

Heisenberg and the German Atomic Bomb

Editorial Board

The German physicist, Werner Heisenberg, was one of the greatest physicists of his generation, if not of all times. He formulated matrix quantum mechanics and was the author of the famous uncertainty principle in quantum mechanics. Along with Max Born, Erwin Schrödinger, Paul Dirac, Wolfgang Pauli, and others, he is recognized as a founding father of quantum mechanics.

During World War II many of Heisenberg's fellow physicists emigrated to the US or elsewhere (prominent scientists like Einstein, Fermi, Szilard, Wigner, Teller, Frisch, Peierls and dozens of others) to escape the horrors of Nazism, but Heisenberg steadfastly refused lucrative job offers from places such as Columbia University, to remain in Germany. He had accepted the inevitability of the war and wanted to take part in the reconstruction of the scientific establishment in post war Germany.

In December 1938, nuclear fission was discovered in a Berlin lab by three physicists Otto Hahn,¹ Lise Meitner,² and Fritz Strass-

¹Hahn received the 1944 Nobel Prize for Chemistry for his discovery of the fission of heavy nuclei.

²Lise Meitner was a trained physicist—the first woman to graduate from the University of Vienna, second in the world to earn a doctorate in physics, and the first woman to become a full professor of physics in Germany (Kaiser Wilhelm Institute). She fled Germany when Hahn and a young associate in their radiochemistry laboratory, Fritz Strassmann, achieved the first fissioning of uranium. But Meitner, along with her nephew, physicist Otto Frisch,

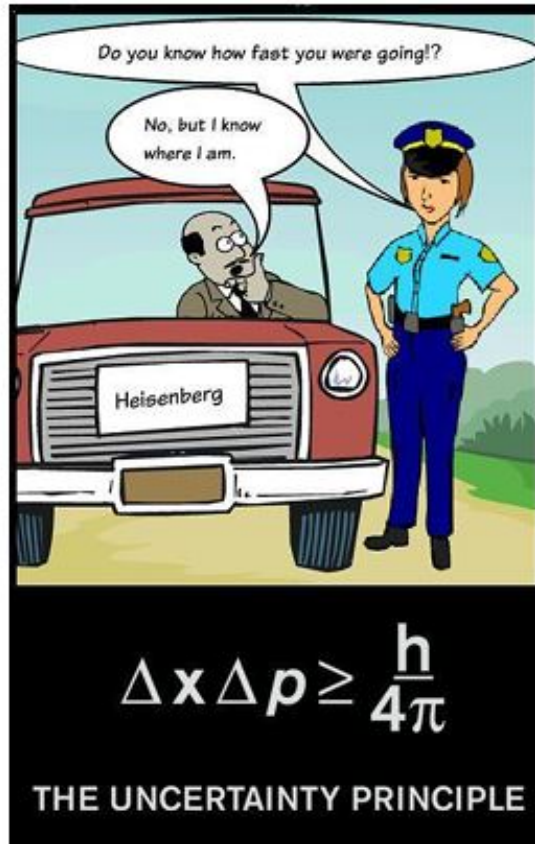


Figure 1: Werner Heisenberg describes his uncertainty principle.

mann. It was quickly realized that the release of nuclear energy in fission could be used to make a bomb, or it could be used to generate power as is done in nuclear reactors today. In April 1939, Germany began its secret program, called "Uranium Society"—*Uranverein* in German—under Erich Schumann, the head of the *Heereswaf* (Army weapon). The government of US became aware of Germany's nuclear program in August, when Albert Einstein warned President Roosevelt in a letter saying, "that it may become possible to set up a nuclear chain reaction in a large mass of uranium by which vast amounts of power and large quantities

were instrumental in explaining Hahn and Strassmann's results. Meitner deserved the Nobel Prize along with Hahn, but she was the victim of the age-old bias against women scientists whose work was attributed to male colleagues (Hahn never mentioned Meitner's work in his Nobel acceptance speech). Although Meitner's work on nuclear fission laid the groundwork for the building of the atomic bomb, she refused to work on the Manhattan Project at Los Alamos. She famously said, "I will have nothing to do with a bomb!" After her death, Otto Frisch wrote the epitaph on her gravestone, which simply reads: "Lise Meitner: a physicist who never lost her humanity."

of new radium-like elements would be generated.”

The German Nuclear Program

US entered the arms race believing whoever built the bomb first would win the war^a. Notably, German scientists also shared the same belief. The German nuclear program was motivated by a letter written on April 24, 1939 by the Hamburg physical chemist Paul Harteck and his assistant Wilhelm Groth to Erich Schumann, head of the weapons research office in Berlin. Incidentally, Harteck became one of the future detainees at Farm Hall. Of the possible applications of nuclear fission, Harteck and Groth wrote “The country which first makes use of it has an unsurpassable advantage over the others.”

