COMMENTARY

Nuclear Earth-Penetrators: a Dangerous Fantasy

A. DeVolpi

As made clear by Frank von Hippel's insightful analysis in the July issue of *Physics and Society* ("Does the U.S. Need New Nuclear Weapons?"), the recently disclosed U.S. strategic posture review reveals an unyielding dependency on a nuclear fantasy: the ill-advised notion that atomic weapons can do useful things that conventional weapons can't. It is worrisome that, according to foreign intelligence reports, nuclear weapons of various types were moved close to Afghanistan after the 9/11 atrocity.

To reinforce Von Hippel's point, I would like to add some specifics about earth-penetrating nuclear weapons (EPNWs), especially with regard to local "collateral" damage and distant fallout, both of which are likely to create far more unfavorable consequences than acknowledged by EPNW advocates.

The earth-penetrating nuclear bomb (B61-Mod11) now in the U.S. arsenal could spray radiation over an area comparable to that at Hiroshima or Nagasaki. The B61-11 reportedly has a yield that can be "dialed" from 0.3 kilotons to 340 kilotons. At the upper end of that range, the explosion is about 20 times as energetic as the one at Hiroshima. Von Hippel quotes Los Alamos's Stephen M. Younger as saying that "some very hard targets require high yield to destroy them." In other words, there is at least one EPNW proponent who envisages the use of yields well above the kiloton range.

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Because of their subterranean objective, EPNWs must enter the ground before detonating. In contrast to air bursts (such as the ones over Japan), atom bombs that are exploded at or under the surface cause much more local and distant radioactive contamination. They vaporize earth and whatever else is there -- all drawn up in the mushroom-shaped cloud mixed with fission products. Much of this condenses and descends from the drifting cloud to become intense local fallout. As a result, the residual radiation effects can be serious.

With a surface (or subsurface) burst, the local and distant fallout have major public significance. When a nuclear fireball touches the ground, some 50 percent of the total residual radioactivity will be ejected into the air and stay suspended for a long time while it decays and disperses.

No EPNW burrows so deep that its explosion will be contained, as shown in a calculation by Robert W. Nelson, one of Von Hippel's students[1]. From Glasstone's *The Effects of Nuclear Weapons*, one can estimate that even a 0.1 kiloton EPNW burrowing 50 feet into dry soil would make a crater with a diameter of over 100 feet [2].

The "local" fallout would be deposited in a cigar-shaped "footprint" extending a distance that depends on the yield of the bomb and prevailing weather. With a 100-kiloton (fission) explosion and a 15 mile-per-hour wind, the radiation-deposit contours for 300 roentgens/hour, one hour after the burst, could extend about 20 miles [3] (an accumulated dose of 600 roentgens kills about half of those exposed).

Many of the people within a mile or two of such a large blast would receive a lethal or near-lethal dose from the prompt radiation. Fires would be widespread within three or four miles of the explosion, where they would probably constitute a greater immediate hazard than the radiation.

According to Nelson, the B61-11 is able to penetrate only about 20 feet in dry earth. He reckons a mushroom cloud radius of over a mile from a 5-kiloton explosion.

Near the low end of the dialable yield, at 1 kiloton, the 300 roentgen/hour contour is somewhat more than a mile, covering an area of one or two square miles [3]. Civilians in this zone who did not quickly evacuate or seek shelter would probably develop radiation sickness, with perhaps some deaths among those within a half-mile or so of ground zero.

A nuclear attack on deep bunkers could devastate an area considerably greater that the damage zone at Hiroshima. Many potential targets are unavoidably or deliberately set in populated areas; so nearby collateral damage (to civilians and the environment) could be extensive, depending on the yield of the EPNW.

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In addition, “distant” radiation fallout is intensified. Subsurface detonation of the EPNW in the U.S. arsenal could send fission products well beyond the borders of the target.

The atomic bombs used in Japan were detonated high in the air; so practically none of those casualties have been attributed to fallout. But the inevitable mushroom cloud from EPNWs would disperse wind-borne fallout not only on the surrounding population but also extending over adjacent nations and into the worldwide atmosphere. Although the distant fallout is unlikely to pose an immediate medical trauma, it tends to be an unacceptable hazard in the public’s perception.

While local fallout normally fans out to some tens of miles, the very fine particles (from a surface burst that creates an atomic cloud in the troposphere) remain suspended in air for days to years. In contrast to megaton explosions, which push the particles up into the stratosphere, nearly all the fine particles from atomic-bomb debris in the kiloton range will generally not rise above the troposphere; so they will remain there until eventually deposited around the world (by which time the fallout is no longer a significant health threat, though it would exceed regulatory and societal thresholds).

The distant fallout would largely consist of radioisotopes that tend to concentrate in bones and tissue: strontium-90 (which is chemically similar to calcium), cesium-137(similar to potassium), and iodine-131 (thyroid-prone).

One nuclear weapons test (“Simon,” 43 kilotons), detonated on 25 April 1953 from a tower at the remote Nevada test site, spread radioactive debris over half of the continental United States[4].

