakes with regard to the German knowledge of fast neutrons and Plutonium, Walker goes on to discredit poor Goudsmit altogether, calling the arguments in his three popular articles 'an often indiscriminate jumble of relevant information, irrelevant material, and unverifiable anecdotes' (Walker, 1989, p. 204). This is unfortunate in view of the generally sober tone of Walker's writing, and, in particular, obscures Walker's most interesting discussion of both Goudsmit's and Heisenberg's hidden agenda and political aims in their respective countries that stood behind their partly public confrontation. In addition, Walker's general 'grey area' point that neither Goudsmit nor Heisenberg was right gets somewhat lost.[64] Replies to Walker's attack came from Goudsmit's former associates Logan and Dresden.[65]

[63] An abridged version of this discussion appeared separately in *Physics Today* (Walker, 1990).

[64] Here Walker's own political agenda seems to play a role, since his championship of the grey zone idea would make it difficult for him to give due credit to Goudsmit, who at least in *Alsos* represented an extreme position.

[65] See their letters, with reply by Walker (1990).

3. Rose's book

After this preparation, we are now ready to consider the book under review. The author is Professor of Jewish Studies and European History at Pennsylvania State University, his original background being in the history of science. HEISENBERG *and the Nazi Atomic Bomb Project: A Study in German Culture* took him fourteen years to research and write. The book is reminiscent of a pop single of the seventies called 'O.K.' by a band *Chicago*, which opens with the words 'O.K.', followed by a three-minute machine-gun salvo, to close with the same words. Thus the entire text is an assault on Werner Heisenberg, carried out with rare intellectual passion and meticulous scholarship. Without either of these, the monotony of its tune would have been indigestible. As it is, the book is annoying yet fascinating.

Rose's book consists of three parts. Part I analyses the debate about Heisenberg's role in the Third Reich in great detail, starting with Heisenberg's own writings, moving on to Goudsmit's contributions and his ensuing polemic with Heisenberg, down to the present era. In addition, the role of Weizsäcker receives attention. Heisenberg attributes the crucial insight about the role of Plutonium to Weizsäcker, who wrote it down in a secret paper in 1940; cf. the Refs. in footnote 54. Before the introduction of fast breeder reactors decades after the war, this insight was of purely military value, and had no significance for the civilian use of nuclear power. As pointed out earlier, Heisenberg and Weizsäcker did not keep this idea for themselves; they told the military. At Farm Hall, Weizsäcker initiated the line that the German scientists had never wanted to build an atomic bomb (cf. Bernstein, 1996, p. 129), and Rose carefully keeps track of Weizsäcker's further twists and turns after the war.[66] The books by Irving (1967), Walker (1989), and Powers (1993) are scrutinized.

Part II is an actual history of the German wartime Uranium project, put into the perspective of the developments on the Allied side, and emphasizing the role of Heisenberg. This last aspect, combined with Rose's program of denigrating Heisenberg both morally and scientifically,[67] leads to some distortions. Large parts of Parts I and II are (mostly polemic) comments on previous authors, but an enormous amount of information is thereby included. Finally, Part III is a sort of

[66] Rose will feel sorry to have left out Weizsäcker's most bizarre argument of all. Long after the war, Weizsäcker confided to the family biographer Martin Wein that 'Durch die neue Waffe, über die mit (W.) zu verhandlen niemand verhindern kann, will (W.) an einen Schalthebel politischen Einflusses kommen. (W.) denkt daran eine bessere Zukunft einem Manne wie Hitler verständlich zu machen, den Diktator, weiß der Himmel wie, zur Beendigung des Krieges zu zwingen.' (Wein, 1994, p. 366). Unfortunately for Weizsäcker, 'Der Plan, Hitler mit Hilfe der modernen Physik zum einlenken zu bewegen, blieb Utopie', because '(Es) war (W.) Mitte 1941 klar, daß der Bau einer Atombombe die deutschen Möglichkeiten überstieg.' (Wein, 1994, p. 387). In other words, Weizsäcker was quite keen to present the bomb to Hitler, in the hope that such a product of modern physics would encourage the latter to end the war, but the former had to give up on this hope because he saw that Germany would not be able to build the bomb.

