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Nuclear Warfare: Then and Now

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It is not merely that the atom possesses a nucleus which can be split that is of such world-shaking importance. Rather, the central fact of world history in the last half of this century is that the nucleus is so *small*. It is the *smallness* of the nucleus which makes nuclear energy so great, so devastating when used in a bomb. But it was this smallness which prevented the discovery of nuclear energy until very late in the history of science. Our generation is the first to have nuclear problems.

The relation between smallness and the magnitude of nuclear energy is easy to understand. The atom consists of a nucleus and electrons moving around that nucleus. Virtually the entire volume of the atom is that space in which the electrons move. The volume of the nucleus takes up less than one-trillionth of the atomic volume. We can understand the importance of the smallness of the nuclear volume when we consider how energy is taken from atoms—and, for that matter, from molecules, which are composed of atoms. Usually the energy which comes from atoms is associated with the movement of electrons. On the average those electrons are, compared to the distance across the nucleus, very far from each other.

But electric charges are involved in electronic motion and holding electrons to the atom so that it is stable. We can disturb the atomic system, so that it does not remain stable, by bringing certain atoms or molecules sufficiently close together to enable them to "react." Thus, some electrons are pulled out of the region in which they ordinarily move because they are attracted to neighboring nuclei.

To understand the consequence of this new kind of motion, consider an analogous situation in which a cannon ball rolls freely over a table top. Should the ball fall off the table, it will hit the floor with a bang and will not on its own return to the table top. That is, when the ball hits the floor, it will lose energy which the floor receives and it will remain in the new, more stable position. When atoms react, electrons move to more favorable positions and give up energy just as the ball gives energy to the floor. Some atoms produce the energy of a flame when they react. Some emit so much energy that there is an explosion, as when TNT reacts.

Our largest military weapons no longer are those which produce fire and ordinary explosion. They are nuclear bombs. The size of the atomic nucleus changed the general direction of world history.

Now we can return to the matter of electrical charges and distances. Any new average position which an electron takes is due to a more favorable electrical charge situation. Very likely the electron in the new situation spends more of its time near an oppositely charged particle, a nucleus, than it did before the atoms were close together. *The closer together two charged particles are, the greater is the interaction between them, and the greater is the amount of energy which is emitted when the situation is disturbed.*

Here is where the smallness of the nucleus is so important. The particles in the nucleus are extremely close together compared to the relevant distances in extra-nuclear reactions. Because distance is a factor in energy production within the nucleus just as it is outside the nucleus, we might expect that a disturbance of the nucleus would produce a much larger amount of energy than a disturbance of the electrons. This is exactly what happens. Our largest military weapons no longer are those which produce fire and ordinary explosion. They are nuclear bombs. The size of the atomic nucleus changed the general direction of world history. (A more detailed description of the origin of nuclear energy would show that nuclear forces are not only quantitatively but also qualitatively different from the extra-nuclear forces.)

Just because the nucleus is so small, and therefore held together by very great forces, it was late in the history of science before ways were found to disturb it. Not until the 1930's, long after ordinary reactions, that is, chemical reactions, were studied in detail, were ways found to disturb the nucleus enough to split it. It is thus no accident that the largest known source of energy, the nucleus, is the source which was developed last. But when the nucleus was split Pandora's box was opened. The size of the nucleus means that that Pandora's box is today's problem, not a nineteenth century problem.

This article is a discussion of some nuclear history, all of it twentieth century history, and of certain lessons we can derive from this history. I shall first describe nuclear developments in the late 1930's and during World War II; then, developments since the war; and finally I shall attempt to interpret the meaning of the nuclear story.

The Bomb

Up to a certain point in the 1930's the nuclear bomb story is but a single story. Nuclear investigations were carried out in many countries—Germany, Italy, France, England, the U.S., and others—and nuclear scientists communicated with each other easily. Because of a discovery made late in 1938 and published early in 1939, many scientists guessed that a nuclear energy bomb was possible.

