CHAPTER 10

The Scientists Making the Atomic Bombs[1]

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Introduction

Atomic bombs with awesome destruction were used to help end World War II. They also carried with them tremendous dangers for the future of humanity. Since the first explosion of American atomic bomb, the other four countries—former Soviet Union, United Kingdom, France and China—had also exploded the atomic bomb between 1949 and 1964. Scientists, the direct builders of these weapons, played vital roles in achieving atomic bomb. A number of books concerning the history of nuclear programs in these countries have been published: Richard Rhodes' books give comprehensive historical reviews about nuclear programs in the United States, Margaret Gowing's book gives an official history of the development of the British atomic bomb, Bertrand Goldschmidt's autobiography reveals the French nuclear program, and David Holloway's book shows a completely historical process of building the Soviet Union atomic bomb, and John Lewis and Litai Xue's book describes a detailed history of Chinese first atomic bomb.[2] However, no single book gives a comparative study of the activities of scientists in the above five countries. Why would the scientists like to undertake such a sophisticated, secret and hard task as building atomic bombs? What roles did they play in helping set up the projects? How concerning were the goals of atomic bombs technically realized? What attitudes did scientists show the final use of atomic bombs and the nuclear arms race? The answers to these questions will illustrate a pattern of scientist's activities among five countries and between two ideologies.

This paper briefly reviews the history of the development of the atomic bomb, concentrating on the activities of scientists in the above-mentioned countries. Despite the different countries and different ideologies, the activities of scientists showed a similar pattern of motivations, roles, work, and attitudes toward the use of atomic and nuclear arms race in atomic bomb projects. Fear of the Nazi Germany possessing such destructive weapon and patriotism were the main forces initially driving scientists into the atomic bomb programs. Working in the field of nuclear science, scientists aroused the attention of government about the potential of nuclear fission and persuaded government to set up atomic bomb projects. The work of scientists in these countries and their collaborations with scientists of other countries led to the final realization of atomic bombs. Facing the final results of their own works—the atomic bomb—the scientists showed different opinions toward the use of atomic bombs and the nuclear arms race.

In the following sections, this essay reviews the early history of atomic physics, describes the history of the American atomic bomb, gives the history of the British atomic bomb project, introduces the French project, reviews the Soviet Union's project, and describes the Chinese program.

Early History of Atomic Physics

On November 8, 1895, the German physicist Wilhelm Rontgen discovered X rays radiating from the fluorescing glass wall of a cathode-ray tube. A year later, French physicist Henri Becqueal discovered radioactivity in uranium salt. In 1897, J. J. Thomson at the Cavendish Laboratory discovered electron having a mass about one two-thousandth part of that of the hydrogen atom and carrying a negative charge. In 1898, Marie and Pierre Curie separated polonium and radium from uranium ore using a chemical method. In the meantime, Ernest Rutherford at McGill University found alpha and beta rays when he studied the radiations emitted by uranium and thorium. A year later P. V. Villard, in France, discovered a third kind of radiation—gamma rays—emanting from radioactive material.

In 1900, Rutherford, working with Frederick Soddy, observed the spontaneous disintegration of the radioactive elements when checking the radioactive gas emanating from the radioactive element thorium. In 1905, Albert Einstein established the theory of special relativity, the theory that predicts that the total energy of matter is equal to the products of mass and the square of light speed. Enormous energy will be released with very small mass, which is the basis of nuclear power. 1911, Rutherford and his collaborators found that the atom had a small, massive nucleus in the center surrounded by a sparse uniform distributed electrons through alpha particle scattering experiment. He proposed his atomic model as a central electric charge concentrated at a point and surrounded by a uniform spherical distribution of opposite electricity equal in amount.

In 1913, Niels Bohr proposed what is now called old quantum theory of hydrogen atom. He assumed that electrons could occupy discrete stationary states in the atom without radiation. When an electron jumps from one orbit to another, it emits light energy equal to an integer times of the product of Planck's constant and light frequency. Bohr's model gave a good match to the spectrum experimental data of hydrogen.

In 1918, Francis Aston at Cavendish invented the mass spectrograph, which can determine the mass of nuclei to a high degree of accuracy. In June 1919, Rutherford published his experimental studies on artificially transmutation in *Philosophical Magazine*. In this study, Rutherford bombarded the element of nitrogen using alpha particles, transforming nitrogen into oxygen and hydrogen. In 1922, Bohr proposed that atoms are built up of successive orbital shells of electrons, which can accommodate up to a certain number of electrons and no more, thereby providing an explanation of the atomic structure in the periodic table of the elements. In 1931, Ernest Lawrence invented the cyclotron, which can accelerate the charged particle to a high energy; such an invention provides an important tool for studying the inner structure of nuclei.

In 1932, James Chadwick discovered the neutron. He used alpha particles to bombard the light metal beryllium to produce the radiation, which was identified as neutron after interacting with the nuclei of hydrogen atoms within paraffin wax. The neutron can pass through the surrounding electrical barrier and enter the nucleus, making the detailed examination of the nucleus practical.

Frederic and Irene Joliot-Curie discovered artificial radioactivity in 1934 using alpha particle to bombard the aluminum. Such a discovery demonstrated that it is possible to force the nucleus artificially to release some of its energy in radioactive decay. Meanwhile, Enrico Fermi and his collaborators in Rome discovered that, when the neutrons had previously been slowed down by water or paraffin, the radioactivity of a metal bombarded with neutrons was abnormally large.

