Chapter 2

GERMAN NUCLEAR PROGRAM

12/29/2022

2.1 INTRODUCTION

In December of 1938, the German radio-chemist Otto Hahn, born in Frankfurt am Main, Germany in 1879, and Fritz Strassman, an inorganic chemist born in Boppard, Germany in 1902, were the first to discover the nuclear fission process and the splitting of the nucleus of uranium. They were both awarded the Nobel Prize in Chemistry for it in 1944.

Figure 1. Otto Hahn, with Fritz Strassman discovered the process of nuclear fission in December of 1938.

The views of historians and authors about the German Nuclear Program during World War II differ substantially.

Some German scientists claimed that they did not want to hand the German Nazi regime a horrible weapon, based on moral considerations. Another view was that accidental fires with powdered uranium used in the first subcritical assemblies that they built discouraged them. Inaccurate calculations about the lattice parameters in a heavy water-moderated thermal subcritical assembly misled them. The inability to secure sufficient heavy water (D_2O, HDO) from Norway due to bombings and commando raids and sabotage, or to manufacture it in Germany, blocked their progress. Some of them used the nuclear research as a pretext to protect themselves and their coworkers from being sent to the killing fields at the battle fronts. Others did not want to make unachievable claims about projects they were not confident could be carried out to a successful end, and be punished if they failed.

Nonetheless, the German nuclear program did in fact build a thermal heavy water moderated natural uranium subcritical assembly that did not achieve criticality for lack of sufficient heavy water moderator and natural uranium fuel. This is in contrast to the graphite moderated critical reactors built on a large industrial scale, and the fast-neutrons assemblies leading to the construction of nuclear devices in the USA.

The brain drain of a large number of German scientists to the UK and the USA, caused by the then prevalent religious fanaticism and racism, and unfair treatment, as well as some German scientists' overconfidence bordering on arrogance, thinking that they knew better than their American and British counterparts, doomed them to failure.

Another display of overconfidence was what the German Army set up on June 27, 1940, during World War II, a two-way radio communication system employing a sophisticated coding machine called "Enigma" to transmit information. The German military considered its coding system as unbreakable. However, the allies were able to capture a German submarine and seize its coding machine. The allied cryptographers were able to break the code and were able to routinely intercept the supposedly secret messages sent through the system. The Allies were able to locate and sink most of the German submarine fleet, all while keeping the capture of the submarine secret.

The end result was that the remaining nuclear scientists in Germany never realized that criticality can be achieved in a miniature fast-neutrons assembly and limited their effort to a massive thermal neutron heavy water-moderated subcritical experiment that never achieved criticality up to the end of the war.

2.2 THE BRITISH "MAUD" COMMITTEE

Lise Meitner, a theoretical physicist, born in Vienna, Austria in 1878, who had worked and corresponded with Otto Hahn, learned through correspondence with him about the fission process after leaving Germany to England. She communicated the news to Niels Bohr in Denmark and with her nephew Otto Robert Frisch, a theoretical physicist born in Vienna, Austria in 1904, developed a theoretical description and the naming of the process of nuclear fission.

In the UK, Rudolph Peierls, a theoretical physicist, and Otto Frisch wrote a "Memorandum on the Properties of a Radioactive Super Bomb" using nuclear fission. Otto Frisch at the University of Birmingham under Mark Oliphant, had worked on the process of gaseous diffusion, and Rudolph Peierls on the calculation of critical masses.

Mark Oliphant submitted the memorandum to the British Government which formed the Military Applications of Uranium Disintegration (MAUD) committee to study the military applications of nuclear fission.

A team of German scientists, led by the theoretical physicist Werner Heisenberg, born in Wurzburg, Germany in 1901, collected and stockpiled uranium and heavy water and built subcritical assemblies but did not achieve a self-sustained critical chain reaction.

Werner Heisenberg had pioneered the field of Quantum Mechanics for which he won the Nobel Prize in Physics in 1932. He met with Niels Bohr in a failed attempt to reassure him that the efforts of his team were not directed toward the development of a weapon.

Carl Friedrichs von Weizäcker came the closest to conceptualizing a weapon by discussing the production of Neptunium^{239} from U^{238}, but not the more potent Np^{237}, and not even Pu^{239} in a heavy water subcritical assembly which never achieved criticality until the end of the war.

Harteck and Groth built a laboratory experiment for using an ultracentrifuge for separating U^{235} from natural uranium that also did not reach an industrial stage.

Figure 2. Carl Friedrichs von Weizäcker.

The MAUD committee recommendations were communicated to the USA's President Franklin D. Roosevelt in 1941. Although World War II had not yet started, the discovery of nuclear fission ultimately led to the formation of the Manhattan District Project, or the "Manhattan Project" in short, which became the USA government's secret project to build a nuclear device.

2.3 ALSOS TEAM MISSIONS

In the last days before the end of World War II, undercover Allied special agents engaged in a frantic race across Europe, sometimes competing against each other, to capture the best and brightest of Germany's scientific community. With the German army in retreat, American, British, and Russian forces set their sights on the architects of the so called advanced Vengeance Weapons. These included high technology jet and rocket airplanes, rockets, laboratory experiments, stockpiles of uranium in different forms and a subcritical heavy water moderated assembly.