In late 1938 war was imminent. Germany had annexed Austria. Chamberlain's notorious appeasement of Hitler in Munich had taken place a few months earlier. But when war broke out in August, 1939, almost all open scientific communication on war-related matters ceased. The nuclear bomb story thus eventually became two stories —one of the German effort and the other of the Allied (later basically the U.S.) effort.

Our story begins before the war in a laboratory of the Kaiser Wilhelm Institute in Berlin, Germany.[1] Otto Hahn, a senior scientist at the Institute, had worked with the nuclei of atoms for about 30 years. In one kind of experiment he and his co-workers frequently carried out, they increased the masses of atoms and sometimes they made entirely new atoms of a heavier element. They did these things by bombarding atomic nuclei with neutrons. The neutron would stick to the nucleus of the target atom; there would be a subsequent, spontaneous reaction and one of the products would be a heavier atom. It was always difficult to ascertain just what happened after the neutron hit the nucleus. But because they were so skilled and usually could determine what happened, they were puzzled when the evidence for what had occurred after neutron bombardment of uranium was slightly different than expected. Hahn with the help of his co-workers was clever enough to realize on December 17, 1938, after many days of puzzling over the data, that the uranium nucleus had been split. They published their results very quickly, in the issue of *Naturwissenschaften* which appeared in Berlin on January 6, 1939, and they made related announcements within weeks.

All the announcements lacked fanfare and were given in dull scientific language. This journal did not have wide circulation. But abstracts of all physical and chemical articles are written and distributed within a few months to technical libraries. Thus, one can find in any technical library, buried among the thousands of abstracts which were distributed in 1939, the following words, referring to one of their early announcements:

> In the irradiation of U [uranium] by neutrons a no. of isomeric Ra [radium] isotopes are formed. . . [T]he "Ra" isotopes have the chem. properties of Ba [barium].[2]

Those obscure 24 words announced a change in the direction of world history.

Hahn and other physicists had known for several years that splitting a uranium atom would release a large amount of energy. The whole matter could have been only a laboratory curiosity. But there was to be more. Hahn realized within days of his discovery that splitting one uranium nucleus might, if the conditions were right, cause other uranium nuclei to split. Each of *those* could cause more to split, and so forth. In other words, under the proper conditions a chain reaction might occur. If this speculation was correct, unbelievably large bombs could be made. When Hahn came to this significant conclusion, he said later, he contemplated suicide.

Since the world was not yet at war in early 1939, Allied as well as German scientists knew because of the Hahn announcement that a nuclear bomb might be a possibility. I shall consider first what the Germans did.

German physicists were able to interest their government in the nuclear project. It is important, however, to understand that from the very beginning of the German story most German physicists were interested in the nuclear program as a *scientific* project, not primarily as a project whereby large parts of enemy cities would be wiped out. But because it was a nuclear project it needed a large amount of support, and physicists were therefore willing to go to the military, which had resources and which did want bombs. Some German physicists tried to think only in terms of the peacetime production of nuclear power, which could, they speculated, be given by a victorious Germany to the world by the still-superior German scientific community. (A technological fact which reinforced this attitude was the necessity, learned also in the U.S. nuclear effort, of making a nuclear reactor similar to a power-producing reactor *before* the much more difficult bomb could be built.) In a sense, then, the nuclear project was for German scientists "science as usual." An interesting scientific puzzle was to be solved; a game was to be won.

The nation which threw millions of people into gas ovens had scientists who by the end of 1941 had correct answers (we know this from the technical reports they wrote at the time) to most of the questions concerning the manufacture of nuclear bombs. But why was a nuclear bomb not produced?

The achievements of the first two years of the German nuclear bomb effort are frightening. The nation which threw millions of people into gas ovens had scientists who by the end of 1941 had correct answers (we know this from the technical reports they wrote at the time) to most of the questions concerning the manufacture of nuclear bombs. But why was a nuclear bomb not produced? What stalled the German effort?