In 1938, Otto Hahn and Fritz Strassmann in Germany bombarded uranium with neutrons to test the radioactivity discovered by the Curie group using radium chemistry methods. The process showed that the bombardment of uranium produced barium, a process which was later named nuclear fission by Lise Meitner and her nephew, physicist Otto Frisch. Meitner and Frisch analyzed the experiment by Hahn using Bohr's liquid-drop model and found that under neutron bombardment the uranium nuclei split into two smaller, lighter nuclei that could include barium and the gas krypton. If more than one neutron is released during the disintegration of uranium, a continuous splitting of uranium atom would be possible, releasing a huge amount of energy. This process was described as a chain reaction as a theoretical possibility as early as 1932–1935 by Fritz Houtermans, Leo Szilard and Joliot-Curie.

American Atomic Bomb

Fearing Germany would build an atomic bomb, Szilard and Eugene Wigner approached Einstein in July 1939, asking him to urge the Belgian government not to sell uranium to Germany. Then, Szilard, Wigner and Edward Teller drafted a letter, which was signed by Einstein, to President Roosevelt to inform Roosevelt of the potentials of nuclear fission and possible dangers from Germany building atomic bomb.

This letter was read to the president by economist Alexander Sach in October. After listening to this letter, Roosevelt suggested taking action and set up the Advisory Committee on Uranium. On November 1, 1939, the Uranium Committee produced a report, recommending the application of nuclear reactions to the source power production and noting the possibility to produce a destructive bomb.

In 1940, after physical chemist Peter Debye informed Szilard and Einstein of the secret German uranium research at the Kaiser Wilhelm Institutes, Szilard and Einstein wrote another letter to Sach to capture the attention of the government again. In June, the National Defense Research Council absorbed the Uranium Committee and gave support for fission research. In the winter of 1941 James Conant, a distinguished chemist and the president of Harvard, traveled to open a liaison office between the British government and the National Defense Research Council in London. In July, Ernest Lawrence told Conant and Arthur Compton that a uranium bomb was possible and that the Nazis were trying to produce such a bomb. He urged the United States to press forward with a bomb project. Mark Oliphant of England flew to the United States in late August to help set up cooperation between the United Kingdom and the United States. He met with the Uranium Committee, talked with Lawrence, Conant, and Fermi about the nuclear program, and rehearsed the Maud report from British nuclear physicists: that atomic bomb is practically possible. Convinced by Compton, Conant, Lawrence and Sir George Thomson, who officially transmitted the Maud Report to Conant, Vannevar Bush reported to the Roosevelt in October about the potential of the atomic bomb.

Roosevelt set up the Top Policy Group to direct the nuclear weapon policy. In March 1942, Bush reported to Roosevelt again about the nuclear program, summarizing that a completion of an atomic bomb in 1944 was achievable and reiterating the dangers from the Germany atomic bomb program. An official atomic weapon program started. In August 1942, the Executive Committee, which included Lyman Briggs, Compton, Lawrence, Harold Urey, Eger Murphree and Conant, concluded that the bomb project was important beyond all previous estimates and that an authoritarian organization should move in to take over the work that had been democratically begun. In September General Leslie Groves was appointed as the head of Corps of Engineers that was responsible for the atomic bomb program, code named the Manhattan project.

Scientists had worked on nuclear fission since 1930s. Szilard and Fermi worked on the chain reaction for a nuclear reactor. John Dunning and Urey worked on the gaseous diffusion isotope separation at Columbia. Lawrence pursued electromagnetic separation at Berkeley; Murphree supervised centrifuge development at New Jersey; and Compton, in Chicago, did theoretical studies and the actual designs of the bomb. In 1941, Merle Tuve group's measurement of the fission cross section of uranium gave a experimental indication that the critical size for a uranium sphere is manageable. Emilio Segre and Glenn Seaborg discovered plutonium in Berkeley, which fissioned like U235 with larger cross section, but could be chemically separated from uranium. Fermi built an exponential pile in Chicago to transmute U238 to plutonium.

In 1942, Seaborg arrived at the Met Lab in Chicago to study the separation of plutonium from irradiated reactor fuel. In the summer, Robert Oppenheimer gathered a small group of theoretical physicists including Hans Bethe, who wanted to do something to oppose Nazism; Teller; John Van Vleck; Robert Serber; George Kistiakowski; and, two postdoctoral assistants to study the actual design of atomic bomb. On December 2, 1942, Fermi had run the pile for 4.5 minutes at one-half watt in Chicago. This was the first time that men had controlled the release of energy from the atomic energy.

After the start of Manhattan project, Oppenheimer was appointed as the director of a new laboratory, now the Los Alamos National Laboratory. The army would administrate the community, which was building around the laboratory. Laboratory security would be Oppenheimer's responsibility, and he would report to Leslie Groves. Oppenheimer secured the scientific freedom of speech within Los Alamos. At the beginning of April, 1943, Oppenheimer assembled the scientific staff—mostly from his friends and students, numbering about thirty of the 100 scientists initially hired—for a series of introductory lectures. Averaging twenty-five years of age, these young men were under the lead of Oppenheimer, Hans Bethe, Teller, Edwin McMillan, Robert Bacher, Segre and Edward Condon. Isidor Rabi, Fermi and Samuel

Allison arrived from Cambridge and Chicago to serve as senior consultants. A review committee, including W. K. Lewis, E. L. Rose, Van Vleck and another expert, was established to follow planning and to advise. Seth Neddermeyer, an experimental physicist, defined a possible new way, the implosion method, to fire an atomic bomb. E. L. Rose, a research engineer, realized that the weight of bomb could be drastically reduced using implosion.

In the autumn of 1943, Scientists at Kellex succeeded in devising a promising new barrier material for gaseous diffusion that combined the best features of the Norris–Adler barrier and the compressed nickel-powder barrier.