Regional aftermaths from exploded EPNWs could be calamitous. Refugees from the impact zone would be unwelcome because potential hosts would suspect (realistically or not) that their bodies, clothing, or possessions were dangerously contaminated. An agricultural embargo would probably ensue, even if the radiation levels were below reasonable health tolerances. Certainly nation re-building would be severely hampered by the presence of radioactive territories.

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New warheads with a lower explosive yield ("mini-nukes") could be devised, but that would

require revision of a 1994 U.S. law that prohibits their development. Also standing in the way are the Comprehensive Test Ban Treaty, the current moratorium on nuclear testing, and the Non-Proliferation Treaty (for which the U.S. pledged not to target non-nuclear weapons states with nuclear weapons). Although also a party to the African Nuclear-Weapons-Free Zone agreement, the U.S. in 1996 reportedly contemplated using nuclear weapons to destroy an underground facility in Libya [5].

In fact, one wonders if these legal constraints are part of the real reason that the Clinton and Bush administrations balked at signing on to the International Court of Justice. If nuclear weapons were to be used in violation of treaties and agreements, then the Court might hold U.S. administration officials personally responsible for crimes against humanity.

With all these drawbacks, using EPNWs to knock out hardened or deeply buried targets -- such as leadership bunkers, command centers, buried mobile-missile shelters, and weapon stockpiles -- would be not be practical either militarily or politically.

Nuclear earth-penetrators have no deterrent value -- they are designed expressly for war-fighting. In acquiring and deploying such weapons, the U.S. would be abandoning all pretense that its nuclear forces exist solely to prevent war.

Nor are they needed. Non-nuclear, high-explosive weapons can be effective. The Pentagon has some that can destroy hardened targets at depths of 50 feet and cause extensive structural damage at greater depths. Collateral damage from conventional warheads would be much less, since there is no radiation or fallout. Conventional weapons have been effective against Taliban/Al Qaeda sanctuaries in Afghanistan.

Collateral damage, distant fallout, and nuclear-weapon use potentially add up to counterproductive consequences of EPNWs. The message the Pentagon is transmitting to the world is that the United States is determined to pursue global dominance by threatening its opponents with nuclear retaliation, regardless of the outcome. The symbolic importance of a policy under which nuclear weapons are legitimated for warfighting cannot be overstated; and , if actually used, the concomitant local devastation and the emotion-rousing increment to global background radiation would surely trigger severe, world-wide political reaction.

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Heisenberg, Bohr and the atom bomb

Wolfgang Liebert

What happened in the autumn of 1941 in Copenhagen during talks between the two giants of science Niels Bohr and Werner Heisenberg? Did Heisenberg at that time want to convince Bohr to work with him towards the creation of a German atom bomb? Or did Heisenberg intend just the opposite, as he later claimed, namely convey the signal that the "Uranverein" was not striving to construct a German atom bomb?

A definite and clear interpretation of the matter does not seem to come into sight. It is no wonder then, that there exists no transcript of the talks, instead, only assumptions, myths, attempts to understand the problem and testimonies formulated later on by the erstwhile participants remain. But even if every spoken word was to have been transmitted to us, only the context of the war times, their past history and future perspectives could provide us with the necessary clues leading to our eventual perception of the subject.

The cause of the present debate is "Copenhagen", the brilliant play by Michael Frayn, in which he brings to life the meeting that took place between Bohr and Heisenberg. His vivid analysis focuses on the contents, context and the purpose of the meeting. At its German premiere in June 1999 in Essen the play was denied a large public response, but engendered rave reviews in London and on New York´s Broadway. Historians pounced on it and used it to fuel their continuing debate about the history of science, a debate that had its roots more within America than across the Atlantic. In February 2002, the Danish Bohr-archive published a number of unsent letters written by Bohr to Heisenberg from 1958-62. For the first time, thanks to these documents, we are offered a private glimpse of Bohr´s own interpretation of the situation. Because of this, the flames of the argument have been rekindled, not only in the American but also in the German press.

The spectrum of reactions Bohr´s letters have provoked is wide. It sways from one extreme of opinion to the other; on the one hand, it has been claimed that the letters have brought "nothing new historically" (Dürr) and on the other "that Heisenberg, during his visit, acted like a 'Herrenmensch' in the eyes of Bohr" (Hagner). The physicist and philosopher Carl Friedrich von Weizsäcker, who was also involved in the German nuclear program, is now repeating what he always reassuringly maintained, that: "We gave up building the bomb in 1941 and only wanted to built the reactor." This message was supposed to have reached the Allied scientists through Bohr. Helmut Rechenberg from the Munich Max Planck Institute of Physics backs up this theory: "All the listed works prove that the scientists involved were only working on an energy producing reactor." The scientific journalist Rubner counter-argues that "Heisenberg´s case is representative of the failure of the German elite during the 3rd Reich."

