

**Women of the Manhattan Project:
An Explosion in Many Parts**

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Senior Division
Paper

As World War II began in Europe, the interest for harnessing nuclear energy for warfare grew strong. The potential to use chain reactions in large quantities of Uranium to generate a power heretofore unfathomable posed as a threat to all humanity if the utilization of this research were to fall into the wrong hands, namely the Third Reich. This information was brought to the attention to the American Government in the form of a letter written to President Franklin D. Roosevelt by physicists Albert Einstein and Leo Szilard on the eve of the outbreak of the Second World War. This letter urged the American Government to use any and all resources they had to match or counteract this now very real and potentially dangerous threat.¹

This suggestion would not be acted upon until nearly three years later. A research project started at Columbia University in New York City and would later stretch across the country, developing research sites in California, Chicago, New Mexico, Washington, and Tennessee. It would go on to produce bombs that would determine the course of history, inspire scientists the world over to find their true calling, and force standards of American science to expand to recognize what would become their greatest resource that was needed to overcome these odds.

This resource, or secret weapon, was the fierce but small group of women who would contribute to this research project and defy the traditional role of women in American science- which at the time was virtually nonexistent. These female engineers, physicists, Army Corp members, biologists, data analysts, and radiologists would raise standards for female scientific involvement to a level that is still held to this day.

The Manhattan Project served as a catalyst for the confirmation of the role of women in the scientific world and the increased involvement of women in the military.

The Time Bomb

¹ Einstein, Albert. "The Einstein- Szilard Letter". Letter to Franklin D. Roosevelt. 2 Aug. 1939. MS National Archives, Washington, D.C.

With Enrico Fermi's discovery that neutrons could penetrate the nucleus of atoms and produce radioactive isotopes came the realization that atomic energy could potentially be harnessed. In 1934, by shooting neutrons instead of protons at the nucleus of atoms as Ernest Rutherford once did, performing the first successful artificial transmutation, Fermi bombarded Uranium particles and was left with a transuranic element not even he was sure of.² Fermi had unknowingly conducted nuclear fission, and was left with Barium particles and uranium fragments. These particles, which weigh less than Uranium atoms, could only be produced by following Einstein's formula of mass-energy equivalence, where in order to reduce the mass of a particle, energy- an aspect of mass- must be given off.³

Unfortunately this conclusion would not be discovered until four years later, in the Nazi state of Germany. Otto Hahn and Fritz Strassmann performed this procedure.⁴ Under the correct circumstances, the neutrons given off in this action could cause a chain reaction of energy emission from resulting particles, increasing with each step. The first to harness this energy would have the power to change history, and put his enemy at his mercy. On your mark, get set.... go.

A Woman's World

The first to recognize this as nuclear fission was the Austrian female physicist Lise Meitner who along with Marie Curie, and Irene Joliot-Curie set the stage for women in the field of nuclear science. A former longtime colleague of Hahn, Meitner was the first female to have

² Marshall, Leona W., and Enrico Fermi. "On the Interaction Between Neutrons and Electrons". A Physical Review (1947):1139-1146. Physical Review Online Archive. Web. Nov. 24. 2012 <http://Prola.aps.org/lababstract/RRiv721p1139_1>.

³ Einstein, Albert. *Ist Die Trägheit Eines Körpers Von Seinem Energieinhalt Abhängig?* Publication. 13th ed. Vol. 323. Berlin: Annalen Der Ohysik, 1905. *Ist Die Trägheit Eines Körpers Von Seinem Energieinhalt Abhängig?* Annalen Der Physik, 10 Mar. 2006. Web. 12 Jan. 2013.

⁴ Meitner, Lise and Otto R. Frisch. "Disintegration of Uranium by Neutrons: A New Type of Nuclear REaction." Nature. 123.3615 (1939):239-40. Library of Congress. Web. 10 Dec. 2012.

a full professorship in physics in Germany at the University of Berlin. After the Anschluss, or unification of Austria and Germany in March of 1938, all Jewish professors were forced to resign their post. She emigrated to Sweden in July of 1938 with her nephew and fellow physicist Otto Frisch.⁵ Nine months after Meitner and her colleagues discovered fission, World War II began.