Crawford Greenewalt, in charge of plutonium production for Du Pont, continued to plan for helium cooling, because the noble gas had no thermal absorption cross section at all for neutrons. Wigner designed the water cooling system of the reactor. In November, the chemical separation processes developed by Seaborg and his colleagues had been used to process slugs in a remote-controlled pilot-scale separation plant. In 1944, Segre measured the spontaneous fission rate of plutonium and found it much higher than the previous results, meaning they would not need to cleanse the plutonium so thoroughly of light-element impurities.

In December, the first members of the British Mission, including Frisch and Ernest Titterton, joined Los Alamos as the Quebec agreement between the United States and Britain in nuclear weapon collaboration:. They were later followed by Jamies Chadwick, Rudolf Peierls and other seventeen members. The official head of the British Mission at Los Alamos was Chadwick, who was informed about the whole Manhattan Project. The members of the British Mission worked in nearly all the existing Los Alamos Laboratory divisions and were integrated into all Los Alamos Laboratory activities. In Los Alamos, John Von Neumann, Seth Neddermeyer, Kistiakowsky, and British scientists James Tuck, Geoffrey Taylor and Peierls worked on the implosion program.

In 1944, Von Neumann designed a theoretical arrangement of an implosion lens, and Kistiakowsky managed to make the theoretical arrangement work. Condon suggested polonium as initiator, the minuscule innermost component of bomb that serves as the neutron source to start the chain reaction off. French nuclear scientist Bertrand Goldschmidt extracted the first half-curie of initiator polonium from an old radon capsule. Tuck designed the initiator for the Trinity bomb. In the April, 1945, Frisch completed his critical assembly experiments with metallic U235. These experiment gave direct evidence of an potentially explosive chain reaction. Kistiakowsk had managed to produce implosive compressions so smoothly symmetrical that their numbers agreed with theoretical predication. On July 16, 1945, the first American atomic bomb was detonated at the Trinity test cite.

In 1945, when the atomic bomb was built and ready to use in the war, Szilard thought it would be a serious mistake to use the bomb against the cities of Japan, and expressed his concerns to Oppenheimer. In May, at an Interim Committee meeting about the future of nuclear business, Oppenheimer suggested opening the door to industrial development. He thought it might be wise for the United States to offer the world free interchange of information about nuclear energy with emphasis on the development of peace-time uses. Lawrence thought that the United States should know more and do more than any others to stay ahead of the rest of the world. In June, a group of scientists from the Metallurgical Laboratory at Chicago—including James Franck, D. J. Hughes, J. J. Nickson, Eugene Rabinowitch, Seaborg, J. C. Stearns and Szilard—produced a powerful memorandum, urging the need for international control of atomic energy to forestall a nuclear arms race and argued against the use of atomic bomb to Japan. In August of 1945, two atomic bombs were dropped in Japan.

Some scientists were happy and thought it was right to force the enemy to accept the peace. Lawrence thought the atomic bomb a terrible, swift sword that would end the war and might succeed in ending all wars. Other scientists, like Einstein, James Franck, Szilard, were unhappy. After the atomic bombing of Hiroshima and Nagasaki, Szilard felt a measure of guilt for the development of such terrible weapons of war and, calling the atomic bombings a flagrant violation of our own moral standards, asked that the bombings be stopped.

In September, the Association of Atomic Scientists headed by William Higinbotham was established to tell the world the truth about the new weapon and entreat their fellow men to renounce all use of atomic energy in warfare. Almost every scientist involved in the project at that time thought that atomic energy should be subject to public supervision. In July 1946, McMahon Bill made the control of atomic research development in the United States by a civil commission become law. In 1946, a group atomic scientists at the University of Chicago, headed by Hyman Goldsmith and Rabinowitch, started the *Bulletin of the Atomic Scientists* to explain the social and political consequences of the new source of power.[3]

In 1949, the Soviets exploded their first atomic bomb, ending the American nuclear monopoly. Some scientists, like Teller, proposed a superbomb project so that America will not become a second-class power. Teller was a key figure in the promotion of the uses of nuclear technology, but he also opposed various attempts to contain the nuclear arms race. The opponents of the superbomb argued that it would be morally wrong to initiate the development of such an enormously destructive weapon. In the 1949 report of the General Advisory Commission (GAC), Oppenheimer and Rabi, suggested some effective forms of international nuclear arms control.[4]

British Atomic Bomb

In 1939, after learning of French scientists' report about the uranium splitting, Thomson at Imperial College, as well as professors of the Cavendish Laboratory, realized if a sufficiently large mass of uranium was composed, it could release a large amount of heat. They suggested the British government getting the supply of uranium from Belgian, so that it would not be captured by Germans. In May, Professor A. M. Tyndall of Bristol University wrote the Government's Chemical Defense Committee a cogent memorandum about the possibility of producing an atomic bomb. In 1940, Otto Frisch and Peierls theoretically worked out that a small amount of metallic U235 would be enough to make a bomb. Peierls and Frisch showed their memorandum to Professor Mark Olophant, Thomson, and John Cockcroft. At the beginning of April, Lt. Jacqués Allier from France informed Thomson, Oliphant and Cockcroft of German interest in uranium. Peierls, Frisch and Oliphant suggested the super-bomb.

A small uranium sub-committee of the Committee for the Scientific Survey of Air Warfare was officially set up and research was pursued in earnest. Thomson gave his committee a new name to disguise its activities: Maud. At the end of July of 1941, the Maud committee finished two reports about nuclear power and the nuclear bomb, discussing in detail the potential of atomic bomb and the feasibility of building an bomb. In the report on the use of uranium as a source of power, the potential of atomic bomb was pointed out and the building of an atomic bomb was suggested as practical. This report was sent to the Scientific Advisory Committee of British government for final decision. Before the formal discussion, the Chairman of Defense Services Panel was approached by Professors Frederick Lindemann and G. P. Tommson. After a careful discussion, check, and recalculation of the Maud Reports, the Scientific Advisory Committee concluded that atomic bomb project should be urgently pursued.