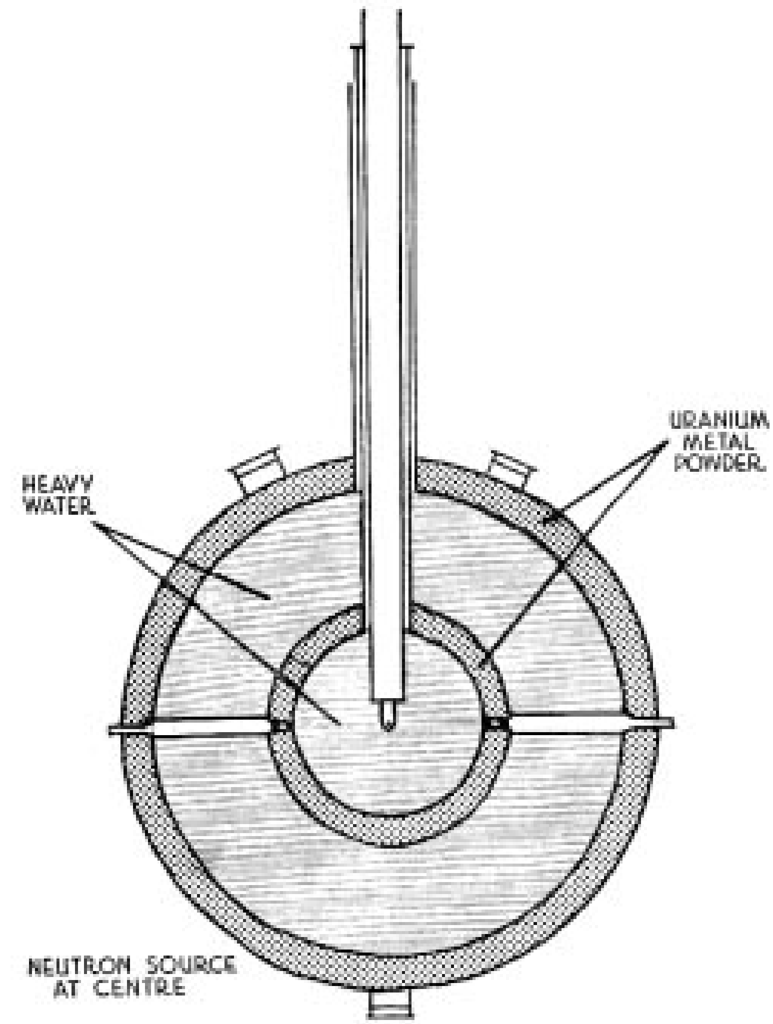

Figure 3. The Leipzig subcritical assembly including a neutron source at its center with heavy water (D_2O, HDO) as a neutron moderator and natural uranium powder as a fuel.

Figure 4. Graphite blocks reflector surrounding an unfinished reactor core.

The reasoning behind the mission was that whoever captures the scientists, the archives and the technology, was expected to gain a major scientific and technological advantage in the looming Cold War. Another goal of the mission on the American side was to deny this perceived advantage to the Russians as well as the French. This assessment proved correct for the USA in the enticement of Werner von Braun and most of his team in the establishment of its space and Intercontinental Ballistic Missile (ICBM) Program.

The USA military launched the "Alsos" mission to search Germany not just for its scientists like von Braun and Heisenberg and their teams, but also their experiments, equipment and laboratories and any stockpiled strategic materials such as gold, silver, copper and uranium. One such experiment was a subcritical assembly of natural uranium powder and heavy water designated as the Leipzig experiment.

The mission consisted of undercover special agents and was led by Lieutenant Colonel Boris T. Pash, and as scientific leader Sam Goudsmit. It was code-named "Alsos," the Greek word for "grove," as in "tree grove" in honor of General Leslie R. Groves, the head of the Manhattan Project. The mission followed immediately in the wake of, and sometimes ahead of the allied armies invading Europe.

When the German scientists first discovered fission, the USA and the UK worried that Germany could develop a nuclear device, and this was the main incentive for the initiation of the MAUD committee in the UK and the Manhattan Project in the USA. Those paranoid fears, based on overzealous and faulty intelligence, were totally dispelled just weeks before the end of the war. The special agents of the American Alsos team discovered a German subcritical assembly under construction in a cave beneath a castle at Haigerloch, Germany, but no functional reactor. Intentionally, or unintentionally uninformed about the residual radiation hazard, they promptly dismantled by hand the assembly which consisted of wire-suspended natural uranium cubes in a heavy water moderator contained in a steel vessel.

Figure 5. The Alsos team dismantling by hand the heavy water (D_2O, HDO) subcritical assembly at the village of Haigerloch, Germany.

Figure 6. Retrieved buried uranium cubes by the Alsos team.

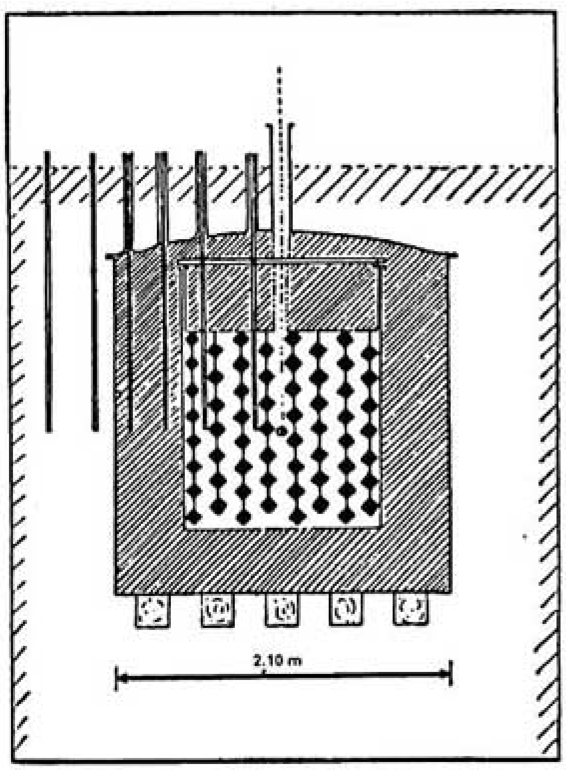

Figure 7. Diagram of the heavy water (D_2O, HDO) natural uranium subcritical assembly.