In 1940, Rudolph Peierls (Heisenberg’s student) and Otto Frisch first pointed out in a memorandum that an atomic bomb could be constructed from a small amount of fissile ²³⁵U. Until the publication of the Frisch-Peierls memorandum it was thought that an atomic bomb would require many tons of uranium—hence was deemed impractical to build such a bomb. The Frisch-Peierls memorandum was instrumental in raising the British and the American authorities’ interest in building nuclear weapons. (See Jeremy Bernstein’s analysis of the Frisch-Peierls memorandum [1]. Frisch computed a critical mass to be of the order of a pound—a value too small. Bernstein points out that the actual critical mass of ²³⁵U is about 115 lbs.)

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The American-led effort to develop a functional atomic bomb had the code name, Manhattan Project. In Germany, Heisenberg took on a leading role in its nuclear research and because of the Nazi context, this became an enormously controversial issue. A reactor was built in Lipsk under his supervision, while in Berlin, Carl Friedrich von Weizsäcker oversaw construction of the nuclear bomb.

At the beginning Germany had a significant head start over the US Manhattan Project with its world-renowned scientists, a strong

industrial base, sufficient raw materials, and the political will of the German authorities.

But Germany never produced the bomb!

The reason is still debated by historians of physics. According to one school of thought the reason is technical. Heisenberg wrongly calculated a key variable—the critical mass of uranium needed for a nuclear explosion—to be on the order of several tons, while the correct value is only about 50 kg! Later, it became clear that there were many other factors that contributed to Germany's failure. In fact, Heisenberg had completely misunderstood the more subtle aspects of reactor and bomb physics. For details see [1],p. xxiv.³

Another viewpoint is that Heisenberg did not want to build the bomb for Hitler. Von Weizsäcker—the longest-living member of the team which performed nuclear research in Germany (von Weizsäcker died in 2007)—had always maintained that the German physicists deliberately chose not to build the bomb because they did not want such a powerful weapon to fall into the hands of the Nazis.

Is von Weizsäcker's moral qualm an afterthought, or did the Germans indeed possess the know-how? Heisenberg's political convictions made things more confusing. "Heisenberg was neither Nazi nor anti-Nazi. He believed that democracy was obsolete and that Europe would endure under either German or Soviet rule;

³Heisenberg was a brilliant theoretical physicist. But he had a certain ineptness with numerical calculations. This was well known among his students. According to Rudolf Peierls, "Heisenberg's inability to do this sort of thing made him, as far as the German program was concerned, often part of the problem rather than the solution." In contrast, Enrico Fermi, creator of the world's first nuclear reactor, was a great engineering physicist who could perform rapid-fire and accurate mental calculations [1],p. 36. Richard Feynman once noted Fermi's dexterity with mental mathematics. He was describing to Fermi a certain calculation that he was once performing. Fermi was able to correctly estimate the result before knowing the details: "He was doing what I was supposed to be good at, ten times better. That was quite a lesson to me [2],p. 132."



Figure 2: Heisenberg’s famous 1941 meeting with Niels Bohr is shrouded in mystery.[4]

he regarded a German dictatorship as the lesser evil. [3]” Plus, Heisenberg could never be sure whether the Allied Forces were developing a bomb to drop on Berlin. That alone could be his impetus for agreeing to make the atomic bomb for Germany.

Heisenberg’s famous 1941 meeting with Niels Bohr—his mentor who shared the same scientific interest and curiosity—in occupied Copenhagen is also shrouded in mystery.⁴ In 1939, Europe became divided with Bohr and Heisenberg ending up in two sides of the divide—Bohr on the Allies’ side and Heisenberg on Hitler’s. Although Heisenberg’s statements were vague and cautious at times, Bohr was shocked by some of his remarks. He thought Heisenberg was trying to hint that Germany was making progress in manufacturing atomic weapons. Heisenberg tried to correct the cloud of “false impression” that he cast upon Bohr, but also felt that his half-hearted efforts may have been fruitless. Nevertheless, Bohr became convinced that Heisenberg wanted to build a bomb. Being fully aware of the enormous destructive power of atomic weapons, Bohr was horrified.⁵

⁴The Bohr-Heisenberg meeting was the subject of Michael Frayn’s award-winning play *Copenhagen*.

⁵After the war, Bohr and Heisenberg returned to their research centers in their respective countries. They never managed to renew the friendship they had before the war.

More clues emerged near the end of World War II, when ten of Germany's foremost nuclear physicists, including Werner Heisenberg, were captured by Allied Forces, and detained for six months at Farm Hall, a comfortable English country house near Cambridge. What the captive physicists did not know was—Farm Hall was bugged.

The Farm Hall transcripts [1]⁶ were finally declassified in the 1990's after much campaigning by historians. Many authors felt that the transcripts appeared to confirm von Weizsäcker's claims.