[67] As he states himself in the Preface, p. xvi.

political portrait of Heisenberg, seen as a German. Compared with Cassidy's (1992) biography, Rose's treatment contains few new facts, but much new analysis; in addition, the novelty of his approach lies in his selection of material, apparently guided by the principle that whatever good can be said about Heisenberg is either omitted, or reinterpreted so as to turn against Heisenberg after all.[68]

Rose's principal thesis about the German nuclear project is repeated a large number of times: In 1940 Heisenberg incorrectly estimated or calculated the critical mass of a pure U_{235} bomb, obtaining an answer in the order of tons (instead of the correct value of 15–60 kg, depending on the presence of a so-called tamper, as found by the Allied scientists), and it was this fundamental scientific error that 'precluded him from recommending an all-out attack on the atomic bomb problem. This was the true reason why Nazi Germany failed to achieve the bomb, and it was a truth that the Heisenberg version tries to conceal—and continues to conceal' (p. 77). As to Heisenberg's behaviour during the war and its aftermath, Rose's conclusion is that the explanation must be 'grounded in the peculiarities of the German mentality' (p. 3), in particular in the 'German capacity for self-delusion (…), a trait exemplified to an astonishing degree in Heisenberg himself' (p. 3).

Hence Rose agrees with Goudsmit and with Heisenberg himself, but disagrees with Bagge and Diebner as well as with Irving and with Walker, about Heisenberg's central and determining role in the project; and he agrees with Goudsmit, Groves (1962), Frank (1993), Bernstein (1996), Logan (1996), and others, but disagrees with Heisenberg, Irving, and Walker, that Heisenberg made fundamental mistakes and lacked proper understanding of bomb physics. However, Rose seems to be the first to put forward this as the main if not the only explanation for the failure of the German project.[69] Moreover, he seeks to explain Heisenberg's character and seemingly paradoxical actions by appealing to his German background in conjunction with the allegedly unique and peculiar German national character. We now discuss some of these points in more detail.

3.1. Did Heisenberg know how to build an atomic bomb?

Rose's book is the first in which the Farm Hall transcripts are correlated with a detailed study of manuscripts and other sources from the war, and in doing so Rose confirms what Goudsmit had said from the beginning: that as far as atomic bombs are concerned, the German scientists never got beyond some very basic insights and had not done a single relevant experiment.

To detail, the Germans knew that natural Uranium was not suitable for a bomb, that one had to use either almost pure U_{235} or some higher transuranic element (such as Plutonium), and that fission by fast neutrons should cause the explosion (as opposed to the case of a reactor). But they had not measured any of the relevant cross-sections, had isolated neither U_{235} nor Plutonium, and had not considered how

[68] For a characteristic example, cf. p. 240.

[69] The claim in Logan (1999) that this theory goes back to Goudsmit (1947) holds only insofar that Goudsmit cites this among many other reasons.

subcritical lumps should be brought together to explode.[70] These facts were known to those who wanted to know them, but Rose provides a very detailed record.

The question of the critical mass of an atomic bomb receives considerable, if not obsessive, attention. Rose exposes in detail Heisenberg's initial and erroneous Farm Hall argument that led to a critical mass of a Uranium bomb of the order of tons.[71] At Farm Hall, Heisenberg arrived at a realistic value for the critical mass only in his lecture on 14 August.[72] Rose projects Heisenberg's initial Farm Hall calculation back to 1940, to conclude that the Germans thought throughout the war that the critical mass of a U_{235} bomb was of the order of tons. The psychological evidence for this is that Heisenberg clearly presented his earlier incorrect Farm Hall calculation without much thought, whereas his later correct argument was arrived at only after a week of intense (and, some would say, brilliant) thinking.