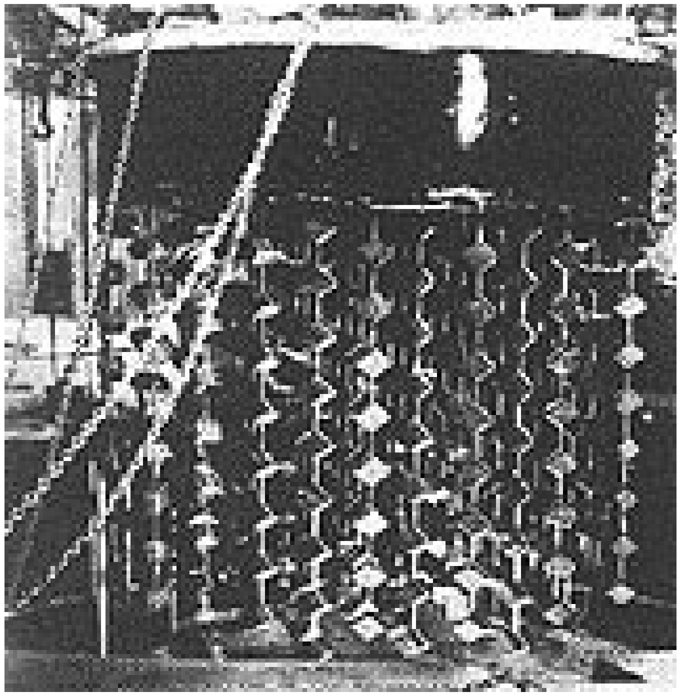

Figure 8. Lid with wire-suspended natural uranium cubes pulled out from the heavy water (D_2O, HDO) moderator vessel of the Haigerloch, Germany subcritical assembly.

Figure 9. Museum at the Haigerloch site.

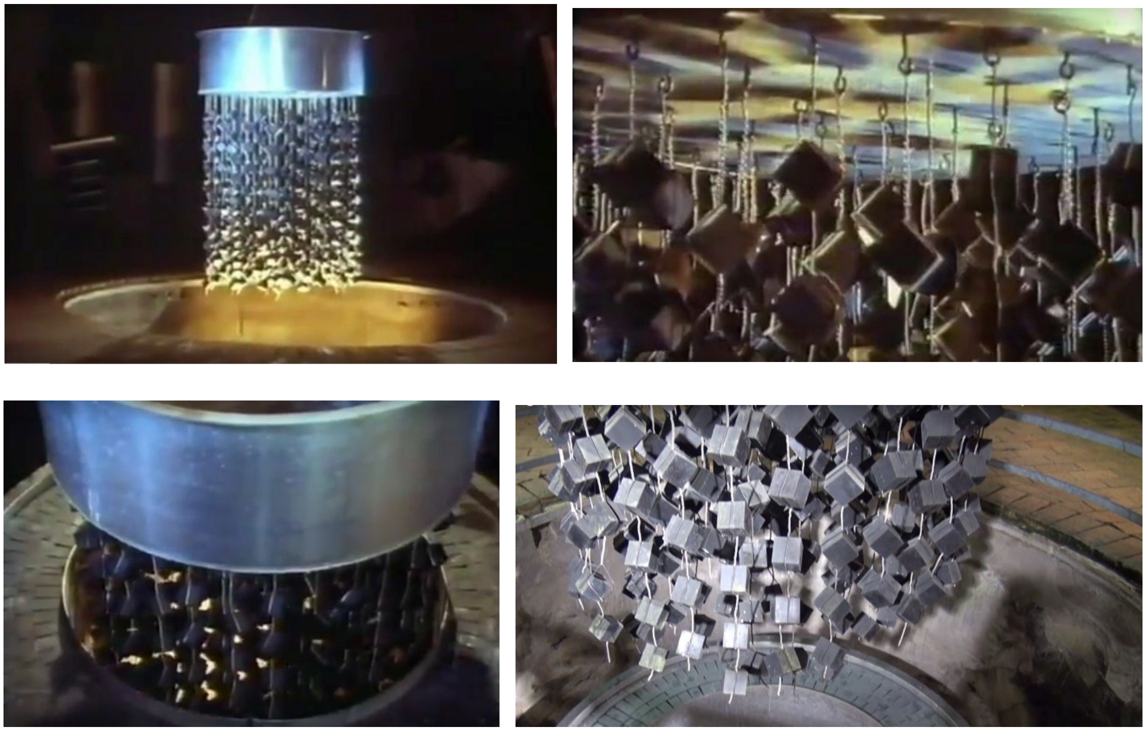

Figure 10. Replica of German heavy water reactor at the Haigerloch Museum.

It was realized that he German nuclear scientists in 1945 were no farther along in their nuclear program than the Americans had been back three years earlier in 1942.

With interrogation and enticements of the scientists, a few days later, buried in a nearby field, the Alsos agents uncovered a cache of about two metric tonnes of natural uranium. The mission also tracked down and secured amounts of uranium in different chemical forms in France, Belgium, and Germany. This uranium was shipped to the Manhattan Project for use in the American nuclear device effort.

A first mission code named “Alsos I” headed to Italy in December 1943, but gained little information of interest, due in part to the slow progress of the Allies’ forces advance towards Rome. A second mission designated as “Alsos II” followed the Allies’ forces advance from France to Germany in 1944 and 1945. It consisted of seven military officers and 22 scientists.

Interrogation of the French and German scientists combined with the searching of laboratories, confirmed that the German program was never close to producing an atomic device, let alone even achieving a self sustained critical chain reaction.

2.4 HEISENBERG’S LEADERSHIP OF THE GERMAN NUCLEAR PROGRAM

Werner Heisenberg (1901–1976) is considered to have led the German nuclear program during World War II. He is known for his formulation of the uncertainty principle in quantum mechanics and its physical interpretation in 1927. He introduced the theoretical insight that quantum mechanical variables do not commute.