Before the writing of the Maud report, several scientists had worked on the nuclear fission project. In 1940, Professor Franz Simon worked on the physical problems of diffusion isotope separation. In one of his papers, Simon described the main features of a plant needed for isotope separation, its estimated size, its equilibrium times, its power consumption, and total weight and price of the machinery. Professor E. Reidal of Cambridge explored the centrifuge separation method. Professor W. N. Haworth of Birmingham University directed the chemical worked on the production of gaseous compounds of uranium and of pure uranium metal. Haworth's group at Birmingham worked on the chemistry of uranium and tried to find other useful gaseous uranium compounds other than hexafluoride.

Frisch and Peierls were involved in isotope separation and the measurements of nuclear constants. The paper of Peierls and Frisch confirmed the potentialities of pure U235 for use in atomic bombs. Their calculations showed that the explosion of one atomic bomb would be equivalent to many thousands of tons of high explosive. In the summer, Peierls and Frisch made a detailed theoretical study of possible separation methods and found that diffusion though fine holes was the most promising answer. By the end of 1940, Peierls and Frisch's work suggested that, theoretically, a bomb was possible, while the Simon's team had shown that the separation of U235 was industrially feasible.

At Cambridge, nuclear physicists Halban and Lew Kowarski from France showed that a divergent chain reaction, maintained by slow neutrons, could be produced in a mixture of uranium oxide and heavy water. Egon Bretscher and Norman Feather discovered another fissile element 94, which was radioactive. This element would have larger cross section than that of U235. Chadwick and his team measured the cross sections at Liverpool and their result tended to support the general conclusion of Peierls' and Frisch's analysis.

In the autumn of 1940, Sir Henry Tizard led a mission to Washington where the scientific secrets of the two countries were freely exchanged. This was the first contact between American and British nuclear research since the outbreak of war. Chadwick made further cross-section measurements and realized that a nuclear bomb was not only possible, but also inevitable. In the April 1941, Taylor calculated that the effect of an explosive 10 kg bomb would be equivalent to about 1000 tons of TNT.

After the Scientific Advisory Committee's Reports was finished in 1941, Sir John Anderson was appointed to take over responsibility for the project. A new organization named the Directorate of Tube Alloys in the Department of Scientific and Industrial Research was established and headed by the research director of Imperial Chemical Industries (ICI), Wallace A. Akers. Anderson formed a Tube alloys Consultative Council to advise on broad questions of policy. At the technical level, a Technical Committee under Akers' chairmanship was established. In the middle of 1941, Bush and Conant of the United State suggested to Lord Hankey of Britain that the uranium work should be treated entirely as a joint Anglo–American project. Anderson wrote in the March of 1942 to Bush concerning the co-operation between the scientific groups in the two countries to express a desire for collaboration in the atomic bomb project. At the end of July 1942, the Tube Alloys Consultative Council agreed that a full-scale British type separation plant should be built in the United States.

In August of 1943, the United States and Britain signed the Quebec Agreement, which restored Anglo–American collaboration. This set up the direct interchange of information between the groups in the two countries working on the each section of the project and determined that there should be full and effective collaboration between the United States and the United Kingdom in bringing the bomb project to fruition. After the Quebec Agreement, the British sent to North America as many British scientists as could make useful contributions to the American and Montreal projects. A committee was set by Thomson to find the best way of meeting the demands of the atomic energy project. A British diffusion mission went to America. Peierls, Klaus Fuchs and Tony H. R. Skyrme were attached to Kellex as consultants. These theoreticians solved for Kellex a number of problems concerned with the control of the plant and the effects of disturbances. Oliphant worked with Lawrence at Berkeley to study electromagnetic separation. At the beginning of 1944, most staff in Britain working on electromagnetic separation went to Berkeley and Tennessee. At the end of 1943, a group of British scientists called the British mission started to join the Los Alamos Laboratory. This group of scientists was officially leaded by Chadwick and included Bohr, Bretscher, Free French, Frisch, Fuchs, James Hughes, Derrick Littler, Carson Mark, William Marley, George Marshall, Winifred Moon, Peierls, William Penney, George Placzek, Michael J. Poole, Joseph Rotblat, Herold Sheard, Skyrme, Taylor, Ernest W. Titterton and Tuck.[5]

To a large degree the normal scientific habits of camaraderie, of free discussion, of talking out a problem with colleagues prevailed at Los Alamos. Most of the British team were concerned with the problems of implosion and bomb assembly generally. During their work, the British were able to acquire a wide and detailed knowledge of the whole subject of the physics and construction of nuclear explosives. There had been one or more British scientists in the great majority of the divisions at Los Alamos.

In November 1944, Chadwick, Oliphant, Cockcroft, Peierls, H. W. Massey and H. W. B. Skinner met in Washington to clarify their ideas on the Government-controlled Experimental Establishment. This would be the basis of the nuclear bomb project in Britain, which was an integration of the research, development and plant sides of the project within one organization.

In 1945, Cockcroft was appointed as the head of Establishment. They listed the minimum main equipment, buildings, and staff and calculated the total initial costs of plant and buildings. The design and construction of a 100,000 kW graphite pile was decided upon. The electromagnetic research and development was to be carried out at the Experimental Establishment.