First, there was the science-as-usual attitude already referred to. One of the consequences of this attitude was a strong competition between the different groups working on the project. For example, at one time it was necessary to determine how much uranium a reactor required for a chain reaction to occur. But because of competition, the limited amount of available uranium was divided among several scientists. Paul Harteck, a physical chemist of Hamburg who worked on the problem of reactor size, received an amount of uranium less than that needed for a successful reactor. It was like getting a screen not large enough to fit a window: bugs can then fly into the room without hindrance. A too-small screen is the same as no screen. For the reactor problem, having too little uranium is the same as having no uranium.

Another reason for the slowdown in the German project was the occurrence of incredible mistakes. The mistakes are especially incredible because they occurred in a scientific establishment which was surely the finest and most efficient in the world. For example, German physicists very early in the war correctly had deduced from theory that under reactor conditions neutrons would have to be slowed down if a chain reaction were to occur. They also correctly deduced that the best substances to use to slow down neutrons—such substances are called moderators—would be either "heavy" water or pure carbon. But when the behavior of neutrons in carbon was examined experimentally, Professor Bothe of Heidelberg concluded that carbon could not be used. He was quite wrong; the theory was correct. The important experiment was not checked. That left heavy water, obtainable in sufficient amounts only from the hydroelectric works of Vermork, Norway. The heavy water from this source became available only after Norway was occupied by the Germans. But eventually an Allied commando raid on the Vermork plant, one of the most important Allied operations of the war, meant that the Germans did not have enough moderating material. Had they repeated Bothe's experiment and obtained the correct answer, they could easily have produced in Germany the carbon needed.

A second important German mistake would ordinarily be considered trivial. In 1942 one of the greatest problems the German nuclear effort had was the lack of enthusiastic support from the highest government officials. What the project needed was money and priority for both men and materials. (For example, the project officials could not prevent the drafting of some key nuclear workers into the military.)

Therefore, the central nuclear research laboratory in Berlin planned a meeting—to be held February 26-27, 1942—of the principal physicists of the project with high government and military officials, none of whom was trained in science. The physicists' contribution to the meeting was to be a series of popular-level talks in which they would explain to the non-scientists what they were doing, what their problems were, and particularly, what they needed.

Since these physicists were to come from widely-separated laboratories, it was considered a good time for them also to meet alone. They could help each other by sharing their problems. Consequently, a meeting with highly technical talks was also scheduled. But the secretary who sent out separate sets of invitations to the two meetings made a fatal mistake. The non-scientists received invitations to the physicists' meeting. The government and military officials thought they were to hear highly technical talks, which had appropriately complicated titles. As a result, all the government and military officials found excuses not to attend. Himmler, for example, expressed his thanks for the friendly invitation, but added, "As I will not be in Berlin at the time in question, I regret I will not be able to attend the event."[3] The whole incident is a bit humorous, but it is also an incident which contributed to the lateness of the necessary vigorous high-level support and therefore to the ultimate failure of the project.

During the last years of the war the Allies destroyed Germany's industrial plant, bit by bit, by intensive bombing raids. Even then, in spite of internal competition, lack of priority, and key mistakes, the Germans doggedly moved ahead on the nuclear project. In the last *days* of the war, in the spring of 1945, bombing raids forced them repeatedly to move their nuclear research facilities. The Germans still hoped to show that their scientific establishment could produce a stupendous result in spite of adverse conditions.

Had the German research been successful at this time, they would have had something like the Chicago reactor (more of this later), which was operated successfully for the first time in December, 1942. Therefore, even though the Germans started out fast and were ahead of their enemies in nuclear research in the early years, and unquestionably had the best scientific establishment in the world, by the end of the war they were at least two-and-one-half years behind, the time from December, 1942 to the end of the war. In spite of their feverish efforts from 1939 to 1945, they were stalled and frustrated from approximately 1942 onward. I shall return to a consideration of this period of frustration after we describe the U.S. effort.