However, there remain a few facts that are hard to doubt and therefore should not be ignored. Nuclear scientists worldwide realised very soon after the discovery of nuclear fission in 1938 what many of them had suspected for a long time, that within their research lay an incredible potential for exploitation in different fields of technology. This concerned in particular the military sector, a fact that can be proved by numerous statements and newspaper articles published in 1939. With the outbreak of World War II, nuclear scientists around the world began

to seriously consider the possible development of a new type of weapon with enormous destructive powers. Directly after the invasion of Poland the German arms office (`Heereswaffenamt´) grouped together the remaining renowned German nuclear scientists who were not Jewish and therefore were not forced to emigrate. They were to form a top secret project of high strategic value, in which Heisenberg soon emerged as the intellectual head of the so-called "Uranverein" and later on became its official leader.

So, it cannot be denied that there was indeed a nuclear weapons program in Nazi Germany. Compared to the US efforts of the last three years of World War II it was quite small, but in 1942 it comprised research groups at nearly 20 scientific institutions and for the first few years of its existence it was ahead of the US program.

By autumn 1941 first results made clear that the creation of the bomb was feasible. The project of uranium enrichment had had a certain amount of success and the first small experiments striving for the construction of an(a) reactor were showing definite signs of progress. Thousands of elite soldiers secured the acquisition of uranium ore and the exploitation of the Norwegian Deuterium production plant. Weizsäcker´s claim, that the scientists involved in the project already knew before the talks between Bohr and Heisenberg in German occupied Denmark, that no atom bomb could possibly be created, therefore seems highly implausible. It was even Weizsäcker himself who, in a report of summer 1940 expounded that a fictive "Uranmaschine" would produce a transuranic element outstandingly useful for weapon building - later on known as plutonium. It would be comparatively easy to separate and only 10 - 100 kg of it would be enough to built a bomb. In this way, Weizsäcker very early on provided the knowledge that the way to the bomb can be paved by a plutonium producing reactor.

It was not until 1942, after an extensive report from the German Heereswaffenamt and two conferences in February and June of that year, in which a number of most prominent government and military figures took part, alongside the scientists concerned, that the preliminary decisions for the reduction of German interest into the project were taken. On the 4th of July General Field Marshall Gerhard Milch openly asked Heisenberg, who had reported with the cold rationality of a scientist: "How big does a bomb have to be in order to obliterate a city the size of London?" Heisenberg responded quite competently, referring to the active nuclear part of the bomb: "About the size of a pineapple." Further questions posed by the military concerned the parallel development of the program in the US and the time it would take to bring a weapons program to completion. Heisenberg correctly answered that a timespan of at least two years would be needed for the production of material within a reactor, due to the scale of scientific and technological enterprise it required.

The Minister of Arms, Albert Speer, offered the scientists financial support, to which they responded with the modest demand of a raise in their budget by several ten thousand Reichsmark. The decision-makers came to the logical conclusion that this project was not going to be one which would decide the outcome of the war . The raise was however accorded, but with the result of a "first class state funeral", as Erich Bagge, another nuclear physicist involved in the project, put it. At the same time, the Allied parallel project overtook its German opponent and from 1942 on the USA built up an official research and industrial program, larger than anything that had ever taken place before, with the single goal of developing a nuclear weapon.

Open ended questions still remain. For example, why was the development of a bomb through uranium enrichment (as it was done in the US, leading to the Hiroshima bomb) not enforced? Was the true cause of this the rivalry between the different groups of German scientists and the tactical moves propounded by them? In this way, was the seemingly more 'elegant' path, namely the use of plutonium (which led in the US to the Nagasaki bomb) pushed to the fore? Or was this decision based on wrong calculations, which predicted the critical mass of the uranium at too high a level? This mistake would have led the scientists to believe that there existed a number of insurmountable technical obstacles. Or was the decision caused by the setbacks due to the bombing by the Allies of the early test areas? Was it just a question of incompetence on the part of the political decision-makers (or of the physicists) themselves? Did Heisenberg's group of scientists want to avoid being quartered in barracks for the rest of their research time like the colleagues in the V2 rocket program? Or, as some people still hope, was there more to their actions than meets the eye, and were they in fact hatching a clever plan to foil the whole nuclear weapon program? In any case, the German project was put on the back burner and carried on quietly. The whole situation was hanging in the balance and the German scientists were teetering on the brink of tipping it and building a bomb for Hitler. Thank God they did not.

Many further aspects are still to be considered. Among these, the ongoing general feeling of the Germans in Autumn 1941, that victory was almost certain, or the role of the hard-liners (like Bagge, Diebner or Harteck) within the German program who were staunchly in favour of the bomb. The need for justification weighed heavily upon the shoulders of Heisenberg and his theoreticians, who, on the one hand, tried to reinstate their so-called 'jewish' and therefore intolerable quantum physics against the fierce accusations of the supporters of the "Deutsche Physik", on the other hand, however, they wanted to use the importance of their science with regard to the war as an argument. Heisenberg´s role in the "Kulturpropaganda" of the 3rd Reich in the occupied countries also needs to be put into question.