In September, Kowarski, working at Montreal Laboratory, succeeded in making the zero power heavy water pile critical. When the members of the British Mission to Los Alamos returned to England, many returned to the academic work. Penney entered full-time British weapons work at the Harwell atomic establishment. He probably knew more about the Los Alamos work as a whole than any other members of the British Mission team. In 1952, October, Britain detonated her first atomic bomb on the Monte Bello Islands off the coast of Western Australia.[6]

In the summer of 1945, a move had been made in England at a high scientific level aimed at stopping the use of the bomb.[7] When the dropping of the atomic bomb on Hiroshima was announced, Sir Henry Dale, President of the Royal Society and a member of the Scientific Advisory Committee, wrote to *The Times* to suggest the dropping of the national secrecy covering scientific discoveries during the war. In general, the British Mission to Los Alamos personnel felt the bomb was a good thing, because that the bomb demonstrated to the world that how terrible this weapon was. Marshall felt triumph and relief after the announcement of Hiroshima. In 1946, Tizard said in a major address that the dropping of atomic bomb opened the eyes of the people of the world. Chadwick confessed that until the very end that he had hoped that the bomb would not work. Peierls thought that the scientists probably should have more dialogue with the military and political leaders. Frisch expressed his feeling that joy was not appropriate after the drop of atomic bomb on Hiroshima; he wished that the first bomb could have been dropped on an unoccupied Japanese island and not a crowded city. His involvement with the Tube Alloys/Manhattan Project left him with a permanent distaste for the contemporary political world.

French Atomic Bomb

In 1939, Frederic Joliot directed his research toward producing a controlled chain reaction which could be used as an energy generator. At the end of 1939, Joliot sent a report to the minister of armaments, specifying that an appropriately mixture of uranium and heavy hydrogen was a possible road to the development of the chain reaction, and consequently a massive release of energy. In the July of 1944, Pierre Auger, Jules Gueron and Goldschmidt, working in the Montreal Lab, informed the General Charles de Gaulle of the atomic bomb project in the United States and its political effects during his visit to Canada. They suggested resuming atomic research in France as rapidly as possible. In November, Halban, the former director of Montreal projects, paid a visit to France, where he talked with Joliot and gave him some information about the existence of plutonium and its fissionable property, and about work on the separation of U235. In May 1945 Joliot and Auger approached de Gaulle and told him that some sort of French organization was needed in the field of nuclear energy. In September de Gaulle asked Joliot and Raoul Dautry to draw up a plan for a nuclear energy organization to enable France to assume its place in this revolutionary field. On October 18, 1945, the Commissariat alEnergie Atomique (CEA) was formed.

On January 3, 1946, the CEA began its first meeting. Six members of its executive committee were appointed for a term of five years. Two-thirds were scientists, including Joliot, Irene Joliot Curie, Auger and Francis Perrin. Perrin took charge of setting up the Chatillon center, Auger the raw materials, and Mme. Joliot the chemical problems. Joliot dealt with the government, the various ministries, and coordination of the other commissioner's bailiwicks. In February, a scientific committee was formed. Kowarski was appointed as the director of technical side to construct the first French pile, with Jules Gerona and Goldschmidt sharing the responsibilities for chemistry. Goldschmidt was asked to purify the CEA's stock of uranium compounds. Gueron was assigned to oversee the conversion of uranium, as well as the production of heavy water and graphite. Young students just out of school were recruited and trained. The recruits were set to study the basics of nuclear engineering. CEA's work included uranium prospecting, the establishment of offices, laboratories, and shops at Chatillon, the processing of minerals and the preparation of extremely pure materials at a gun-powder factory and the construction of a nuclear physics research center.

In 1946, France got ten tons of uranium oxide from Morocco due the efforts of Joliot. At the end of 1947, the French industry under Gueron's direction began to produce high-purity graphite necessary for the piles to use. In 1947, the windy plateau of Christ-de-Saclay was chosen as the center of nuclear studies of the CEA. In 1947, the uranium refining plant at Le Bouchet was completed and work began on the purification of a few tons of uranium oxide.

In December, 1948, the first heavy water pile was built in France under the direction of Joliot. In November, 1949, Goldsmith succeeded in isolating the plutonium at the first French file reactor. In 1952, CEA desired a plan to produce not less than fifty kilograms of plutonium (a quantity sufficient for some six to eight bombs). In 1958, when de Gaulle returned to power, he endorsed the work that had been done and the organization he had founded. In 1959 the French undertook one the most challenging of all types of nuclear engineering projects, a uranium-235 isotope separation plant. In 1960, France made the first plutonium atomic bomb explosion at an experimental center set up in the Sahara.

Joliot was a patriot. In a world where nuclear energy was expected to become the backbone of industrial and military strength, he wanted to build an independent nuclear energy organization for France. He believed that it was dangerous for a single country to monopolize or dominate nuclear power. In July of 1946, Joliot helped found the World Federation of Scientific Workers with Paul Langevin to promote world peace and the control of the nuclear weapons that he had helped create. In a meeting of World Congress of Partisans of Peace, Joliot stated that atomic bombs were a shameful misappropriation of funds. He said that if the effort spent on them were put to peaceful work, science could advance to a point where all of France's electrical power could be supplied by nuclear centers. A few days later, Joliot publicly expressed his unwillingness to work on atomic bomb. Auger openly objected to the building of an atomic weapon by France. Perrin felt that the few bombs that France might eventually build would be more dangerous than useful to possess. Goldschmidt thought the use of atomic bomb in Japan could save hundreds of thousands of dead that an Allied landing would have entailed. In 1946, one or another of the chief CEA scientists presented as an adviser to the French delegation at the United Nations meetings about the nuclear disarmament negotiations hoped that an international control system could be set up. In May, Goldschmidt suggested that the members of the Scientific Committee themselves translate the book *One World or None,* a compilation of articles by Bohr, Compton, Einstein, Szilard, Urey and others to warn public of the perils of nuclear weapons.[8] However, Goldsmith believed that his country should stay in the vanguard of nuclear arms race. Some of the scientists, including Goldschmidt, Gueron, and Kowarski, were willing to produce plutonium even if it might be usable for weapons in the distant future.