The parallel U.S. story of the development of the nuclear bomb began in 1939 when three physicists, Leo Szilard, Eugene Wigner, and Edward Teller, convinced Albert Einstein, who lived in the U.S., that he should sign a letter to President Roosevelt asking for U.S. support of a project which would determine whether a nuclear bomb could be made.[4] (At the very beginning there was a separate British project. For practical reasons the U.S. and British efforts were combined and all the work was carried out in the U.S. We shall therefore refer to the Allied project as the U.S. project.) The reason Einstein was approached was that his name was a household word in the U.S. A letter from him might influence some government officials, all non-scientists. At first official interest in the project was not great: only $300,000 was made available for the first year.

From the beginning there was central direction of the U.S. project, known by code as the Manhattan Project. Early in the history of the project it was given top priority. Therefore, divisions within the project and competition with other parts of the military effort, both allowed by the Germans, were minimized. Another difference was important. With the German physicists, the nuclear project was, as described earlier, a science-for-science-itself project. But almost all the top scientists were European refugees from Hitler. Most, like Einstein, were Jewish; Enrico Fermi, the Italian physicist, was a refugee because his wife was a Jew. With these refugees making the bomb was no game. They knew Hitler was satanic and therefore had to be defeated at all costs.

Once the U.S. nuclear bomb effort was under way, it became an amazing story of fighting a scientific-technical war on many fronts; of wining some battles and losing others; and even of winning some unnecessary battles. But the success which was achieved by Fermi's group on December 2, 1942, was what made other successes possible. That day, in their reactor under the stadium of Stagg Field at the University of Chicago, Fermi's group carried out the first self-sustaining chain reaction caused by man.

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That was an important first step. To make a bomb, it was necessary to separate the different kinds of uranium atoms, that is, the uranium "isotopes," from each other. All the known separation methods are extremely tedious and so expensive that only the largest nations can afford them. Two such methods, the gaseous diffusion method and the electromagnetic method, were used in very large plants in the new, secret city, Oak Ridge, Tennessee. A third way to make a bomb was just as difficult. Uranium could be transformed in reactors into plutonium, a new element, which could in turn be used to make a nuclear bomb. A large plutonium plant was built along the Columbia River in Hanford, Washington. All together, there were tens of thousands of workers in the three plants and hundreds of workers in the laboratories associated with the nuclear project. Even so, only a handful of people knew enough of the project to understand what was actually being done.

Finally the bomb—or rather, three bombs—were manufactured. The first bomb, a plutonium bomb, was exploded in a test near Los Alamos, New Mexico, on July 16, 1945, more than two months after the war in Europe had ended. Then on August 6 a uranium bomb, where uranium separation had been accomplished using the electromagnetic method, was exploded over Hiroshima, Japan; 78,000 died. Three days later another plutonium bomb was exploded over Nagasaki, destroying that city. The war ended. Some persons argue that nuclear bombs should not have been used and the deaths were unnecessary. But before the bombs were used the American military estimated, probably correctly, that far more would die if nuclear bombs were not used.

Since World War II

The nuclear bombs used at the end of the war were only a very small beginning. The tremendous bomb plants were not dismantled. Some startling developments also helped to change the picture. Thus, nuclear physicists knew that the energy produced by splitting large nuclei, such as the nucleus of uranium, could be used to fuse small nuclei, such as the nuclei of hydrogen atoms. Such fusion would also produce energy. A fusion bomb, also called an H-bomb or a hydrogen bomb, was produced by the U.S. and first exploded in 1952. For certain theoretical reasons the fusion bomb is thousands of times more powerful than the uranium and the plutonium bombs.

The bombs used against Japan were difficult to make. But the knowledge obtained in making those bombs made it possible to make large numbers of nuclear bombs. Furthermore, because the general outline of how they were manufactured became public knowledge and because of Soviet spying on the U.S. nuclear project (for example, the notorious Klaus Fuchs was a Soviet spy who gained access to the U.S. nuclear project during the war as a member of the British mission), many countries have been able to make nuclear bombs. There were so many bombs made that between 1945 and 1957 over six hundred were exploded, ususally for test purposes. Because the explosions of either the atom bomb or the hydrogen bomb harm the environment, negotiations for a test ban treaty were begun in 1958. In 1963 such a treaty was signed by many, but not all, nations which possessed bombs.