In the end it seems that the nuclear scientists of the war do not set a good example with regard to dealing responsibly with the process of discovery and way it can be shaped by technical and political means. This represents the actual core of the debate, of which the meeting between the former friends and colleagues Heisenberg and Bohr could be seen as its culmination point. The key question, the one which reveals itself to be relevant to us today, lies hidden beneath the surface of what actually happened: How far should research with potentially dangerous consequences be allowed to go before it gets out of hand? How much do we have to take national power relations and the outside influence of international politics into account? To what extent must the perception of foreseeable consequences influence the way a research project is conducted? From this point of view, this type of critical question must also be asked of the participants of the British-American nuclear weapons project. Why did only one of the members of the Manhattan project (Joseph Rotblat, winner of the Nobel Peace Prize in 1995) leave the program in 1944 after the Allied secret services were able to give the all-clear that the German nuclear weapons program had not come to significant results? The study of the history of science can and should help us to answer these complex and underlying questions , leading to a better understanding of today's science.

The parable of "The resistance of German nuclear scientists", which is told with good intentions by Robert Jungk in his book "Brighter Than a Thousand Suns" has now, in any case, been obliterated by the publication of Bohr's texts: "You related how in the preceding years you had devoted yourself almost exclusively to this question [that of nuclear weapons] and were quite certain that it could be done, but you gave no hint about efforts on the part of German scientists to prevent such a development." Doubts about the true resistance of the German scientists had begun to grow already in 1993 after the publication of the transcripts of the bugging in England of interned German scientists in 1946.

But inconsistencies still remain, just like they do with the question of nuclear weapon plans in the young Federal Republic of Germany. In this situation however, Heisenberg, Weizsäcker and a number of other nuclear scientists knew exactly where they stood. With the "Göttinger Erklärung" of 1957 they refused publicly and explicitly Chancellor Konrad Adenauer and his Minister of Defence Franz Joseph Strauss their possible participation in a nuclear weapons program. However, their willingness for the further and unconditional development of "civil" nuclear technologies did everything but hinder the fact that at least all material-technological prerequisites for the possible production of an atomic bomb were also prepared in Germany. Once again, the acquisition of plutonium was the main focal point.

The dilemma must however have been clear for a long time for all people involved: Civil-military ambivalence is inherent to nuclear science and technology. It is exactly this matter that deserves true analysis and interpretation. Where is it impossible to draw a clear line between civil and military aspects and where an how can this be made possible? Which intentions are the driving force of those scientists, politicians and economists who take part in the projects? Which consequences are we faced with? Which alternative pathways are seriously taken into consideration in order to avoid potentially dangerous developments? Which of these still exist today? In the meantime, these problems are not only those of the historical figures Bohr and Heisenberg, but now they have general importance in our everyday dealings with the world of science and technology.

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Copenhagen in Europe:
Why not the same debate as in the US ?

Jean-Jacques Salomon

Why is it that the production of *Copenhagen* in New York did not lead to the same intense discussions in London or Paris? The reaction in Paris was, as in London, extremely positive to the play as much as to the actors, the three outstanding and superbly led by the same director as in London: a real theatrical success. For those who didn't know anything about the story of the building of the atomic bomb, it was the discovery of some of the ethical issues at stake in a piece of history which precipitated not only the end of World War II, but also opened up a New World (as qualified by the title of Hewlet and Anderson's account **please reference this**) doomed to live for ever under the threat of a nuclear warfare. And for those (scientists, political scientists, journalists, etc.) who were aware of this story and its strategic stakes, it was a theatrical show whose reconstruction of the dramatic dialogue between the two geniuses, the master and his disciple, could indeed be challenged in some parts, but did stand with great talent on its own legitimacy. By the way, at the performance I attended, the theater was full (most likely with reservations organized by scientific Unions) of members of the National Center for Scientific Research (CNRS, the public institution supporting basic science) who obviously discussed, at the end, the story they were confronted with. But, apart from the most favorable reviews in the press and the media, no debate took place as intensely as in the United States.

I personally, knowing the story, having read almost all the literature and being familiar with many of the actors who took part in The Manhattan Project and having written often about it (to start with, *Science and Politics*, MIT Press, 1973), I certainly had questions about the real motivations of Heisenberg's visit that Frayn's play did not really answer or clear in my mind, but I simply considered that the author of a play is absolutely free to write or rewrite history as he wishes or can — granted that it is a real good piece of literature (which is indeed the case, in my mind). Even if this story is still close to us, with some survivors still, there is no reason at all to reproach the author for presenting (or occulting) the various possible explanations of what the real purpose of Heisenberg's visit to Bohr was. The value of good playwriting is certainly not its historical accuracy. Moreover, how far the play gave a "real" historical account may appear in the future as derisory as to try to know, between Shakespearean specialists, whether the reasons expressed on the stage by Henry the IVth to call to the Crusade were exactly those of the "real" king, or whether he "really" died in "the room called Jerusalem".

All the more so since, when the play was produced in Paris and later on in New York, Bohr's famous letters were still supposed not to be released before 2012. The unsent letters were the mystery that justified Frayn to think of writing the play — one of its basic themes being the difficulty, if not the impossibility, to determine why Heisenberg made his visit, in spite of all that was said later on by Heisenberg himself, and, in particular, von Weizsäcker, or their disciples and the various and divergent historians who wrote about it. And now that the unsent letters are no longer a mystery, it is fair to acknowledge that — except for very small points not really new, but

confirmed — Heisenberg's visit remains a mystery, so much that Frayn was well advised and gifted to organize his play around its "debateability".