Soviet Union's Atomic Bomb

In 1940, Igor Kurchatov, a nuclear physicist, alerted his government to the possible military significance of nuclear fission. In July, on the basis of Vladimir Vernadskii's memoranda, the uranium Commission was created. Vitalii Khlopin was named chairman, with Vernadskii and Abram Ioffe as his deputies. The commission determined what research the Academy should do, organized the development of methods for separating isotopes of uranium, and initiated research into the controlled nuclear fission. By the end of May of 1941, Soviet scientists had done research work on chain reaction calculations, methods of isotope separation, and the use of fluorescent tests for detecting uranium.

At the end of 1941 Georgii Flerov, one of physicists discovering the spontaneous fission, deduced from the silence of nuclear physicists in the United States that America was involved in a big secret project concerning nuclear weapons. Worrying more about Nazi Germany, he wrote to the other physicists, the State Defense Committee and even to Stalin to persuade the Soviet government to set up a nuclear project. In one of his letters to Kurchatov, he proposed a model of atomic bomb. Fuchs, a physicist working on British atomic bomb project, informed of the Soviet Union the work done in Britain. At the end of 1942, Stalin decided to start nuclear research which led to the production of atomic bomb in the Soviet Union.

In January of 1943, Boris Kurchatov spoke to Mikhail Pervukhin of the danger that Germany might build an atomic bomb. In February, at the suggestion of Pervukhin and Kurchatov, the State Defense

Committee adopted a special resolution on the organization of research into the utilization of nuclear energy for military purposes. In March, Kurchatov wrote two memoranda to organize research, outlined particular questions to be investigated, and suggest a path to a Soviet bomb.

In April, a new laboratory, No. 2 Laboratory, was set up under the direction of Kurchatov for the nuclear project. In July, Kurchatov wrote another memorandum about the intelligence on the Manhattan project from Fuchs, in which he reviewed a list of reports on various topics: methods of isotope separation, the uranium heavy water and uranium-graphite pile, transuranic element, and the chemistry of uranium. Alan Nunn May, a physicist who had joined the nuclear team in the Montreal Laboratory, sent information to Soviets to ensure that the development of atomic energy was not confined to the United States. He handed over macroscopic amounts of U235, a slightly enriched sample, and some U233.

Kurchatov decided to use graphite as a moderator. He took direct charge of the work on the uranium-graphite system. Isai Gurevich and Isaak Pomeranchuk, theoreticians in Laboratory No. 2, worked out a theory for a heterogeneous pile in which uranium lumps were distributed in the graphite moderator in a lattice configuration. In 1943 Kurchatov began to assemble a group of physicists and engineers to work on the design of the atomic bomb. In April 1945, Kurchatov wrote another report about the implosion method after reviewing information from the Fuchs at Los Alamos. In June, Fuchs provided a detailed description of the plutonium bomb. This included the components of materials, dimensions, and a sketch of a design.

In August, a special Committee for the Soviet atomic bomb was created, chaired by Lavrentii Beria. Kurchatov remained as scientific director of the project. In October, Kurchatov and Iulii Khariton decided to use the information Fuchs had supplied as the design of the first Soviet bomb. At the end of 1945, the uranium plant was ready to produce uranium metal under the direction of Nikolaus Richl, a scientist who was brought to Soviet from Germany in 1945. In December 1946 the first reactor, directed by Kurchatov, went critical. This reactor was designed to study the production of the plutonium needed for atomic bomb. In August 1947, Kurchatov and his colleague succeeded in separating plutonium from uranium oxide irradiated in the F-1 reactor.

In 1945, Kurchatov set up a branch of the laboratory away from Moscow to work on the design and development of atomic bombs. Khariton was appointed as chief designer and scientific director. He recruited Kirill Shchelkin, head of the laboratories at the Institute of Chemical Physics, to study detonation lenses for plutonium bombs, and Zel'dovich, one of the most versatile theoreticians, to study how plutonium would behave under pressures of high pressure and temperature, and to do calculations of critical mass. V. A. Tsukerman, who worked at the Institute for the Study of Machines, was recruited to study diagnostics of explosions. V. A. Turbiner, a designer and engineer, joined the project to head the design group. In 1946, Turbiner and his group prepared a technical drawing of a bomb. In July General N. L. Dukhov, an experienced mechanical engineer, was appointed deputy scientific director and deputy chief designer. V. I. Alferov, director of a plant that produced naval mines and torpedoes, was recruited as a deputy to Khariton. In 1948, V. S. Komel'kov, who had worked in electrophysics, was brought to the installation. He succeeded in designing a new detonation caps that could be fired synchronously. The plutonium metal hemispheres were fabricated under Bochvar's direction at Cheliabinsk-40 in June 1949. After George Flerov conducted dangerous critical mass experiments, Soviet Union exploded her first plutonium atomic bomb on the steppes of Kazakhstan, on August 29, 1949.