Their reasoning was based on two facts:

- Heisenberg and his colleagues were genuinely shocked when they heard about US bombing of Hiroshima. This did not support the suspicion that the Germans ever possessed a blueprint of an atomic bomb whose design needed massive planning and coordination between different research groups and laboratories.
- About a week after Hiroshima was flattened by an atomic bomb, Heisenberg delivered a formal lecture to his colleagues at Farm Hall. The material was new to many and only a handful appeared to understand the physics of fission. Walter Gerlach, the head of the German uranium project, was particularly ill at ease and had to be coached from the very beginning. Hans Bethe, one of the main theoreticians for the Manhattan Project, after reviewing the same Farm Hall documents forty-seven years later, remarked: "Heisenberg knew a lot more than I have always thought." This seemed to indicate that Heisenberg had kept much of his knowledge to

⁶Jeremy Bernstein's book, "Hitler's uranium club," contains the complete text of the Farm Hall transcripts with expert scientific and historical annotations. Its extensive prologue outlines the history of fission up to Farm Hall, important technical appendices, and an excellent summary on the German wartime nuclear program by David Cassidy, one of Heisenberg's most trusted biographers.

himself during the war. There is some evidence [5] that he (and other fellow scientists) purposely held back or misrepresented significant details of fission science from the German leadership, which resulted in discouraging them from pursuing a nuclear bomb in wartime. This seemed to explain why the German bomb never existed.

However, Samuel Goudsmit, the Dutch-American physicist,⁷ who had full access to the Farm Hall transcripts, had a different take on this matter. In the book *Alsos* that Goudsmit published in 1947, he argued that the German physicists simply lacked the knowledge needed to engineer an atomic bomb [6].

Clearly, the conclusions reached by various authors from the Farm Hall transcripts differ widely on the question of why the Germans never produced a bomb. But one thing seemed clear: Most of them did not show any moral objection to building a nuclear bomb. A notable exception was Otto Hahn, who once told von Weizsäcker, “But if my work leads to a nuclear bomb for Hitler, I will commit suicide.” And there was the highly respected Nobel Laureate, Max Von Laue, who felt strongly that he was not involved with uranium or other experiments that were carried out at Kaiser-Wilhelm Institute.

Many people on this side of the Atlantic who were involved in the Manhattan Project suffered from serious moral misgivings, especially when they witnessed the extent of human misery after the bombings over Hiroshima and Nagasaki. But other people did not suffer from a similar pang of consciousness because they feared that the Nazis would prevail otherwise. Richard Feynman who shared the 1965 Nobel Prize for his work on quantum electrodynamics had worked on the Manhattan Project when World War II was raging in Europe. About nuclear weapons and his role in

⁷Goudsmit jointly proposed the concept of electron spin with George Eugene Uhlenbeck in 1925.

making them, Feynman said this in an interview for “Viewpoint,” conducted by Bill Stout for KNXT Television in 1959 [7], p. 421:

I have a philosophy that it doesn't do any good to go and make regrets about what you did before but to try to remember how you made the decision at the time. . . . if the scientists in Germany could have developed this thing, then we would be helpless, and I think it would be the end of the civilization at that time. I don't know how long the civilization is going to last anyway. So the main reason why I did work on it at the time was because I was afraid that the Germans would do it first, and I felt a responsibility to society to develop this thing to maintain our position in the war.

It is possible that Heisenberg, too, was at peace with his own involvement in the German atomic bomb because he also thought that the Allied forces would get it first.⁸ After all, it was not his side that unleashed the bomb on the two Japanese cities that killed thousands. In a post-war article published in *Nature* [8], Heisenberg claimed that the German physicists “had consciously striven to keep control of the project” and avoided work on a bomb, preferring to work on reactors and cyclotrons.

But what Heisenberg actually did to help or to hinder the bomb project still remains unclear, not only to his biographers but also to the history of twentieth-century science. Was he truthful to the world? Or did he take the moral high ground? Is it true that the Germans came nowhere close to manufacturing an actual nuclear weapon because they could not have succeeded under war conditions?⁹ We may never know the answers for sure. But they do raise the broader ethical questions summarized in [3]: “Should inventors work on problems that might bring death and destruction if they get into the wrong hands? Is it necessary to define the notion of scientific morals? Can political affairs alter

⁸Recently, 84 boxes of documents belonging to Max Born (that includes photographs of his contemporaries and family, as well as a postcard from Albert Einstein) were unveiled as part of a Cambridge University exhibition of archives. The archive includes a 1947 letter from Max Born to his son Gustav, describing Heisenberg as “somewhat infected by Nazi ideas. . . but in spite of all that we liked him immensely.”

⁹In Ref. [8] Heisenberg briefly discusses his view about the moral implications: “Finally – and this is a most important fact – the undertaking (a German atomic bomb project) could not even be initiated against the psychological background of the men responsible for German war policy. These men expected an early decision of the war, even in 1942, and any major project which did not promise quick returns was specifically forbidden. . . .”

our internal morality, making us insensitive to others' circumstances?"

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