What may appear as new doesn't help to understand what Heisenberg "really" tried to convey to Bohr: alert him, spy upon him, or even threaten him; but it underlines how deeply Bohr was shocked by Heisenberg's conviction (in September 1941) that Hitler would win the war, by learning "that everything was being done in Germany to develop atomic weapons", that Heisenberg "had spent the last two years working more or less exclusively on such preparations" and that "it was quite foolish to maintain the hope of a different outcome of the war". How could the patriot Bohr, already involved in the Danish Resistance, tolerate Heisenberg's appeal to "cooperate" (which had no other meaning but "collaborate") with a triumphant Germany ?

The number of drafts of these unsent letters show how precisely Bohr tried to memorize again and again what was said (or not said) during Heisenberg's visit, and how deeply he felt deceived by Heisenberg's and von Weizsäcker's explanation given to Robert Jungk (who later on said indeed that he had been manipulated by von Weizsäcker). At the same time Bohr admitted, with some fair indulgence for somebody he considered almost as his son, that he understood that "it may be difficult for you to keep track of your thoughts and express yourself at the various stages of war, the course of which changed as time passed so that the conviction of German victory gradually had to weaken and finally end with the certainty of defeat". Of course, one year and a half after the Copenhagen visit, Stalingrad had fallen, the United States had entered the war, the final fate of the Nazi regime was obvious and the German program for an atomic bomb was almost stopped for the sake of more urgent and feasible priorities such as von Braun's missiles. In the paradise or the hell where *Copenhagen* takes place, this "dialogue of the dead" is not and has not to be directly affected by "the various stages of war the course of which changed". It is revealing that it is Bohr's wife, Margrethe who, like the chorus in Greek tragedies, always calls the two men to go back over facts and dates.

But then the real question remains: why such a debate in the US — and almost as intense in Germany — but not in France or England? The answer may simply be that what was *then* at stake — a German victory as expected, if not wished for, by Heisenberg thanks, perhaps, to the availability of Nazis atomic weapons, as opposed to the final bombing of Hiroshima and Nagasaki, the result of an American program mainly meant to precede the German nuclear threat —*was out of European hands*. Some have thought (Goudsmit, for instance, who led the Alsos mission) that the Manhattan Project was a race for the bomb with Heisenberg himself. And when Goudsmit discovered that von Weizsäcker's laboratory in Strasbourg hadn't gone very far and that Heisenberg's reactor had never worked, the Alsos mission was like Don Quixote fighting the windmill — difficult to digest. Yet, from then on, the advice to control or decide on the launching of the bomb was no longer (if it ever was) in the realm of British or French scientists' influence. Remember that Joseph Rotblat, who later became Secretary General of the Pugwash conferences and won the Nobel prize for peace, left the Manhattan Project precisely after the German defeat. Launching the bombs on the Japanese cities was an exclusively American decision (although of course, many ex-Europeans in exile took part in their building and some tried desperately to affect the decision, such as Szilard and Franck).

The core of the American and German debate resides in what Frayn claims about the "epistemology of intentions" which is what the play is about ("Copenhagen Revisited", *The New*

York Review of Books, March 28, 2002, p. 23). His Heisenberg is saying that "Bohr will continue to inspire respect and love, in spite of his involvement in the building of the Hiroshima and Nagasaki bombs, and he himself will continue to be regarded with distrust in spite of his failure to kill anyone". By the way, if this doesn't change what the play is about and its value, it is one example of Frayn's distortion of history. Actually, Bohr didn't play any important role in the building of the bombs; on the contrary, suspected after his talk with Churchill to be communist and excluded from Los Alamos, if he inspires respect it is because of his very early and continuous fight for an international agreement against these weapons. And Heisenberg ? True, he didn't kill anyone — not more, not less than Bohr. He was not at all a Nazi and he was effectively threatened by death in a SS newspaper denouncing him as a "white Jew" who, following Einstein's theories, didn't trust the "pure aryan physics" of Stark and Leonard. But, true again, he was protected by Himmler himself against the SS, not necessarily because he was a great scientist, but perhaps because in a simpler fashion his father was a friend of Himmler's father, both having been teachers in the same elementary schools and their mothers were very close friends. And not only did he take part in the building of German weapons systems, he also considered that Hitler's offensive against Russia was justified and his nationalism was such that he didn't see, at least up to the end of 1941, any problem in Hitlers' victory against the Allies.

Whatever Heisenberg's motivations were, he didn't come to Copenhagen to warn Bohr on the ethical dimensions of the nuclear venture in such a way that it should or could refrain the Allies from going ahead. Between the two extreme interpretations — converting Bohr to the rightness of collaborating with Germany, trying to find out what Bohr may have known of the Allies' program — there are still many other possible interpretations that Frayn's play exposes very well without exhausting the mystery. Obviously Bohr has been much more angered in his unsent letters than in Frayn's play: time and "the dialogue of the dead" make great minds more indulgent to each other's intentions. But one could also consider their intentions in a very different manner: for instance, that the real hero was Bohr, patriot, already part of the Danish underground, definitively opposed to the Nazi domination on Europe, convinced already in September 1941 that Hitler could not win even if he was then close to occupying Moscow, and who helped the Danish Jewish community to escape to Sweden just before he himself left his country, whereas Heisenberg led — after all — the German nuclear program, believed that Hitler could win and that destroying communism was the most urgent target, and didn't show much concern as to the concentration camps and what they implied.