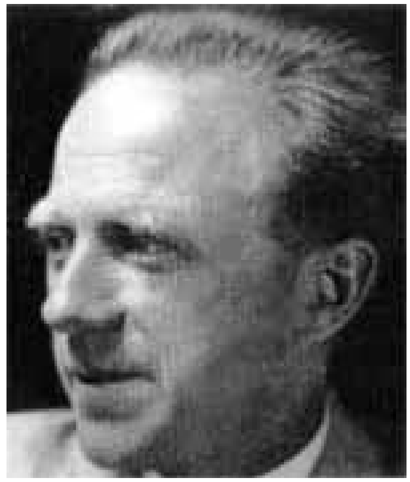

Figure 11. Werner Heisenberg, (1901-1976).

At 20 years of age, and well before the introduction of the concept of electron spin, Werner Heisenberg made the proposal to allow half-integral quantum numbers in the context of the Zeeman Effect. 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."

He provided the quantum-mechanical explanation of the occurrence of para-helium and ortho-helium and provided an explanation for ferromagnetism. His most important contribution is the foundation of the quantum field theory with Pauli. He became one of the founders of theoretical nuclear physics with a description of the interactions between protons and neutrons in a nucleus.

He went out of his way and used his influence to help his own students and collaborators, both in peacetime and during the war, sometimes at risk to himself. Some of them avoided death at the European and Russian fronts by being enlisted by Werner Heisenberg in his nuclear research program. At one point he had to face treason accusations by his political opponents as a "White Jew." He was investigated and cleared of the charges. From a totally opposite perspective, he was also accused of reaching a Faustian pact with the devil for his refraining from emigration like many other German scientists, and for participating in the German nuclear program.

He tried his best during the war in preventing the German forces from destroying physics laboratories such as at the University of Leiden and of Bohr's institute in Copenhagen, Denmark. He implied that he steered the German nuclear program toward nuclear energy and scientific applications and away from weaponization.

2.5 THE URANIUM CLUB, "URANVEREIN"

In September 1939, Werner Heisenberg was recruited into the German nuclear research team known as "Uranverein" or "Uranium Club" by an order from the German military. This team was assembled by Kurt Diebner, a competitor to Werner Heisenberg on behalf of the Heereswaffenamt (HWA) or Army Ordnance Office.

The formation of the Uranium Club followed 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. Paul Harteck built a single-stage ultra centrifuge experiment for the enrichment of uranium of scientific but of no industrial relevance.

Figure 12. Paul Harteck built an experimental centrifuge.

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 or Kernforschungsrat, and managing director of the Kaiser Wilhelm Institute for Physics. He ran his own subcritical experiments, in direct competition with Werner Heisenberg. Kurt Diebner was a Nazi party member, and was held in contempt by Werner Heisenberg, supposedly because he was an experimentalist with ideas on experimental designs that were more successful than Werner Heisenberg's.

Werner Heisenberg obeyed an order from the German leadership and generated a report on "The possibility of technical energy production from Uranium fission," which laid the theoretical foundations for the subsequent research in Germany on that topic. The report correctly foresaw that a nuclear reactor could be built in two qualitatively different ways, each posing its own challenges.

In the first approach one could use either use enriched uranium and an easily obtained moderator such as ordinary water (H_2O), or one could adopt natural uranium in association with heavy water (D_2O, HDO) or a highly pure graphite as a moderator. Admittedly, Werner Heizenberg did in fact emphasize nuclear power production and not weapons production.

The use of graphite as a moderator, which met with success in the USA program, was not pursued in Germany due to a miscalculation in estimating its absorption cross section to neutrons, and the German team had only two options left. Various isotopic separation projects such as centrifuge enrichment, as well as a number of methods to produce heavy water, were pursued, principally by Paul Harteck, just on a laboratory scale.

2.6 INTERNMENT AT FARM HALL, SOPHISTICATED BRITISH INTERROGATION

The German nuclear research project was interrupted by heavy Allied bombings and sabotage of Germany's supply of heavy water from Norway. A subcritical moderated assembly never achieved criticality all the way to the last days of the war.

Ten of the German nuclear physicists, including Werner Heisenberg were taken as prisoners by the Allied Forces between May and December 1945. To sanitize their detention, they were designated as "interns," not as "detainees," and kept during the last six months of the war at a country estate, Farm Hall, near Cambridge in England.

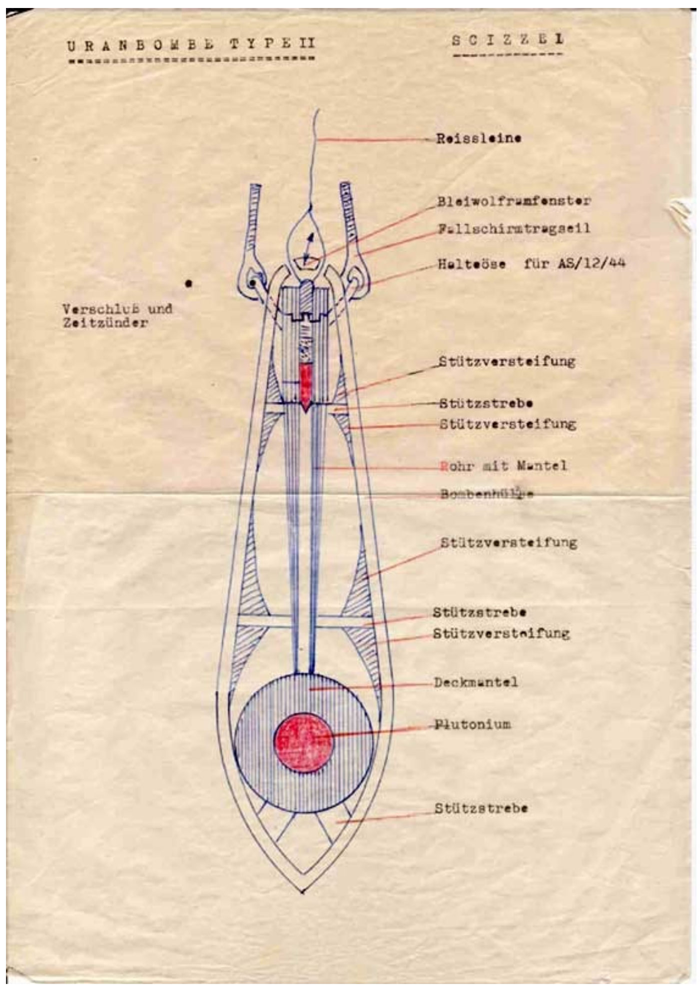

Figure 13. Totally unworkable diagram of a gun barrel design for a plutonium device of alleged German origin. The design is unachievable since plutonium requires an implosion process to attain super-criticality. The diagram was possibly drawn by some unknown individual after the war. Source: Nova.