Small-scale research projects concerning nuclear energy had already existed in America prior to World War II at the University of Columbia in New York, which focused on nuclear fission; and at the University of California in Berkeley, led by Ernest Lawrence, creator of the cyclotron. Female scientists were present and involved at both of these locations. In an effort to combine the research of these locations and turn the focus toward creating an atomic bomb, when the Manhattan Project began in June of 1942 the Metallurgical Laboratory or “Met Lab” at the University of Chicago was created to centralize the project, and to make the research more covert. The task this research center was entrusted with was to determine if in fact the energy given off in nuclear fission could be continued in chain reactions, and if so, to create fissionable material, and develop a bomb capable of storing and detonating such explosives.⁶

With this movement came Enrico Fermi’s team to the Met Lab which included Leona Woods Marshall. Having just acquired her doctorate degree in molecular spectroscopy, Marshall’s assistance to Fermi at the Met Lab was crucial in the building of the first nuclear reactor or pile, so called because it was built upon stacks or piles of blocks of uranium and graphite. This reactor was built underneath the Stagg Field at the University of Chicago and went critical (capable of producing a self-sustaining chain reaction of nuclear fission) on December 2,

⁵ Howes, Ruth, and Caroline L. Herzenburg. “Their Day In the Sun: Women of the Manhattan Project”. Philadelphia: Temple UP, 1999. Print. 38.

⁶ Rhodes, Richard. *The Making of the Atomic Bomb*. New York: Simon & Schuster, 1988. 526.

1942. After its success, the pile was moved to the more remote location of the forest preserves just outside of Chicago known as Site A. Marshall became pregnant after her marriage to fellow physicist John Marshall in July of 1943, and worked at Site A until two day before the birth of her son. She remained working at the Met Lab until the transfer of her husband to the Hanford site in Washington State which was responsible for building larger reactors and producing the radioactive fissile element plutonium.⁷

Jane Hall was another female physicist involved in the Met Lab and Hanford research site. After receiving her PhD from the University of Chicago in 1942, she spent the years 1943 and 1944 working with scientists from Columbia University at the Met Lab. In 1944, she moved to the Hanford Engineering site with her husband John Hall and became a state supervisor for the DuPont Co., where she headed the Special Studies Section and assessed the safety of the reactors, and the dangers of plutonium inhalation. She then moved back to the Argonne Laboratory at the Met Lab and served as the associate physicist and assistant to Enrico Fermi at the age of 30.⁸

Chien Shiung Wu traveled to the United States from China to pursue a graduate degree in physics from the University of California, Berkeley. After receiving her PhD, she was recruited by the United States government to work with other physicists at Columbia University in the hopes of making an atomic bomb. Her research helped develop fuel from uranium ore that would fuel the atomic bomb.⁹

The Unholy Trinity

⁷ Howes, Ruth, and Caroline L. Herzenburg, 38-41.

⁸ "Jane Hamilton Hall." *Los Alamos National Laboratory*. U.S. Department of Energy, n.d. Web. 13 Jan. 2013.

⁹ Wu, Chien-Shiung "Experimental Test of Polarity Conservation in Beta Decay" *A Physical Review* (1957): 1413-1415. *Physical Review Online Archive*. Web. Nov. 24, 2012. <http://prola.aps.org/abstract/PR/v/051.41p1413_1>

The third main research site of the Manhattan Project was Los Alamos Laboratory in Los Alamos, New Mexico although its exact location was kept from the public. Directed by Julius Robert Oppenheimer, the laboratory was created for the design of nuclear weapons. Here, bombs of mass destruction that would change the course of history would be created.¹⁰ In 1944, Enrico Fermi was persuaded by Oppenheimer to leave the Met Lab and assist in Project Y, which would eventually produce the results of the Trinity test, the first detonation of a nuclear device at Alamogordo on July 16, 1945.¹¹ Less than a month later the atomic bomb code named “Little Boy” was dropped on Hiroshima to be followed three days later with the dropping of the atomic bomb code named the “Fat Man” on Nagasaki. These bombings resulted in the deaths of 150,000-246,000 Japanese people due to both the immediate and lasting effects of the bombs.¹²