This is where, it seems to me, the "epistemology of intentions" has different meanings in the US and in Germany, but it presents no reason to mobilize the other Europeans towards the same *committed* discussions. There were of course French scientists who took part in the Manhattan Project, notably the group of F. Joliot-Curie's disciples who worked in Montreal on the heavy water reactor. The last survivor, Bertrand Goldschmidt, died this year; he could have explained, as he did in many books, how this part of the Project was considered as less important and not well supported by the Americans. All were even more excluded than their British counterparts from the decision-making process which led to the atomic bombing of Japan. This is already one factor which may explain that the controversy raised by *Copenhagen* was not part of their personal involvement as it was for the other European scientists (German, Hungarian, Dutch, etc.) who were directly

associated to the building of the bombs and who had a say, although it was not taken into account by General Groves and President Truman, on the decision to launch the bombs on Japan.

From the American standpoint (including, of course, the European scientific émigrés), Heisenberg was *anyway* guilty of two sins. First, invited to stay when he visited the US in 1939, he decided to come back to Germany and thus, as in Albert Hisrchman's enlightening analysis in *Exit and Voice*, he couldn't appear as disapproving the regime and became it's "objective" accomplice — which he was, no doubt, at least up to 1942. And thus his visit to Bohr has for ever raised in some American's eyes the suspicion that he could have won the race with them — *if* so many factors beyond his will or good faith had not interrupted, after two years, the German effort in this field in which he was then, without contest, the most competent, and the main, leader.

Secondly, and more important, thanks to von Weizsäcker's self-aggrandizing propaganda transmitted by Robert Jungk, the claim that Heisenberg has been spared ethical dilemma is even much stronger than in Frayn's play. Here, we are very far indeed from Oppenheimer's sense of guiltiness when he told Truman, following Dean Acheson's interview, that he "had blood on his hands" — and was immediately considered by the President as a "damn fool" (*New York Times*, 0ctober 11, 1969). In von Weizsäcker's version, which he never ceased to defend, the German nuclear scientists kept their hands as clean as possible, as for instance when he wrote in his *Bewussteinwandel* that "History will record that the peaceful development of the uranium engine was made by the German under the Hitler regime, whereas the Americans and the English developed this ghastly weapon of war." It was, no doubt a ghastly weapon and the hydrogen developments which did flow under the Cold War have become even more evil (as Rabi said). Yet, speaking of the "peaceful" nuclear activities of the German physicists under Hitler may appear to their American counterpart as a provocation, as if such "peacefulness" could occult what was the cost in terms of horrors and victims of the Nazi regime in Germany as well as in the occupied European territories. And, by the same token, what was the cost of the Japanese horrors and victims in Asia.

Such an interpretation tends of course to obliterate what Bohr underlined in his unsent letters, namely that he and Heisenberg "had to be regarded as representatives of two sides engaged in a mortal combat". In "the dialogue of the dead", in paradise or hell, this mortal combat appears as belonging to another world and time. Certainly not for the Americans (survivors or successors of the nuclear complex) concerned by "the decision to launch the bombs": if, as Oppenheimer said, "physics has known sin", von Weizsäcker's version tends to imply that such sinfulness is exclusively on the American side — and if not at all on the German one, at least in such a way that one could forget or forgive what were Hitler's crimes and intentions.

Let me underline that few Europeans, French or British, would not consider that such a interpretation is unbearable, and if they would be consulted, as I was by *Physics and Society*, I am ready to bet that all would conclude that any version presenting Heisenberg's motivations as "innocent" or "neutral" in September 1941 is ludicrous. But the debate is not *theirs, if what is basically at stake* is not the building of an atomic bomb, but the moral decision to drop it. It remains that von Weizsäcker's argument seems to exclude by definition that, if Hitler or Himmler or Speer would have taken more seriously the program led by Heisenberg — and if they would have had available the material and technical resources to build the bomb, the fate of Europe might have been quite different. In such circumstances, could Heisenberg have been in position to resist such a

pressing national mandate, or even to resist (as Oppenheimer said of the building of the H bomb) the "pleasure" to find such "technologically sweet" solutions? Nobody knows the answer, and if *voicing* in a totalitarian regime to the point that one challenges its orientations implies that one is ready to martyrdom, it hardly could be said that Heisenberg was of such stature. Bohr says in his unsent letters that "there was no hint on your part that efforts were made by German physicists to prevent such an application of atomic science." And there is no proof that Heisenberg and his colleagues did, or even attempte to, torpedo the nuclear project: their discussions when they were prisoners in Farm Hall don't lead at all to such a conclusion.