The three 1945 bombs were therefore but a small beginning because many countries subsequently manufactured thousands of bombs, some of which are the very large H-bombs. But another series of technical developments made the situation even more dangerous than suggested by what has been described. In fact, there is no resemblance between the nuclear bomb situation which existed at the end of World War II and the present bomb picture. The difference lies not only in the present number and size of nuclear bombs, but also in the bomb delivery systems used then and now. At the end of the war the only means of delivering bombs was by manned bombers or conceivably by Hitler's relatively crude unmanned V-2 rockets. But today missiles with multiple nuclear warheads can be sent accurately any distance to any target in the world within minutes.

Several technical developments are responsible for the improvement in the bomb delivery system. Two such developments are the modern jet engine and the guidance system now available. First, the modern jet engine is far superior to anything known during the war. Second, its guidance system makes World War II guidance systems look truly primitive. Modern guidance systems depend upon modern computers which, in turn, depend upon the transistor. The transistor did not even exist before 1948.

We shall presently attempt to ascertain what we can learn from the world's experience with nuclear research and nuclear bombs. But we must first remember that the difference between 1945 and the present with respect to nuclear bombs has consequences. During the war there were many military operations which cost tens of thousands of lives; altogether 35 *million* were killed. Therefore, in the climate existing at the end of the war it was relatively easy to undertake one more operation, the dropping of two atom bombs, which would cost perhaps a few hundred thousand lives. It was expected that this operation would end the war and save many lives. This expectation was realized. Today the climate and the potential are vastly different. In nuclear warfare, tens —perhaps hundreds—of *millions* would die. Surely it would then be impossible to rebuild civilization in the way it was rebuilt after World War II.

What Does It Mean?

There are some lessons in the nuclear bomb story.

We need to realize once again that the efforts of highly intelligent people—in our story, the efforts of the German nuclear physicists—can be marshalled for evil purposes. The nation of the gas oven was also the nation which plotted to destroy cities by using nuclear bombs. The men who had created the foundations of modern physics were willing to build those bombs if only it meant that they could continue their scientific work. Perhaps the nations of the world, including our own, presently have groups of intelligent people who can be manipulated for satanic ends. A related point is of interest: in the present nuclear bomb debate, in which so many Europeans protest the deployment and use of nuclear bombs in Europe, two groups of Europeans, the Germans and the European refugees in the U.S., schemed to build bombs which would be dropped on European targets.

Frequently Christians maintain it is extremely important that they work together. Communal effort is far superior to individual effort. This can also be learned from the nuclear story. We are taught by strange teachers, the World War II nuclear research establishments, that it is fatal when people who are supposed to cooperate with each other fail to do so. The superior German scientific establishment could not accomplish what zeal, patriotic attention to military secrecy, and a will to work together did accomplish in the U.S. effort. Had the Germans truly pulled together, there is every reason to believe (except for the providence of God) that they would have checked the neutron-carbon experiment, making the Vermork, Norway, commando raid irrelevant; that they would have given the nuclear project the top priority such a project needs; that their organization would have been efficient enough to eliminate petty, debilitating rivalries and uncertainties which prevented smooth progress.

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Some of those German World War II problems resemble modern U.S. problems. Compare the U.S. World War II effort, especially with respect to the nuclear project, with present U.S. projects. During the war devotion to the war effort was intense. Patriotism was considered a virtue. Elaborate arrangements to keep the nuclear project secret were successful, except for the Soviet infiltration already mentioned, even though thousands were involved in various parts of the project. The project had strong central direction, with intelligent leaders at the top. There was no question of harmful competition.

On the other hand, it will probably be a long time before this country recovers from the "me" generation. Until then, it is doubtful that patriotism and respect for authority, so necessary in a national effort, will be as much a fact of national life as they were in the 1940's.