Rose is fully aware of evidence that during the war, and certainly in 1942, the Germans did work with a perceived critical mass of 10–100 kg. The formal part of such evidence would be the 1942 HWA report *Energiegewinnung aus Uran* (cf. footnote 39), which Rose discusses in his Chap. 11, whereas an informal piece is Heisenberg's famous 'pineapple remark' in June 1942,[73] which Rose analyses on pp. 32 and 180–182. He gives a number of arguments, the most convincing of which in his own eyes is that the 10–100 kg must refer to Plutonium. While this is probably true (in both cases the context is just too ambiguous to be quite certain of this), it by no means resolves the tension between the evidence just mentioned and the Farm Hall transcripts, which remains puzzling.[74]

In any case, the 10–100 kg seems a rough estimate, whose origin is unknown; it is quite evident from the Farm Hall transcripts that even if by chance the German scientists got the value of the critical mass roughly right, they had not nearly arrived at the correct reasoning leading to this value. On the Allied side, this reasoning started with the work of Frisch and Peierls in England in March and April 1940.[75] On the other hand, granted that the Germans got both the value and the origin of the critical mass all wrong, this should be seen in the perspective of the general confusion that followed the discovery of fission in December 1938. Even Fermi's estimates of the critical mass were initially wrong by orders of magnitude. It is to the credit of Rose that he describes this perspective in detail (Chap. 4 and 5).

[70] The implosion mechanism used to detonate the Plutonium bomb dropped on Nagasaki was a technical tour de force. See Rhodes (1986).

[71] Also see Logan (1996) and Bernstein (1996, pp. 139–143, 152, 177–178), for an exposition of this issue.

[72] See Frank (1993) or Bernstein (1996, pp. 217–232), for the original German text.

[73] In reply to a question by a military official, Heisenberg stated in public that an atomic bomb would have the size of a pineapple. This was already reported by Irving (1967); also see Walker (1989). It goes without saying that Rose disagrees with their analysis. There are additional arguments for the Germans's knowledge of a low critical mass, involving recollections of Hahn and of Ardenne.

[74] In fact, the critical mass of a Plutonium bomb is about a third of the value for U_{235}, rather than orders of magnitudes smaller.

[75] Their calculations led to the MAUD Report in the UK, which in turn became a key factor in convincing the US Government that it should launch an all-out effort towards nuclear weapons. See Rhodes (1986) and Bundy (1988).

Beyond the issue of the critical mass, Rose gives an interesting account of various ideas on 'reactor bombs', showing that at a certain stage Heisenberg saw a nuclear bomb as an extreme type of nuclear reactor, with highly enriched Uranium and vast quantities of moderator, that went out of equilibrium. This idea was subsequently pursued by some of Heisenberg's associates, and is amusing in the light of contemporary knowledge.[76] This account is new; Heisenberg's strange and dangerous ideas about the self-stabilization of ordinary nuclear reactors at high temperature were known before, but Rose also surveys these in an instructive way.

The question is, then, why Heisenberg failed to arrive at least at the correct design of an atomic bomb. Rose's answer, tirelessly repeated, that Heisenberg was basically incompetent,[77] seems incompatible with Heisenberg's established genius as a theoretical physicist. However, bomb design is in essence an engineering problem, and Heisenberg was already a very poor experimental physicist, not to mention a poor engineer.[78] In addition, the 'hero worship' to which Goudsmit had already drawn attention worked against other members of the Uranium Club correcting Heisenberg's ideas. Finally, Heisenberg's intensely competitive spirit[79] caused him to take much of the Uranium that the Germans possessed for his own experiments, at times denying Harteck and Diebner (both of whose experiments were generally superior to Heisenberg's) their fair share.

Rose's discussion of Heisenberg's achievements in the Uranium project is very selective and one-sided. For example, Heisenberg's first paper on reactor theory (G-39) is highly regarded in nuclear physics circles, but Rose singles out an unfortunate passage about bombs, which do not form the subject of the paper, to deride it and disqualify Heisenberg. In fact, not once does Heisenberg obtain the benefit of the doubt.

Much of the discussion around the alleged incompetence of the German team fails to take into account that the German research efforts towards atomic weapons were really feasability studies, carried out at a level needed to write a large-scale research proposal. The report *Energiegewinnung aus Uran* (cf. footnote 39) is such a research proposal; most of it was never carried out.[80]

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[76] Rose is fair enough to point out that at the time Chadwick and others considered reactor-type bombs as well.

[77] Rose has written to the reviewer that he now regrets this terminology.

[78] Cf. the interview with Harteck in Ermenc (1989). ERMENC: 'It has been said that if Heisenberg had considered himself less of a leader than a co-worker more would have been accomplished.' HARTECK: 'But how can you be a leader in such technological matters when you have never run an experiment in your whole life? That's ridiculous! (…) How could they think they could lead the development of a new technology? That was poor judgement; it is almost unbelievable.' ('they' here refers to Heisenberg and Weizsäcker). In contrast, the leading scientific personality on the Allied side, Fermi, happened to be as brilliant an engineer as he was a theoretical and an experimental physicist.