At an anti-Fascist rally of scientists in Moscow on October 12 1941, Peter Kapitsa talked about the possibility of atomic bombs and suggested that scientists should warn people of this danger. In a speech to the third Anti-Fascist Meeting of Soviet Scientists in June 1944, Kapitsa argued that scientists had a role to play in securing international peace. The scientists who took part in the project believed that the Soviet Union needed its own bomb in order to defend itself and welcomed the challenge of proving the worth of Soviet science by building a Soviet atomic bomb as quickly as possible. Lev Al'tshuler, Vikto Adamskii and Andrei Sakharov thought that the Soviet atomic weapons were needed to balance power in the world. Khariton thought atomic bomb was necessary to secure the defense of the country. Nikolai Dollezhal, the chief designer of the first production reactor, regarded the bombing of Hiroshima as a repulsive act of cynical anti-humanism. He thought the Soviet Union needed all the means of attack posed by the aggressor to secure the country. Dollezhal's viewpoint was shared by other scientists like Lev Artsimovich, Vitalii Khlopin, Andrei Sakharov and Kurchatov. They regarded themselves as soldiers in a new scientific war. In 1960's, Igor Kurchatov was reported to play an important part in persuading Soviet authorities, particularly Khrushchev, to move toward a nuclear test ban. Kapitza, A. P. Vinovgradov, and V. S. Emel'ianov joined the international Pugwash movement to stop and then reverse the nuclear arms race as its main objective.[9]

Chinese Atomic Bomb

Frederic and Irene Joliot-Curie also felt motivated to help China break the American nuclear monopoly. In the spring of 1949, shortly after the Communist takeover of Beijing, the Chinese government gave the nuclear physicist Qian Sanqiang foreign currency to purchase the country's first nuclear instruments, with the help of the Joliot-Curies, when he attended a peace conference in Europe. In Pais in October 1951, Frederic Joliot-Curie urged the Chinese radiochemist Yang Chengzong to raise the level of consciousness in Beijing about the bomb and its potential significance for China. In early 1955, facing a threat from the United States, the Chinese Politburo launched the nation's nuclear weapons program.

By the year of the nuclear decision, China had available some key scientists who had been trained abroad in nuclear physics. Qian Sanqiang and He Zehui had studied nuclear physics at the Curie Institute in Paris, and Peng Huanwu had studied with Max Born in Edinburgh. Wang Ganchang, a specialist on radioactivity and bubble chambers, studied with Lise Meitner in Berlin. As the leader of the program, Qian Sangqiang recommended Pend Huanwu, his longtime friend and schoolmate, to head the theoretical unit that designed China's first fission and fusion bombs.

In January 1955, Premier Zhou Enlai ordered the Ministry of Education to form a Nuclear Education Leading Group. Professor Hu Jimin and Zhu Guangya organized a Physics Research Section at Beijing University. At the same time, Professor He Dongchang set up the Department of Engineering Physics in Qinghua University. From 1955 to 1958, the ministry recruited hundreds of college seniors majoring in science and technology for these two universities, as well as one in Lanzhou.

To help train them in nuclear physics, the ministry hired Soviet lecturers. Many Chinese studying in the Soviet Union and Eastern Europe shifted their majors to nuclear science and engineering. Moreover, in October and November 1955, the Chinese Academy of Science sent two delegations to the Soviet Union to study the theory and operation of nuclear reactors, cyclotrons, and other equipment. The specialists who were assigned to the nuclear weapons program retained only nominal ties with the academy. The moment they passed into that program's secret world, they fell under the military's control. The Central Military Commission asked science and all scientists to serve the party's policies. These scientists gave their youth and their knowledge to the development of the nuclear weapons program.

On January 17, 1955, the Soviet government had announced that it would help China toward the peaceful uses of atomic energy. In that year, Soviet sent a cyclotron and a nuclear reactor to China. In the mid-1950s, several hundred advanced trainees received general instruction in nuclear physics after the Joint Institute for Nuclear Research was set up in Dubna, near Moscow. Soviet nuclear experts cooperated with Chinese engineers and designers who were busy building an atomic bomb. Within a few months of the January 1955 decision, the Bureau of Architectural Technology was created; Qian Sanqiang was the deputy to supervise construction of the experimental nuclear reactor and cyclotron being supplied by the Soviet Union. In 1956, the Soviet government signed an agreement to help build China's nuclear industries and research facilities.

Soviet, Polish and Hungarian experts taught a cadre of Chinese many well-tested geophysical and geochemical research and development methods. The country's geologists took three years, from 1955 to 1958, to develop the minimal scientific and technical foundation for their all-out hunt for uranium and came relatively close to the international standard for exploration.

In 1958, Lu Fuyan, returning from the Soviet Union, developed a simple and quick method to produce the uranium oxide and tetrafluouride by combining the United States's method with the one used in the

Soviet Union. In July 1960, the Second Ministry chose Professor Wu Zhengkai, the British-trained chairman of the Fudan University Chemistry Department in Shanghai, to supervise the production of the uranium hexafluoride. He studied and tested the production of uranium hexafluoride and the engineering requirements for enriching uranium. In July 1962, Wu Zhengkai and Cao Benxi, a nuclear chemist, succeeded in producing the hexafluoride. In 1962, Wang Chengxiao, a young scientist, accelerated the enrichment process in the Lanzhou plant to move the production timetable ahead to January 1964.