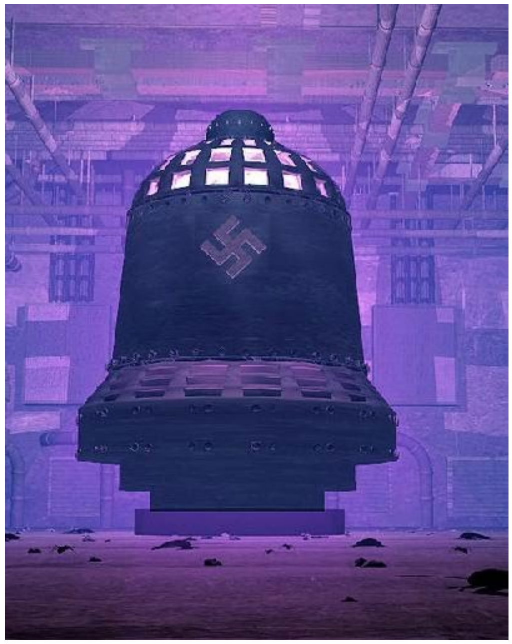

Figure 14. Die Glocke, the Bell, an alleged attempt at "torsional fields" to achieve nuclear fusion was surrounded by secrecy.

Using a sophisticated, smart and effective way of harvesting information, the British did not use the crude ineffective methods of torture, dogs, water-boarding, nor sexual degradation and humiliation or coercion à la Abu Ghraib, Bagram Base and Guantanamo Bay styles against them. In a sophisticated and smart interrogation fashion, they treated them with the utmost respect and called them interns, instead of prisoners or detainees. They nicely housed and generously dined and wined them.

However, their conversations were cleverly and secretly monitored and recorded and were made public in 1992. At Farm Hall, the internees produced a carefully drafted statement in their own defense 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." They seemed to be doubly hedging their bets; so as not to be considered as traitors who effectively sabotaged the war effort by the defeated Germans, and not as war criminals by the victorious Allies.

From the Farm Hall transcripts, Werner Heisenberg and his German colleagues believed that their knowledge about nuclear technology and its possible military uses was superior to that of the allied's scientists. Their belief was shattered by the British Broadcasting Corporation (BBC) News at 9 pm on August 6, 1945, announcing the nuclear bombing of Hiroshima.

Werner Heisenberg suggested on various occasions in an ambiguous manner that he had actually actively withheld the bomb from the German leaders. This line was defended more vigorously by von Weizsäcker. Werner Heisenberg's published writings on the German nuclear project emphasized that its goal had been the: "Technical utilization of atomic energy." He stated 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."

At Farm Hall, Werner Heisenberg said: "We would not 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." He also admitted: "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."

2.7 EARLIER HYBRID FISSION-FUSION RESEARCH

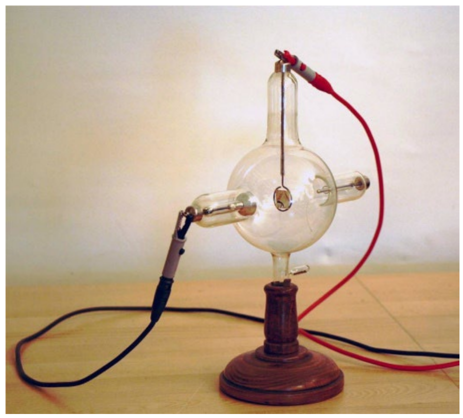

Figure 15. Deuterium gas filled Crookes glow discharge tube with uranium metal foils experiments in the 1920s.

In 1929, Walter Hernann Nernst (1864-1941), Nobel Laureate in Chemistry in 1920, remarked on experiments on hydrogen gas interaction with uranium metal in the Zeitschrift magazine: "Hydrogen will dissolve into certain metals as if the metal was acting like a dry sponge absorbing water."

Glow-discharge experiments were conducted using Crookes tubes filled with deuterium gas and uranium foils. These were precursors to the Farnsworth Fussier experiments attempting the electrostatic fusion of deuterium in the 1960s. Niels Bohr suggested that this approach could lead to the production of small nuclear devices instead of the critical mass approach, which would be more suitable for large devices.

If deuterium is dissolved in heavy elements such as uranium or palladium metal beyond a critical threshold concentration, an interaction between the deuterium and the heavy metal was expected. It can be suggested that if it is a form of deuteron disintegration, it becomes an avenue of energy release from the heavy metals without the need to reach a critical mass of the fissile elements.

2.8 SAM GOUDSCHMIT AND WERNER HEISENBERG RIVALRY

Sam Goudschmit (1902-1978), was an emigrant scientist from Brookhaven National Laboratory (BNL) in the USA who was assigned as a scientific head to the Alsos project which was the scientific intelligence mission that followed the Allied troops in the wake of their invasion of Europe. Its initial goal 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."

After it had become clear that nothing of substance was to be feared, its goal evolved into keeping whatever scientists and scientific equipment that would be of any military value out of the hands of the Russians and the French. Reporting directly to General Leslie Groves in the USA, its military commander in Europe was Boris Pash, and its scientific head was Sam Goudschmit.