[79] As reported by Cassidy (1992), Heisenberg could not stand losing even in such trivial endeavours as table-tennis and chess.

[80] The typical claim in Heisenberg (1980) that 'in Deutschland nie der Versuch unternommen worden ist, eine Atombombe zu konstruieren' (p. 96) would, strictly speaking, have been true if she had written 'bauen' instead if 'konstruieren'. But feasability studies are certainly part of a 'Versuch' (attempt).

3.2. Did Heisenberg's mistakes block the bomb program?

As we have seen, Rose claims that during the war Heisenberg did not know how to correctly compute the critical mass of an atomic bomb, and, more generally, was unable to design an atomic bomb even in outline. This claim is well argued, and seems correct. However, Rose goes on to claim more, namely that this failure on Heisenberg's part was the main if not the only reason behind the failure of the German bomb program. To assess this second claim, let us note that the Allied Manhattan Project reached its goal because *all* of the following conditions were satisfied:

1. There was a strong initial drive by a small group of physicists to get the project off the ground;
2. From a certain point in time,[81] there was unconditional support from the Government;
3. Practically unlimited industrial resources and manpower were available;
4. There was an unprecedented concentration of brilliant scientists working on the project.

(See Rhodes (1986) and Bundy (1988).[82]) If any one of these conditions had not been met, the project would have failed, and even in the actual situation, the first bomb was only ready when the war in Europe was already over. In contrast, in wartime Germany only the first condition was satisfied, and even this in a much weaker sense than on the Allied side. The German scientists did not trust and in some cases despised their Government, and vice versa,[83] so that it is unlikely that a relationship leading to the second condition could ever have been established, even if both parties had desired it. For example, it is clear from the Farm Hall transcripts that some of the German scientists, including Heisenberg, were afraid of ending up in a concentration camp in case they would fail.

The failure of the third condition in Germany was clearly recognized by Heisenberg, whose postwar (1947) statement quoted at the end of the Introduction seems a fair and valid account.[84] Whether or not he was aware of the correct value of the critical mass during the war, Heisenberg correctly foresaw the massive industrial

[81] Put by Bundy (1988) as October 9, 1941.

[82] Bundy (1988) also contains a description of the German project, but this is almost entirely based on Irving (1967). In view of his father's approval of the latter book, it is not surprising that Martin Heisenberg refers to Bundy as supporting his father's version (cf. footnote 36).

[83] For example, there was constant spying in all laboratories by the Gestapo. At Farm Hall, Heisenberg said 'The point is that the whole structure of the relationship between the scientists and the state in Germany was such that although we were not 100% anxious to do it, on the other hand we were so little trusted by the state that even if we had wanted to do it, it would not have been easy to get it through.' Cf. Bernstein (1996, p. 131).

[84] So why did Heisenberg not stick to this version? His American colleagues were very angry at him after the war, and Heisenberg may have concluded that stating the truth did not suffice to temper them. It seems, in any case, that Heisenberg did not understand what he had done wrong; 'there are none so deaf as those who will not hear.'

scale at which isotope separation (for building a Uranium bomb) and heavy water production (necessary, according to the Germans, to build nuclear reactors for the production of a Plutonium bomb) would have had to take place. In the early years of the war, when Germany seemed to be on the winning side, such an industrial effort might have been possible, but was seen to be unnecessary to win the war, whereas in later years it would have been impossible. Even apart from the manpower, large industrial resources of the kind necessary for isotope separation or Plutonium production would have been recognized and bombed by the Allies.[85] It follows that Heisenberg never took the possibility of building a bomb very seriously, and, accordingly, hardly tried. In contrast, Heisenberg made an almost irrational effort to complete a nuclear reactor during the war. Contrary to Rose's claims,[86] it seems that Heisenberg mainly wanted to complete a nuclear reactor in order to impress the Allies in peacetime, thereby hoping to secure both Germany's physics and his own leading role in it (cf. Bethe, 2000).