Among the physicists present at this Laboratory was Elizabeth Riddle Graves. “Diz” had acquired her doctorate in physics from the University Chicago and then proceeded to contribute to the research of the Met Lab during the years 1942 and 1943.¹³ She and her husband Al Graves then moved to the Los Alamos Laboratory site. She was seven months pregnant at the time. She was so dedicated to her work that while she was calculating the time between her contractions, she was finishing writing notes on an experiment. She and her husband observed and monitored the radioactivity of the explosion (which went off of their Geiger counter) from a safe distance. Shortly after her husband showed symptoms of radiation overexposure after a lab accident, she was offered the position of one of the five commissioners for the Atomic Energy Commission, having been nominated by the president, and approved by the Senate. She turned down this offer

¹⁰ Kelly, Cynthia C. *Oppenheimer and the Manhattan Project*. Singapore. World Scientific, 2005. Print.54.

¹¹ Fermi, Enrico. “My Observations During the Explosion at Trinity”. 16 July. 1945. National Archives. Washington, D.C.

¹² Rhodes, 847.

¹³ Graves, Elizabeth Riddle “Energy Release from Be 9 (d,a) Lit and the Production of Lit”. *Physical Review* (1940) Ph.D. Dissertation.

to remain with her husband and at her position at Los Alamos. This enabled her to work there and continue her scientific research for 30 more years until her retirement in 1972.

After being an assistant to Enrico Fermi, Jane Hall came to the Los Alamos Laboratory and became involved in the Plutonium reactor project, which remained a lifelong interest of hers. Her technical and leadership achievements during her 25 years at Los Alamos led to her appointment as associate director of the Laboratory.¹⁴

Elda Anderson was a physics professor and department chair at Milwaukee-Downer College, where she earned her doctorate in physics in 1941. After working for the Manhattan Engineering District, she joined the Manhattan Project in Los Alamos. She studied spectroscopy with the cyclotron group and the experimental measurement of neutron cross-sections, which was essential in the development of the atomic bomb. She also was an eyewitness to the Trinity test.¹⁵

Women in the Military

In 1942 the Women's Army Corps began as a smaller branch of the army that women were eligible for. As a government funded project, the U.S. Army Corps of Engineers was entrusted with the task of aiding the United States create an atomic bomb during World War II. This included the construction of the cross-country research sites, and at \$2 million, would be the most expensive public work program the government had ever taken on at that point. Members of the Women's Army Corps were assigned to assist the U.S. Army Corps of Engineers. Under the command of Brigadier-General Leslie R. Groves 400 WAC members assisted the Manhattan Engineering District by performing clerical, technical and administrative work. The work of the Corps varied from a telephone operator, to cryptographers, to technical

¹⁴ Stockton, Bill. "Dr. Jane Hamilton Hall." *Schenectady Gazette* [Schenectady] 13 Nov. 1970: 19. Print

¹⁵ Howes, Ruth, and Caroline L. Herzenburg. 35.

mechanics.¹⁶ Each member of the Women's Army Corps played a significant role in making the Manhattan Project a success, and in turn, the Manhattan Project helped establish and show the use of the Corps in its earliest days.¹⁷ With a large percentage of American men fighting overseas, female military members became invaluable as a resource for the carrying out of domestic government operations. This involvement helped lead to greater participation of females in the military, an effect that is able to be seen today in the latest news of the ban being lifted from women engaging in combat.

The Aftermath

The bombings of Hiroshima and Nagasaki were the first indication to some of the participants of the Manhattan Project of what exactly they were working on, and the impact they had made on the fate of the war. Ethical and moral tensions grew, and called for the suspension of the production of any more weapons capable of such catastrophic results. After the surrender of Japan to the Allied Forces and the resulting end of the war, men returned home in need of jobs, and expected the women who had risen to the challenge of sustaining a nation to hand them over willingly. Though some of the women workers accepted this, some female scientists were not going to be demoted to their positions (and salaries) before the war, and were not willing to accept that this major event in their lives, where they had found equal partners in their husbands and developed a true sense of self, could be so easily forgotten. Although many women were proud of the significant contributions they made, they felt they were unable to speak out about their accomplishments because of the secret nature of the Project, the political and social tension of such a subject in a war-wizened nation, and the necessity to justify their work as something

¹⁶ Ibid., 148.

