How close were the Nazis to developing an atomic bomb? The truth is that National Socialist Germany could not possibly have built a weapon like the atomic bombs dropped on Hiroshima or Nagasaki. This was not because the country lacked the scientists, resources, or will, but rather because its leaders did not really try.

They were certainly trying to win the war. And they were willing to devote huge amounts of resources to building rockets, jet planes, and other forms of deadly and sometimes exotic forms of military technology. So why not the atomic bomb? Nazi Germany, it turns out, made other choices and simply ran out of time.

A NUCLEAR PROGRAM IS BORN
In January of 1939, the German chemists Otto Hahn and Fritz Strassmann published the results of an historic experiment: after bombarding uranium with neutrons—neutrally charged particles—they found barium, an element roughly half the size of uranium. Their former colleague Lise Meitner, who a few months before had been forced to flee Germany and seek refuge in Sweden, and her nephew Otto Frisch realized that the uranium nucleus had split in two. These revelations touched off a frenzy of scientific work on fission around the world.

The German "uranium project" began in earnest shortly after Germany's invasion of Poland in September 1939, when German Army Ordnance established a research program led by the Army physicist Kurt Diebner to investigate the military applications of fission. By the end of the year the physicist Werner Heisenberg had calculated that nuclear fission chain reactions might be possible. When slowed down and controlled in a "uranium machine" (nuclear reactor), these chain reactions could generate energy; when uncontrolled, they would be a "nuclear explosive" many times more powerful than conventional explosives.
During the last months of the war, a small group of scientists working in secret built and tested a nuclear device.

Whereas scientists could only use natural uranium in a uranium machine, Heisenberg noted that they could use pure uranium 235, a rare isotope, as an explosive. In the summer of 1940, Carl Friedrich von Weizsäcker, a younger colleague and friend of Heisenberg's, drew upon publications by scholars working in Britain, Denmark, France, and the United States to conclude that if a uranium machine could sustain a chain reaction, then some of the more common uranium 238 would be transmuted into "element 94," now called plutonium. Like uranium 235, element 94 would be an incredibly powerful explosive. In 1941, von Weizsäcker went so far as to submit a patent application for using a uranium machine to manufacture this new radioactive element.

Researchers knew that they could manufacture significant amounts of uranium 235 only by means of isotope separation. At first German scientists led by the physical chemist Paul Harteck tried thermal diffusion in a separation column. In this process, a liquid compound rises as it heats, falls as it cools, and tends to separate into its lighter and heavier components as it cycles around the column. But by 1941 they gave up on this method and started building centrifuges. These devices use centripetal force to accumulate the heavier isotopes on the outside of the tube, where they can be separated out. Although the war hampered their work, by the fall of the Third Reich in 1945 they had achieved a significant enrichment in small samples of uranium. Not enough for an atomic bomb, but uranium 235 enrichment nonetheless.

Uranium machines needed a moderator, a substance that would slow down the neutrons liberated by chain reactions. In the end, the project decided to use heavy water—oxygen combined with the rare heavy isotope of hydrogen—instead of water or graphite. This was not (as one of the many myths associated with the German nuclear weapons effort had it) because of a mistake the physicist Walther Bothe made when he measured the neutron absorption of graphite. Rather, it appeared that the Norsk Hydro plant in occupied Norway could provide the amounts of heavy water they needed in the first stage of development at a relatively low cost.

The Norwegian resistance and Allied bombers eventually put a stop to Norwegian production of heavy water (see Norwegian Resistance Coup and See the Spy Messages). But by that time it was not possible to begin the production of either pure graphite or pure heavy water in Germany. In the end, the German scientists had only enough heavy water to conduct one or two large-scale nuclear reactor experiments at a time.

Heisenberg and his colleagues did not push as hard as they could have to make atomic bombs.

Heisenberg used this diagram during a secret lecture in February 1942. On the left is a schematic diagram of a "uranium machine" (nuclear reactor); on the right is a schematic of a nuclear explosive, either uranium 235 or plutonium. Enlarge

Photo credit: Courtesy Mark Walker

NEARING A NAZI BOMB

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By the very end of the war, the Germans had progressed from horizontal and spherical layer designs to three-dimensional lattices of uranium cubes immersed in heavy water. They had also developed a nuclear reactor design that almost, but not quite, achieved a controlled and sustained nuclear fission chain reaction. During the last months of the war, a small group of scientists working in secret under Diebner and with the strong support of the physicist Walther Gerlach, who was by that time head of the uranium project, built and tested a nuclear device.

At best this would have been far less destructive than the atomic bombs dropped on Japan. Rather it is an example of scientists trying to make any sort of weapon they could in order to help stave off defeat. No one knows the exact form of the device tested. But apparently the German scientists had designed it to use chemical high explosives configured in a hollow shell in order to provoke both nuclear fission and nuclear fusion reactions. It is not clear whether this test generated nuclear reactions, but it does appear as if this is what the scientists had intended to occur.

This can best be explained by focusing on the winter of 1941-1942. From the start of the war until the late fall of 1941, the German "lightning war" had marched from one victory to another, subjugating most of Europe. During this period, the Germans needed no wonder weapons. After the Soviet counterattack, Pearl Harbor, and the German declaration of war against the United States, the war had become one of attrition. For the first time, German Army Ordnance asked its scientists when it could expect nuclear weapons. The German scientists were cautious: while it was clear that they could build atomic bombs in principle, they would require a great deal of resources to do so and could not realize such weapons any time soon.

Army Ordnance came to the reasonable conclusion that the uranium work was important enough to continue at the laboratory scale, but that a massive shift to the industrial scale, something required in any serious attempt to build an atomic bomb, would not be done. This contrasts with the commitment the German leadership made throughout the war to the effort to build a rocket. They sunk enormous resources into this project, indeed, on the scale of what the Americans invested in the Manhattan Project.

Thus Heisenberg and his colleagues did not slow down or divert their research; they did not resist Hitler by denying him nuclear weapons. With the exception of the scientists working on Diebner's nuclear device, however, they also clearly did not push as hard as they could have to make atomic bombs. They were neither heroes nor villains, just scientists working on
weapons of mass destruction for Hitler’s Germany.

This feature originally appeared on the site for the NOVA program Hitler’s Sunken Secret (http://www.pbs.org/wgbh/nova/hydro/).

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