A plea was made by Sam Goudschmit to Werner Heisenberg in 1943 for help in saving his Jewish parents from deportation and almost certain death in a concentration camp. Short of approaching Himmler this time or any German authority in Germany or Holland, Werner Heisenberg merely sent a letter of support to Sam Goudschmit's colleague, Coster. As pointed out by Sam Goudschmit himself, it is doubtful that any action by Werner Heisenberg would have been effective in his parents' sad tragedy.

The internment of Werner Heisenberg and other German nuclear physicists at Farm Hall in 1945 was part of the Alsos effort. A 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 and by the USA.

Sam Goudschmit wrote three popular articles and a book about the Alsos mission, which served as a point of reference for later assessments of the German wartime nuclear program. His conclusions were that the German nuclear 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 Nazis that led to the exile and migration of notable scientists, the lack of vision of the German scientists, and, finally, because of the role of hero worship.

This specifically refers to Werner Heisenberg, who is portrayed by Sam Goudsmit as holding competent research groups, such as those lead by Ardenne and Diebner, in contempt. At the same time, Werner Heisenberg's own erroneous judgments and decisions, of which there were many according to Sam Goudschmit, were hardly openly questioned by the other German researchers. Werner 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 Nazi Regime.

Werner Heisenberg seemed far more worried about accusations that he had not understood bomb physics than about criticism of his general behavior during the Nazi era. It appears that Werner Heisenberg did not understand how his courageous behavior during the Nazi era, which he contrasted with the treason of emigration, could possibly be the subject of controversy.

2.9 WERNER HEISENBERG AND NIELS BOHR MEETING

Werner Heisenberg met Niels Bohr in September of 1941. The accounts about that meeting have been contradictory. Niels Bohr stated about the meeting that he remembers quite clearly that Werner Heisenberg was confident that Germany would win the war, and that Werner 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. Niels Bohr communicated this opinion to the UK and the USA, and this contributed to the decision to initiate the Manhattan project.

From a contradictory perspective, von Weizsäcker responded about this statement with: ‘‘Bohr’s memory is deeply mistaken.” He asserted that himself, Werner Heisenberg, and other German scientists had already stopped their work on an atomic weapon in September 1941, and that Werner Heisenberg had tried to persuade Niels Bohr that the USA and the UK should not build atomic weapons either, an option Niels Bohr allegedly refused to consider.

Niels Bohr agreed with Werner Heisenberg that no technical discussions took place, and that Werner Heisenberg refrained from pumping Niels Bohr for information.

2.10 ERICH BAGGE AND DIEBNER ACCOUNT

Erich Bagge (1912) was a theoretical physicist who had written his thesis with Werner 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 a diary which was later turned into a book.

Erich Bagge and Diebner state their views on the German nuclear project claiming that the crucial error was the Heereswaffenamt (HWA) or Army Ordnance Office, 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 (RFR) or National Research Council, and the appointment of the technical physicist Abraham Esau as the man in charge, sealed the fate of a possible German nuclear device, despite the fact that almost simultaneously the RFR was placed under Goring’s supervision.

Esau was followed later by Speer as head of the RFR but had nothing to do with these decisions since he became involved with the project only in the spring of 1942. There is no mention by Erich Bagge and Diebner of Werner Heisenberg’s encounter with Speer in June 1942, which according to Werner Heisenberg had been the pivotal meeting leading to Speer’s, and not the HWA’s, decision to assign a relatively low profile to the German nuclear project. This corresponds to Werner Heisenberg’s perception that he was the main figure in the project and he possessed the power to influence the cardinal decision to step up the project to industrial proportions.

Erich Bagge and Diebner maintained that Sam Goudsmit was incorrect 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 Werner Heisenberg in correspondence with Sam Goudsmit.

In their failed attempts to at least build a critical assembly, Erich Bagge and Diebner blamed the repeated Allied attacks on the Norske Hydro factory at Rjukan, the main source of heavy water (D_2O, HDO) for the German project, for their failure. Rivalry and disagreements about the subcritical assembly design between Werner Heisenberg’s group and Diebner’s also led to failure.

2.11 THE VIRUS HOUSE

In the book: “Virus House,” David Irving, a controversial British citizen author wrote about the German nuclear project. He got himself employed as a factory worker in Germany to perfect his mastery of the German language. This gave him access to the German documents, literature and publications about World War II seized by the USA. He used that capability to translate the documents and was able to publish several books about various aspects of the Third Reich, some of which became best sellers.

Even though an Anglo Saxon, his books reflect the German perspective about World War II. His first book describes the fire-storm bombing of Dresden. Another book: “The Virus House,” 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, as well as on interviews and correspondence with the main players.

The bombings, raids and sabotage of the Norske Hydro plant producing heavy water for the German nuclear project are described in detail. Paul Harteck is placed at the center stage instead of Werner Heisenberg. David Irving is of the opinion that the German nuclear scientists failure to “Fire Speer’s imagination with the possibilities of nuclear fission” as their greatest shortcoming. David Irving suggests that the German scientists “Given the funds, the men, and the materials, could certainly have produced an atomic bomb for Germany.”

David Irving blames the slow pace of the project on the fact that the project was directed by scientists and not by the military, as in the USA: “In short, the behavior of the German scientific leaders demonstrated that during war, science cannot be safely left to scientists.” He blames its failure on the emphasis on theory with direct reference to Werner Heisenberg, whom he implies intentionally sabotaged the project by slowing it down and directing it toward unpromising directions.