Although Heisenberg would never have conceded it in his lifetime, the fourth condition was not met in Germany either. Because of the emigration or expulsion of Jewish scientists, the German team was clearly much weaker than the Allied one, where one should constantly keep in mind that the Allies only just succeeded. Harteck was good, but no match for Fermi, and even on the theory side Heisenberg and Weizsäcker were evidently outclassed by Bethe and Serber. Although Heisenberg and Weizsäcker saw an open road to an atomic bomb based on the extraction of Plutonium from a nuclear reactor burning Uranium, they were clearly unaware of the incredible technological difficulties of actually extracting and separating this Plutonium, let alone that they had any idea of the difficulties of bringing a Plutonium bomb to explosion. Seaborg, who solved the first problem for the Allies, may have had a match in Hahn, but von Neumann, who solved the second, had no parallel in the German team. In addition, brilliant men like Wigner and Feynman were needed to solve the innumerable problems that were unexpectedly encountered all the time. With hindsight, there would have been dozens of steps at which the German project, had it been pursued, would have collapsed.

Returning to Rose's second claim, even beyond the above arguments it should be pointed out (cf. Walker, 1998) that both Heisenberg's advice to the Government and its actual decisions about the project were based on far more than the value of the critical mass.[87] Thus it is likely that all of the explanations that have been forwarded in the literature to explain the decision of the German Government not to step up the nuclear project to industrial scale played some role. This certainly also includes Heisenberg's false idea of the critical mass, but its importance seems vastly overestimated by Rose.

[85] As they incapacitated the German heavy water supply in Norway and bombed the Auer factories. See also Bundy (1988, pp. 22–23).

[86] 'For the rest of the war Heisenberg's plan was to construct a natural-uranium reactor that would be the door to the development of both atomic engines and atomic plutonium bombs' (p. 184).

[87] Dennis (2000) notes that James B. Conant's 1943 report *History of the Development of an Atomic Bomb* on the Manhattan Project does not even mention the critical mass.

3.3. Heisenberg as a German

In many sections of his book, but most explicitly in Part III, Rose ventures to explain Heisenberg's general character and his behaviour during the Nazi era as predicated by his background as a German. Where this will lead is already obvious from Rose's confession that 'I cannot say that my British background has made me entirely sympathetic to German culture. Although I would be the first to admit its outstanding achievements in science, music, and intellectual life in general, its insistent abstraction as well as the more sinister traditions that accompanied it induce in me a certain skepticism and even aversion' (p. xvi).

Thus Rose's verdict is that Heisenberg should either have emigrated from Germany in 1935 at the latest, or, while staying, should at the very least have resigned from his professorship by then, to join some of his colleagues (such as Laue) in open defiance of the regime. Indeed, Rose approvingly quotes Weizsäcker (of all people), who, while interned at Farm Hall, remarked that 'the right position would really have been in a concentration camp, and there were some people who chose that' (cf. Bernstein, 1996, p. 196).

Instead, according to Rose, Heisenberg's endless compromises with the Nazi State left him morally bankrupt, a standing reinforced by his shameful behaviour after the war. All this is to be explained by 'a certain German predisposition to avoid moral issues and look at things cynically, especially when such an attitude is personally opportune' (p. 252). Indeed, 'moral blindness and noncomprehension were thus characteristic of German mentality' (p. 257), so that, like Irving, Rose suggests that Heisenberg would have moved on to build the bomb if he had been able to. Heisenberg's 'evasive personality' (p. 249) is seen as typically German, to be explained by a long-standing tradition (originating at least with Luther) of transferring personal authority to the State. Thus the book closes on the note that 'This German mentality of Heisenberg and his friends, fertilized by astounding powers of self-delusion and rationalization, spun the tissue of deception and self-deception that produced the Heisenberg version and the cocoon of fabrication and denial that has blurred the history of Heisenberg's work on the atomic bomb to the present day' (p. 324).