The very fact, it seems to me, that nobody can demonstrate that Heisenberg made any effort to prevent work on weapons is enough for the American side to balance their possible sense of guilt against the good conscience of the German scientists who claimed after the war that they avoided — thanks to Providence —sharing the same ethical burden. I may add that this American passionate sensitiveness is best illustrated by the reproach made to the play that it did not put a greater stress on the persecution of the Jews. In particular, Lawrence Rose, "the most outspoken critic of Heisenberg and (the) play" as Frayn himself noted in *Copenhagen' Revisited*, who "managed to detect in it a subtle revisionism": since the calculation of the critical mass (which persuaded the Americans of the possibility of building a nuclear bomb) was made by Frisch and Pierls, German and Austrian Jewish émigrés in Britain, the Heisenberg comment in the play on this "historical irony" implies to him that Frayn attempted to blame "the Jews" for the bomb's invention. Really, this looks to me as stupid as the fact that any criticism to day of Israel's policy, even coming from a Jew, is immediately considered as an act of anti-Semitism!

Moreover, it tends to ignore (as usual in most American literature on the subject) the following historical facts: already in May 1939, before the beginning of the war and thus much before the Maud Committee's conclusions were transmitted to the US, F. Joliot-Curie's team had deposited within the CNRS three patents - one on nuclear energy production, two for the building of an atomic bomb; already in the early months of the war, a program was launched for a reactor based on heavy water; that Francis Perrin correctly calculated the necessary critical mass; and that they had already thought of preparing a site for an experimental explosion in the Sahara. It was indeed the French team which alerted their British colleagues to create the Maud Committee (see for instance, in addition to Bertrand Goldschmidt's personal accounts and Margaret Gowing's history of "the atomic relations between the Allies", Spencer R. Weart, *Scientists and Power*, Harvard University Press, 1979, translated into French as *The Great Adventure of the French Atomic Scientists* : *Scientists in Power*, Fayard, Paris,1980).

But then who today is in a position to judge Heisenberg? As Bohr was a Danish patriot, Heisenberg was a firm nationalist. That may be enough to explain that if he chose not to exit, it was in order to save the cause of German science against the pseudo aryan physics and, after 1942, to prepare himself to help rebuilding Germany after the Nazi collapse. We simply don't know, in spite of the release of his unsent letters, whether Bohr, shocked and angered by Heisenberg speaking of collaboration, misunderstood his intentions or understood them too well. How and who can judge today those who have chosen to stay in a totalitarian regime rather than to emigrate, even those who have — more or less reluctantly, as was Heisenberg's case — worked for it?

Again Albert Hirschman's *Exit and Voice* has definitive conclusions on what it costs to try to change *from the inside* a regime that one contests or even claims to fight. Here "the epistemology of

intentions" is inevitably confronted with *objective roles* which open the door to endless interpretations. Who can decide, following Shakespeare, that Caesar was or wasn't an honorable man? Beyond this debate, clearly restricted between Americans and Germans scientists — if one takes for granted that they raced at a certain stage of the war for the same objective — there cannot be a definitive answer. A close friend of mine, a brilliant French physicist, has concluded, after having much enjoyed Frayn's play, that the mystery of Heisenberg's visit remains and will remain in a quasi- Heisenberg fashion an "undecidable affair" that nobody can either clear nor judge. Which means that there is still room for another excellent play.

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The Role of German Physicists in WWII Science

Harry Lipkin

I keep being amazed at the stuff written about the role of Heisenberg and German scientists during World War II. The emphasis on the bomb, which played no role during the European war, obscures the enormous efforts of American physicists on the military R&D during the war which had an enormous impact, and the fact that there was no counterpart in the German war effort. The German government did not appreciate the fact that scientists could contribute usefully to the war effort; the Americans and British did. Nikolaus Riehl, who directed the German uranium production plant and was grabbed by the Russians immediately after they entered Berlin to do the job for them, states in his memoirs that "Hitler and all the men around him were intellectually incapable of understanding how so much energy could come from anything as small as an atom. Rockets they understood because they made noise."

I was at the Radiation Lab at MIT working on microwave radar where many hundreds of physicists, perhaps nearly a thousand, were working fulltime on the war effort, including top physicists like Rabi, Alvarez, Purcell, Bloch, Dicke, Schwinger, Uhlenbeck, Goudsmit and more. Even Hans Bethe spent several years at the Rad Lab working on radar before moving to Los Alamos. Their counterparts in Germany evidently did no war work at all. While our microwave radar annihilated the German submarines in the Atlantic, the Germans never knew what hit them; they did not realize that radar was feasible at microwave frequencies and never thought of recruiting their top scientists to try to help them figure out why they were losing submarines. And Luis Alvarez developed the GCA which enabled planes to land in bad weather and incidentally invented the air controller which is now the crucial feature of our ability to schedule commercia flights in all kinds of weather.

Heisenberg was free to work on a nuclear reactor, when the authorities knew that it would not produce any useful weapon during the European war, and devote a large part of his time to

cosmic ray resarch and other activities. In the U.S. anyone with his ability would have found a niche in the war effort.