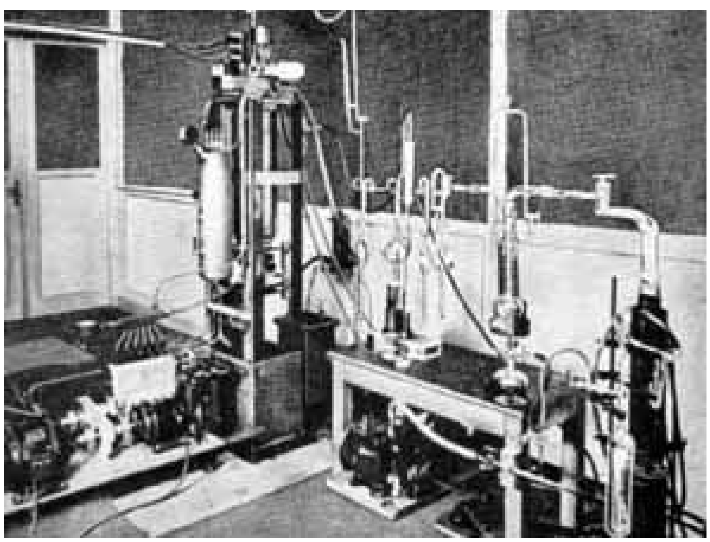

Figure 15. Ultra centrifuge laboratory experimental setup by Paul Harteck and Groth.

Werner Heisenberg’s commented: “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.”

David Irving follows Werner Heisenberg's version of the events, such as in his emphasis on incorrect measurements by Bothe of the graphite nuclear properties. The measurements were in impure graphite leading to a large absorption cross section for neutrons, which precluded its use as a moderator instead of heavy water in the German program, whilst it was used in the USA program. He describes the subsequent decision to continue with heavy water as a moderator. He sides with Werner Heisenberg's claims against those of Sam Goudsmit, that he had fully understood the principles of the atomic bomb.

David Irving discards the suggestion by many German scientists that they did not pursue the bomb because they did not want it on moral principles. He wrote 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."

2.12 WERNER HEISENBERG'S PERSPECTIVE

In his autobiography: "Der Teil und das Ganze" or "Physics and Beyond," Werner Heisenberg relates conversations between himself and some of his friends on the principal themes that occupied his mind. He states that he saw National Socialism as a catastrophe right from the beginning, which could only lead to the destruction of Germany. He relates a conversation in 1939 with Enrico Fermi, Sam Goudsmit, and other colleagues in the USA, in which he expressed no doubt whatsoever that Germany would lose the upcoming war.

Werner Heisenberg maintains that the German physicists had fully understood applied nuclear physics with regard to both reactors and weapons. Werner Heisenberg denies the fact that the German scientists basically told their military all they knew, even about fast neutrons. This implies that a German nuclear device was never built because the German politicians and military officials, based on information provided by their scientists, decided that it would not be possible before the end of the war, and allocated their limited resources to what they perceived as more promising concepts such as military airplanes and rockets.

Werner Heisenberg saw himself as the originator of the decision not to proceed in the direction of building a weapon which he subsequently placed it in the hands of Speer.

2.13 WERNER VON HEISENBERG'S MISCALCULATION

In the book: "Heisenberg and the Nazi Atomic Bomb Project: A Study in German Culture," P. L. Rose advances a thesis about the German nuclear project that was repeated a number of times.

He suggests that in 1940 Heisenberg incorrectly estimated or calculated the critical mass of a pure U^{235} device, obtaining an answer in the order of tons or thousands of kilograms, instead of the correct value of 15-56 kgs; depending on whether the assembly was bare or had a reflector/tamper as shown in Table 1.

His mistake was based on the misconception that a nuclear explosive reaction would only occur by creating a supercritical condition in a moderated assembly such as what he built with heavy water and natural uranium, instead of a fast assembly consisting of separated metallic U^{235} or Pu^{239}.

Table 1. Critical masses in kilograms of bare and reflected U^{235} and Pu^{239} cores.

	U^{235}	Pu^{239}
Bare unreflected core	56	11
Core with an infinite U Reflector / Tamper	15	5

This may have precluded him from recommending a serious effort on the atomic weapons problem. Rose suggests that this was the true reason why Germany failed to achieve the bomb, and it was a situation that the Werner Heisenberg version of events tried to conceal.

Rose's conclusion is that the explanation must be "Grounded in the peculiarities of the German mentality," in particular in the "German capacity for self-delusion, a trait exemplified to an astonishing degree in Heisenberg himself."

Rose confirms what Sam Goudsmit had said that as far as nuclear devices were concerned, the German scientists never got beyond some very basic insights and had not done any relevant experimentation. He concludes that the Germans knew that natural uranium was not suitable for a weapon, that one had to use either almost pure U^{235} or some higher transuranic element such as plutonium or neptunium, and that fission by fast neutrons should cause the explosion as opposed to the case of thermal neutrons in a moderated reactor.

However, they had not measured any of the relevant reaction cross-sections, had not isolated neither U^{235} nor Pu^{239} and had not considered how subcritical lumps should be brought together to initiate an explosion.

Rose exposes in detail an initial and erroneous Farm Hall argument made by Werner Heisenberg that led to an estimation of a critical mass of a uranium device in the order of tons instead of the kilograms level.

At Farm Hall, Werner Heisenberg arrived at a realistic value for the critical mass only in his lecture on August 14, 1945. Rose projects Werner 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} device was of the order of tons. Werner Heisenberg presented his earlier incorrect Farm Hall calculation without much thought, whereas his later correct argument was arrived at only after a week of intense thinking.

During the war, and certainly in 1942, the Germans did work with a perceived critical mass of 10–100 kg in the 1942 HWA report: "Energiegewinnung aus Uran." Werner Heisenberg's made a famous remark about the volume of an atomic weapon being of the size of a "pineapple" in June 1942.

Rose suggests that the 10–100 kgs must refer to plutonium. The 10–100 kgs seems a rough estimate, whose origin is unknown. 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 USA's side, this reasoning started with the work of Frisch and Peierls in England in March and April 1940. Even Enrico Fermi's estimates of the critical mass were initially wrong by orders of magnitude.