To argue these points, Rose paints a political portrait of Heisenberg that mostly consists of events and facts that may be found also in Cassidy's (1992) biography or in Walker's (1989, 1992, 1995) writings, such as Heisenberg's approach to Himmler in 1937, the 1941 Bohr–Heisenberg encounter, Heisenberg's foreign trips in wartime, and the clashes between Heisenberg and Born both before and after the war. Rose's discussion of these matters stands out because of its absolute lack of balance with regard to other aspects that actually shine a positive light on Heisenberg. For example, while it is undoubtedly true that a number of Heisenberg's motives for not emigrating were selfish, Rose gives him no credit whatsoever for his argument, however misguided it may have been, that he stayed in Germany to protect less fortunate physicists and modern physics as a whole. It is clear from all other accounts that Heisenberg felt a genuine responsibility in this direction. Indeed, Rose

holds even that against him, accusing him of being interested in the fate of a small and selective group of people only.

In his obituary of Einstein, Heisenberg drew attention to a feature of Einstein's life that is indeed tragic in view of Einstein's general pacifism and noble character, namely that he had urged Roosevelt to develop an atomic bomb,[88] which, quoting Heisenberg, 'killed as many thousands of women and children who were just as guiltless as those for whom Einstein was anxious to intercede.' There is no evidence at all that Heisenberg did not himself equally regret the Jewish and the Japanese victims he mentions, or that he implied that Einstein would not have mourned the victims of the two atomic bombs, but Rose comments that the 'shockingly antisemitic implication here is that out of selfish Jewish concern Einstein had contributed to the making of an Allied atomic weapon that was used immorally to kill other innocents for whom he felt no compassion' (p. 318).

One feature of Heisenberg's character, German or not, which provokes Rose's particular contempt is that, paraphrasing Elisabeth Heisenberg, her husband was never ready to identify one side as criminal, and the other as heroes of freedom and justice, always seeing the errors of ways on both sides (cf. Heisenberg, 1980, p. 184). Hence Heisenberg's repeated statements, both during and after the Nazi era, that there were both good and bad sides to Nazism, as well as the parallel he occasionally drew between the German and the Allied nuclear projects. Rose's own view here is that Western democracies are intrinsically good,[89] whereas the Nazi state was purely evil in all its aspects from its beginnings in 1933.[90] This parallels his view that proper thought is 'Western' in style (whatever that may mean),[91] German political thought having been morally corrupt since the days of Luther.

Such jingoism is striking, especially from a historian. If Heisenberg really would have had to emigrate in 1935 for moral reasons, as Rose has it, then it seems that in good conscience he only could have gone to Iceland. For one thing, colonial powers were not particularly kind to the indigenous populations they controlled. Massacres were routine expressions of power then and now; politicians, scientists, and other citizens of almost every country in the world with some power have cultivated the art of looking in the other direction to perfection, whilst being convinced of their own benevolence (cf. Glover, 1999).

Rose implies that Heisenberg and his collaborators were morally bankrupt because they at least investigated the possibility of building weapons of unprecedented destructive power for a deeply criminal regime. They may well have been, but in the reviewer's opinion this seems rather caused by their predisposition as scientists than by their being German (as Rose suggests). As to their colleagues on the Allied side, Otto Frisch (who was one of them) recalls that 'Somebody opened

[88] Heisenberg probably did not know that Einstein's letter hardly played a role in Roosevelt's actions, which somewhat relieves this episode of its tragic nature.

[89] Although he concedes that evil things may happen within them.

[90] For the opposite view, in which Hitler and Nazism receive credit for some of their actions, cf. the classic study by Haffner (1978).

[91] He gives the game away by saying 'how difficult it was for scientists—including even Jews—educated in Germany to attain an objective (Western!) understanding of the situation' (p. 300).

my door and shouted, "Hiroshima has been destroyed!"; about a hundred thousand people were thought to have been killed. I still remember the feeling of unease, indeed nausea, when I saw how many of my friends were rushing to the phone to book tables at the La Fonda Hotel in Santa Fe, in order to celebrate.'[92]

4. Conclusion

4.1. Heisenberg

George Steiner has recently remarked that from a certain ripe age, one should start writing the errata to one's life. Although Heisenberg had ample opportunity to do so, for example during his Farm Hall internment, in his correspondence with Goudsmit, or in his autobiography, one instead finds an embarrassing mixture of myopia, pride, and self-pity. One feels that the following words of Born really apply to Heisenberg:[93] 'Denn ich wusste seit der Zeit, da er mein Assistent in Göttingen war, dass er ein Genie war, nur vergleichbar mit EINSTEIN selbst, ja dass er rein wissenschaftlich vielleicht noch grösser war als EINSTEIN, wenn auch ein ganz anderer Menschentyp, der in meinen Augen EINSTEINS Grösse nicht erreichte.'