Has the Forum on Physics and Society ever looked into the real activities of science during World War II and this basic asymmetry between the German and Allied approaches?

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Creating a New Past: Heisenberg and Radioactive Decay

Alvin M. Saperstein and Betsy Pugel

One of the lessons quantum mechanics draws from the familiar phenomenon of radioactive decay is the nuclei's lack of memory. Each nucleus is "unaware" of whether it has just arrived in an excited state or whether it has been in that state for a very long time. In short, a lack of a physical memory means that *individual nuclei have no past*. Eyewitness accounts of events are often clouded by the associative nature of human memory, which biases the account, calling into question what we call "the past." How similar is the biased nature of eyewitness accounts to the nuclei's lack of memory? Without delving into issues of the quantum nature of consciousness, which often leads to misrepresentations of physics, this commentary attempts to raise the following questions: Can an analogy of the memory of nuclei be applied to the manner in which we remember events? Can *people have no past*? Can deliberate absence of past explain the actions of those German physicists, who having tried but failed to make “the bomb”, senselessly groped in attempts to grasp the moral high ground over those individuals and nations who had created and used nuclear weapons in WWII, namely, the United Kingdom and the United States?

The play, *Copenhagen* recently reminded many of us of such analogies between physics and human behavior. *Copenhagen* explores the *post-mortem* attempts by Danish Niels Bohr, his wife Margarethe, and German Werner Heisenberg to reconstruct what happened to them at their infamous September 1941 meeting in the Nazi-occupied Danish capital. The author, Michael Frayn, built upon the “Complementarity Principle” of Bohr and Heisenberg’s “Uncertainty Principle” to reveal his characters’ inability to understand or communicate with each other and to attain perspective on their place in the world. This is best shown by Margarethe, who, at one point, comments to Heisenberg that he sees everything in the world but himself.

The play emphasizes the inability of the two physicists to communicate with each other. Also evident, though not emphasized by Frayn, is Heisenberg’s inability to communicate with his own past, his lack of memory. This is best exemplified in discussions between Heisenberg, Weisacker and a group of other Nazi and "non-Nazi" German “bomb physicists”, discussions secretly recorded by British intelligence while the German physicists were

confined at Farm Hall, an English manor house, at the end of the war in Europe. This inability to assess their past actions allows Heisenberg and his colleagues to create a new past whenever needed. Unlike some religious converts who, although "born again", are well aware of their own past "sinful" life as they awaken to a new life of grace, these fine physicists seemed oblivious to their "real past" (as observed by others) as they went about deliberately creating a "new past."

The lack of memory is also apparent in the attitudes of the many German scientists, who, if kindness is afforded to their actions, could be described as "turning a blind eye" to the horrors which took place in Nazi Germany, continuing to work on weapons research for the sake of its intrinsic physics interest and their intense nationalism. They apparently could not understand the post-war repugnance with which they were greeted by their former scientific colleagues of pre-war days. Their actions illustrate the associative nature of the human mind, the ability to disregard the “excited state” that one is in and function at a normal level of operation.

This disappearance of "real past" has been demonstrated by several historians and physicists including: Paul Lawrence Rose in *Heisenberg and the Nazi Bomb Project: A Study in German Culture*; Jeremy Bernstein in *Hitler’s Uranium Club*, which contains his commentary alongside the recorded Farm Hall diaries. Not only are the members of this distinguished group of German physicists unaware of their moral past, they create for themselves a new history of physics and a new understanding of physics with no apparent memory of their previous activities or accomplishments in the same field of research. In spite of a great deal of evidence to the contrary, this group created, post-war, a past in which they understood, from the beginning, the physics of "the bomb". They could have built a bomb if they so desired, but they did not so desire! The contrary evidence of bungled and misdirected research includes their own writings in German physics journals and Army Weapons Bureau reports as well as recorded statements to scientific and political meetings.

In a world of resurgent tribalism, it is appropriate that the play forces us to contemplate the tribal loyalties of some, otherwise very rational, German physicists. They remained in their German “motherland” to "protect" the next generation of German physicists. Despite the evident Nazi destruction of their beloved science, Heisenberg and his colleagues refused to emigrate, considering themselves "non-ideological" and "non-political", as they worked on weapons research for the German military establishment. This should be contrasted with those many German physicists who left Germany to struggle against such tribalism and support more humane goals.

Much of literature has been devoted to pondering about the difficulties of human communication: one facet is the difficulty of eyewitnesses achieving mutual agreement on observed events. In addition to, Frayn's Copenhagen, the Japanese movie Rashomon comes immediately to mind. Here, we are raising concern with the failure of single individuals to communicate with their own pasts. It would be very interesting to have a Frayn develop a play about people of formidable intellect, but with no past - a human analogy to our understanding of radioactive decay. The resultant physics play might be called “Berlin” rather than “Copenhagen”. (Perhaps such plays, without a physicist “hero”, have already been written?). Hopefully, it would attract the attention of the physics world as well as of the non-

scientist world, all of whom would recognize that the human failures and strengths dramatized in such a play would be characteristics not only of the physicist, but of the human being.

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