Rose gives an interesting account of various ideas on "reactor bombs," showing that at a certain stage Werner Heisenberg saw a nuclear device as an extreme type of a nuclear reactor, with highly enriched uranium and large quantities of moderator that went supercritical. This idea was subsequently pursued by some of Werner Heisenberg's associates. Werner Heisenberg did in fact study in detail the self-stabilization by the negative temperature coefficient of reactivity of ordinary nuclear reactors at high temperature.

Rose maintains that Werner Heisenberg was basically incompetent in spite of his established genius as a theoretical physicist. After all, weapons design is in essence an engineering problem, and Werner Heisenberg was neither an experimental physicist nor an engineer.

2.14 CAUSES OF FAILURE AND SUCCESS

Werner Heisenberg was an excellent theoretical physicist, but not a skillful project manager, an experimentalist nor an engineer. He was the wrong choice for leading the German nuclear program. He did not know how to correctly compute the critical mass of a nuclear device, and was not able to generate its outline. Werner Heisenberg's lack of leadership has been suggested as the main cause behind the failure of the German nuclear program. The significant lead time that Germany initially possessed, by the discovery of nuclear fission on its soil, was promptly lost.

The "hero worship" alluded to by Sam Goudsmit, worked against other members of the Uranium Club correcting Werner Heisenberg's faulty calculations and ideas. In addition, Werner Heisenberg's intensely competitive spirit and egocentrism led him to control much of the uranium and heavy water that the Germans possessed for his own experiments, even at times denying a fair share of them to Paul Harteck and Diebner; both of whose experiments were generally more promising and superior to Werner Heisenberg's ones.

In comparison, one can surmise that the USA's Manhattan Project successfully reached its goal, albeit after the surrender of Germany, because of the following reasons:

1. There was a strong initial drive by a dedicated group of scientists and physicists to get the project started. Key figures such as Albert Einstein lent their support with a letter to the USA President.
2. There was unconditional support from the USA and UK governments and adoption by the leadership and by the USA president.
3. The top management of the project was assigned to the military and engineers, and not just the envious and competing scientists, in the person of Brigadier General Leslie Groves, from the USA Corps of Engineers who had earlier built the Pentagon structure. These have the resources and technical experience to carry an armament project to its ultimate success.
4. Unlimited industrial resources such as from the DuPont Company and manpower were made available to the project in the USA.

5. There was an unprecedented concentration of brilliant and dedicated scientists working on the project under the leadership of Robert Oppenheimer at the Los Alamos National Laboratory, LANL.

In contrast, the German scientists did not trust, held in contempt, and in some cases despised their government officials; and vice versa. From the Farm Hall transcripts it is clear that some of the German scientists, including Werner Heisenberg, were afraid of ending up in a concentration camp in case they would start a project and then fail in achieving its stated goals.

Whether or not he was aware of the concept of a critical fast spectrum mass during the war, Werner Heisenberg correctly foresaw the massive industrial scale at which isotopic separation and heavy water production 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 it was seen to be unnecessary to win the war. In later years with the tide turning against Germany, the resources and human power were not available, and the task became impossible to achieve.

Overconfidence and arrogance, racism and religious fanaticism led to the emigration or expulsion of both non-Jewish and Jewish prominent scientists such as Shrödinger, leaving Germany with a reduced limited scientific base.

Werner Heisenberg and von Weizsäcker saw an open road to an atomic bomb based on the extraction of plutonium from a heavy water nuclear reactor burning natural uranium, but they were unaware of the monumental technological difficulties of actually extracting and separating this plutonium.

It was mentioned that von Weizäcker was mistaken in considering neptunium^{239} rather than plutonium^{239} or neptunium^{237} as possible weapon materials. Even if they had obtained them, they had no idea of the difficulties of bringing a plutonium bomb to super-criticality by the implosion process.

Some historians contend that Werner Heisenberg and his colleagues in wartime Germany had only a shallow understanding of the physics and technology of nuclear devices. This agrees with the conclusion of Allied intelligence work during and after the war. Werner Heisenberg and some of his colleagues were in no position to claim that during the war they had known how to build a nuclear device, let alone that they had refrained from doing so for moral reasons, as some of them conveniently claimed after the war.

2.15 DISCUSSION

There has been an unsubstantiated rumor that during the last months of the war, a small group of scientists working in secret under Diebner and with the support of the physicist Walther Gerlach, who became head of the uranium project, tried to build and tested a nuclear device. The allegation is that the German scientists run an unsuccessful test using chemical high explosives configured in a hollow shell in an attempt at initiating both nuclear fission and nuclear fusion reactions.

A great irony is that the German scientists, their politicians and their military apparently never tried nor realized the practical and industrial possibility of building a nuclear device, and concentrated their efforts on the pure scientific goal of achieving a self-sustained chain reaction. Werner Heisenberg apparently never took the possibility of building a nuclear device seriously and hardly tried. He was aware of the possibility of achieving criticality in a thermal-neutron moderated assembly, but not in a fast-neutron spectrum assembly. He expended a substantial effort to achieve criticality in a moderated subcritical assembly to impress the Allies in future peace time, thereby hoping to secure Germany's physics and his own personal leading role in it. Through rivalry and misconception he hindered the effort of other German scientists such as Diebner.

Another irony was that the atomic bomb developed by the USA and meant to be used against Germany, could not be used against it any more after its surrender, and was targeted instead against Japan. Yet another irony is that Germany's dominance over Europe repeatedly failed through military means, but subtly succeeded within the economic realm of the European Union (EU). With a powerful manufacturing base and a vast export capability, Germany follows the example of the British Empire in dominating its previous colonies through economic and political means, rather than by military means. This is achieved by holding and controlling the sovereign and private debt of the European GIIPS quintet of economically depressed countries of Greece, Ireland, Italy, Portugal, and Spain; as well as France.

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