Another thing we can learn from a specific part of the nuclear story is that the facts of science and technology cannot be swept under a rug. We might wish that the nucleus of the atom were not so small. Then, perhaps, we could have nothing worse than a conventional war. We might wish that there were no such thing as semiconductivity, a property of some solid materials which makes it possible to manufacture transistors. Without transistors, we could not have the modern computer; and then we could not have the guidance system which can take a missile to its target with deadly accuracy. Such wishes are vain. There is no point in adopting a know-nothing attitude toward science and technology. But there is a point in Christians working together in science and technology, in refusing to leave technical work to those who think science and technology are neutral, and in teaching science and engineering in Christian colleges. The Christian can work in the world in a redeeming way when he is properly active in science and technology. When the Christian scientist or engineer works for the Lord, he reckons with creation as it is.

Let us now look at the larger picture. How does the Lord accomplish His purpose in history, and in particular how does He use the events of the nuclear project history? The Lord restrained evil by not allowing Hitler to win the war. It is hard to overestimate the wickedness we would have known had Hitler won.

But why did Hitler not win? Often when we consider how the Germans came to lose the war we think of the bad military decisions Hitler made in North Africa, in France after the Second Front was launched, and in Russia; of the incredible sacrifice of life in the defence of Stalingrad; and of the night-and-day bombing of Germany during the last years of the war. Those were factors in Hitler's defeat; but we ought also to praise the Lord for holding back the nuclear bomb project. The best scientific establishment in the world did not complete the most revolutionary scientific project of history up to that time. After a fast start, with many of the correct answers in hand, one incredible thing after another prevented the Germans from making at least a reactor. Had they produced a reactor by December, 1942, when the U.S. reactor in Chicago began functioning, they—considering their scientific capability—might well have made a nuclear bomb before the U.S. did. Yet it seems that beginning some time in 1942 that those in charge of the German nuclear project were incomprehensibly frustrated. The Allies were certainly not the people of the Lord; but one is reminded of how the Lord blinded His enemies, a band of Arameans, enabling the prophet Elisha to lead them away so that they could not do the evil that they had intended (II Kings 6:18-23).

Today the nations' capability for death and destruction is so great that a nuclear war is called unthinkable. But people are thinking and worrying about it. Not the mushroom cloud, but the thought of the mushroom cloud, hangs over our generation. How does the Lord use these things to accomplish His purpose?

Because nuclear bombs are so terrible two of them ended the greatest war in history. The threat of thousands of those bombs, many of them infinitely larger than the first ones, has been a deterrent ever since. It is not that we have not had war; in fact, millions have died in wars since 1945. But the war in which far more were killed than in any other war is now thirty-seven years behind us. The potential for world war is, were it not for the nuclear deterrent, as great as it ever was: there is no international peace-keeping apparatus worth the name; many countries are governed by either thugs or psychotics; numerous countries possess an incredible amount of arms; virtually every government considers war as a legitimate means to an end; and greed and hate are as widespread as they ever were. In an age in which developments occur on every front with mind-numbing rapidity, an age of future shock, the rush toward the next world war has been stalled. The Lord has used the nuclear bomb itself to hold off the holocaust which the world has feared since 1945.

In any discussion of nuclear stockpiling we must take account of recent history. We have had neither the unthinkable war nor another conventional war like World War II, even though the time elapsed is now almost four decades. Does that mean then that any request by the military for increasing the stockpile must be granted? Matters are not so simple.

For here is the most important and ironic point of all: The very means the Lord has used to put off the unthinkable war may be the same means He will use to lay our civilization low. But we don't *know* that there will be a nuclear war. Least of all do we know when the end will come. What we do know is what Lord has done. Because of the awful bomb we have been given time. Do we —either as individuals, as the people of God, as a society, as a nation, or as a family of nations—use this time properly?

Notes

[1]Much of the material on the German nuclear effort was taken from David Irving, *The German Atomic Bomb* (Simon and Schuster: New York, 1967).

[2]*Chemical Abstracts*, 1939, *33*, 3684.

[3]Irving, p. 107.

[4]Most of the information concerning the Allied project which was used is found in Stephane Groueff, *Manhattan Project* (Little, Brown: Boston, 1967).