4.2. The Nazi atomic bomb project

Following the publication of the Farm Hall transcripts, it is now clear beyond reasonable doubt that Heisenberg and his colleagues in wartime Germany had only some tentative understanding of the physics and technology of nuclear weapons. This agrees with the conclusion of Allied intelligence work during the war and its aftermath (cf. Goudsmit, 1947; Groves, 1962), which, however, overstated its case somewhat. It follows that Heisenberg and some of his colleagues were in no position to claim that during the war they had known how to build a bomb, let alone that they had refrained from doing so for moral reasons, as some of them did after the war. The questions why they knew so little, and why the bomb project was effectively shelved in 1942, are very complex, and have no single answer. Many equally well-informed authors, such as Goudsmit (1947), Bagge, Diebner and Jay (1957), Irving (1967), Walker (1989), as well as Rose, have forwarded as many explanations, each of which probably played a role.

4.3. The book under review

As a correction to previous literature, Rose's book is a must. It contains the most detailed discussion to date about what the German scientists actually knew about the bomb. On all other matters he discusses, however, such as the question why the

[92] See Frisch (1979, p. 176). Previously quoted by Rhodes (1986, pp. 735–736), and by Glover (1999, p. 101).

[93] Rather than to Pauli, about whom they were written; cf. Pauli (1990, p. 6).

German bomb project failed, or the analysis of Heisenberg's character and motives, Rose merely propounds a number of vitriolic opinions. Thus his book cannot serve as an introduction to either Heisenberg or the German wartime work on Uranium. The lack of balance of Rose's book is a pity, obscuring the many valid points that he does make also on these more general issues.

One of Rose's heroes is Goudsmit, and the book proves a number of the latter's (1947) suggestions. Nonetheless, one should compare the tone of Rose's book with that of Goudsmit's (1976) condoning obituary of Heisenberg.

Note added in proof

Unexpectedly, a number of unpublished documents concerning the Bohr-Heisenberg meeting in September 1941 were released by the Niels Bohr Archive (where they had been deposited by the Bohr family) on 6 February 2002 (10 years ahead of the date originally scheduled). These documents may be found on the internet site http://www.nbi.dk/NBA/papers/docs/cover.html.

In particular, in Document 1 (dated as 1957) Bohr states that he remembers quite clearly that in September 1941 Heisenberg was confident that Germany would win the war, and that Heisenberg had made it clear to him that he was leading a German program to develop atomic weapons, with whose details he claimed to be completely familiar.

Weizsäcker's immediate response to the release of these documents was that "Bohr ist in seiner Erinnerung einem tiefen Irrtum erlegen" ("Bohr's memory is deeply mistaken"), adding that he, Heisenberg, and other German scientists had already stopped their work on the atomic bomb in September 1941, and that Heisenberg had tried to persuade Bohr that the US and GB should not build atomic weapons either, an option Bohr allegedly refused to consider. For Weizsäcker's full statement to the dpa (German Press Agency) on 7 February 2002, see, For example SPIEGEL ONLINE, http://www.spiegel.de/wissenschaft/0,1518,181179,00.html.

Assuming, with most commentators, that Bohr's memory is not deeply mistaken, it is now clear that the accounts of Heisenberg's role in wartime Germany presented in Jungk (1958), Heisenberg (1969), Hermann (1977), Heisenberg (1980), and Powers (1993) have lost what little credibility they might still have had before the above release. Cf. our Sections 2.4 and 2.5, as well as footnotes 30, 50, and 66.

As to Rose's book, his analysis of the Bohr-Heisenberg meeting (pp. 271–282) and of Heisenberg's general attitude concerning the outcome of the war (Chap. 19) is largely supported by the documents just released. In fact, Rose's quotations of S. Rozenthal (p. 276) and of Bohr to Ladenburg (p. 277) already give a fair impression of the main contents of these documents. Two exceptions are that Bohr now appears to agree with Heisenberg that no technical discussions took place (against Rose on p. 280, and in fact many others), and that the documents provide no evidence for Rose's claim that Heisenberg tried to pump Bohr for information (p. 282).

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