In the summer of 1957, Li Jue was assigned the head of Nuclear Weapons Bureau, known as the Ninth Bureau. Li Jue picked three principal colleagues to run the Ninth Academy: Wu Jilin, Zhu Guangya and Guo Yinghui. Wang Ganchang, Peng Huanwu, and Guo Yonghuai were selected into Ninth Academy. Along with Zhu Guanya, these three men were to become deputy directors of the Beijing institute and then of academy. Then Chen Nengkuan, Deng Jiaxian, and Zhou Guangzhao, Yu Min, Qian Jin and Yu Daquang came. In 1960, Wang was appointed director of a second technological committee of the Ninth Academy. He assumed overall direction of both experiments on the fundamentals of nuclear detonations and on the design and manufacture of the bomb's neutron initiator. Peng Huanwu was appointed as the head of the third technological committee. Guo Yonghuai, a Ph.D. from the California Institute of Technology, was appointed as the head of fourth technological committee. Guo and an engineer named Long Wenguang contributed greatly to the design and testing of the bomb. Most of Guo's work delved into the mechanics of nuclear weapons structure strength, distribution of pressures, and vibration. Chen Nengkuan, helped to complete and test the atomic-bomb explosive assembly. Chen was joined by Fang Zhengzhi in designing the initiator for the first atomic bomb. Cheng and Fang recruited promising graduates from science and engineering departments in China's top universities to work as their research assistants. Deng directed the theoretical section on design of the atomic bomb. In 1960, Zhou Guangzhao, was brought to academy to work with Deng on theoretical design. He did a careful calculation of the probability of the test's success.

In early 1960, Wu recommended dividing the academy into four departments—the Theoretical Department, the Experimental Department, the Design Department, and the Production Department—and forming an integrated technological commission to oversee four high-level technological committees, each in charge of specific bomb production tasks. The first, under Wu Jilin and Long Wenguang, had overall responsibility for designing the bomb's technology; the second, under Wang Ganchang and Chen Nengkuan, for testing the non-nuclear components; the third, under Guo Yonghuai and Cheng Kaijia, for conducting weapons-development experiments; and the fourth, under Peng Huanwu and Zhu Guangya, for working on neutron initiation. These four committees had direct access to higher officials in the academy and, with Li Jue's authority as director of the Ninth Bureau, to ministry leaders in Beijing.

In 1961, Chen and Qian Jin succeeded in designing the explosive assembly for China's first bomb. By the end of 1962, Wang Fangding identified the key element in the initiator. Qian Sanqiang and He Zehui worked out the theories and checked experiments on the making of initiator devices. In the November 1963, Chen succeeded in making explosive assembly and initiator in one unit. By the end of 1962, Deng Jaxian, Zhou Guangzhao and their collaborators had worked out the theoretical principles of implosion, including the use of enriched uranium in the core and the mechanics of high explosives in the bomb assembly. In September 1963, they completed a draft design for the bomb and performed key static tests to verify it. In 1964, Zhu Linfang and his team manufactured the nuclear core for the China's first atomic bomb. On October 1, 1964, China detonated its first atomic bomb at the Lop Nur base.

Conclusion

The previous sections offer a brief description of the history of atomic bomb projects in five nuclear declared countries. Despite the different countries and different ideologies, the activities of scientists showed a similar pattern of motivations, roles, work, and attitudes to the use of atomic and nuclear arms race in atomic bomb projects.

Most scientists in these five countries participated in atomic bomb projects with great enthusiasm. The immigrant scientists, like Peierls and Szilard, initiated atomic bomb projects in the United States and

Britain out of fear that Nazi Germany would build an atomic bomb first. Such thoughts were shared by many host country scientists, like Thomson and Lawrence, and were reinforced by the patriotism of scientists during World War II. The French patriotic scientists, such as Joliot-Curie and Auger, felt it right to inform their government of the potential significance of nuclear energy and atomic bombs and to persuade their government to restart nuclear research as early as possible. They thought this was a way to recover France's prestige and break the monopoly of the United States in this field. Finding out about U.S. secret nuclear research, Soviet Union scientists, such as Kurchatov and Flerov, suggested their country set up an atomic bomb project in 1941. These scientists regarded themselves as soldiers in the new scientific war to defend the security of their country. They also took the atomic bomb as a scientific challenge to the worth of Soviet science and as a tool to balance world power. Many Chinese scientists, like Qian Sangqiang and Zhu Guangya, returned from abroad and devoted themselves to the atomic project to defend the security of their country. Scientists in all five countries, either fearing Nazi possession of an atomic bomb or motivated by patriotism, or both, formed the main stream of those joining atomic bomb projects.

The final success of atomic bomb projects in these countries depended primarily on the hard work of their own scientists. Meanwhile, each of these countries took advantage of the benefits from collaboration with the other countries. After the Quebec Agreement, British scientists directly joined the building of the first American atomic bomb at Los Alamos. The Anglo–American collaboration accelerated the achievement of American atomic bomb in 1945 and also facilitated the British atomic bomb explosion in 1952. French scientists worked in the Montreal Laboratory in support of the British program, giving French scientists solid experience in the field of nuclear science and background to work for their own country. The Soviet Union gained from the espionage of scientists like Klaus Fuchs, who provided important information about the American atomic bomb. China got help from the Soviet Union in the form of instruments, personnel and training.

After the use of atomic bomb in Japan, some scientists like Szilard in the United State, Frisch in Britain, Joliot-Curie in France, and Dollezhal' in the Soviet Union thought it was wrong to use such destructive weapon. Other scientists, like American scientist Lawrence, the British scientist Marshall and the French scientist Goldschmidt, thought it was right to use the atomic bomb to end the war and to bring triumph and peace. In 1949, the Soviet Union exploded its first atomic bomb. The nuclear arms race started. Scientists like Teller in the United State proposed a super bomb project and opposed various attempts to contain the nuclear arms race. Other scientists like Oppenheimer in the United State and Kaptisa in the Soviet Union suggested some effective forms of international nuclear arms control.

In summary, the brief atomic bomb history provided in this essay illustrates an integrated story of scientist's motivations, roles, work and attitudes in the atomic bomb programs of their countries. Today, the world is in a new stage of world peace, and the nuclear scientists are playing and should play an active role in reducing and eventually destroying nuclear arms.

Notes

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