¹⁷ Boyce, Westray Battle. "A Message to The Members of the Women's Army Corps Assigned to the Manhattan Project." Letter to Women's Army Corps. 6 Sept. 1945.

other than being responsible for millions of deaths.

Though many went back to their housewife duties, some were able to use the connections they made during the war to acquire posts at laboratories and universities. The involvement of women in a scientific study as monumental as the Manhattan Project challenged generations of female scientists that would come after them. Though most of the women did not hold major positions in the research above assistants or technicians, they still made remarkably important contributions to the scientific world. The fight to remain a part of scientific society was still prevalent even after the war ended, due to the return of the male workforce, and its expectations that the woman's place was in the home, no matter what she may have achieved while the men were gone.

Female scientists such as Maria Goeppert Mayer built off of discoveries made in the Manhattan Project to eventually win Nobel Prizes in physics, and pursue their scientific careers.¹⁸ Elda Anderson was recruited by Oak Ridge National Laboratory to take command of nuclear health and safety training. An award that bears her name is given to members of the profession who show devotion and significant contributions to Health Physics.¹⁹ Other women, like Katherine Lanthrop managed to have it all by combining their family life with their work. She raised five children while working at the Argonne Cancer Center at the University of Chicago after working as an associate biochemist at the Argonne National Laboratory during the Manhattan Project.²⁰ The continuance of scientific interest shown by women after the war implies that the Manhattan Project had a direct impact on the future of female scientists. These

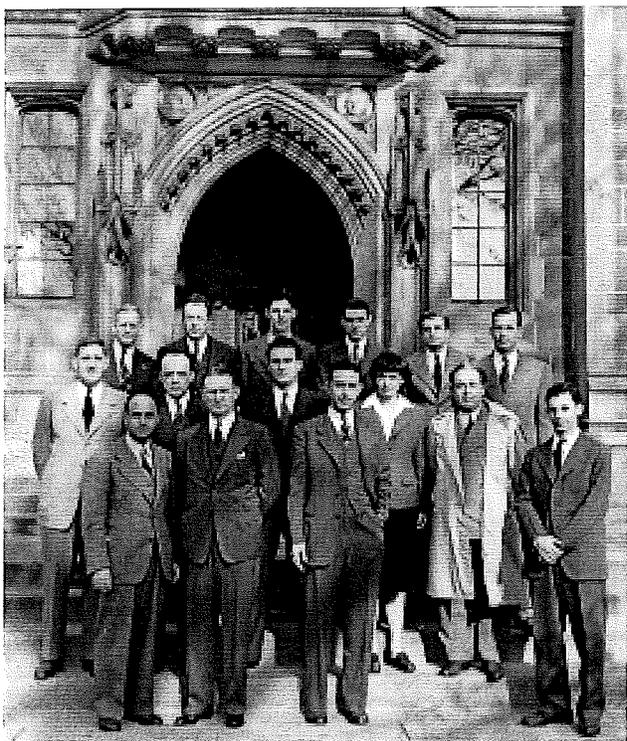
¹⁸ Mayer, Maria G. "On Closed Shells in Nuclei" U.S. Atomic Energy Commission (1948). Research and Development of the U.S. Department of Energy. Web. Nov. 24. 2012.

¹⁹ Howes, Ruth H., and Caroline L. Herzenburg, 192.

²⁰ Ibid., 193.

brave women have continued to pass the torch of the demand of acceptance for women in the scientific world, defying standards and stigmas one at a time.

Appendix I



The Met Lab reactor team at the University of Chicago. In the second row, third from the right is Leona Woods Marshall, the only female on the team.

Appendix II

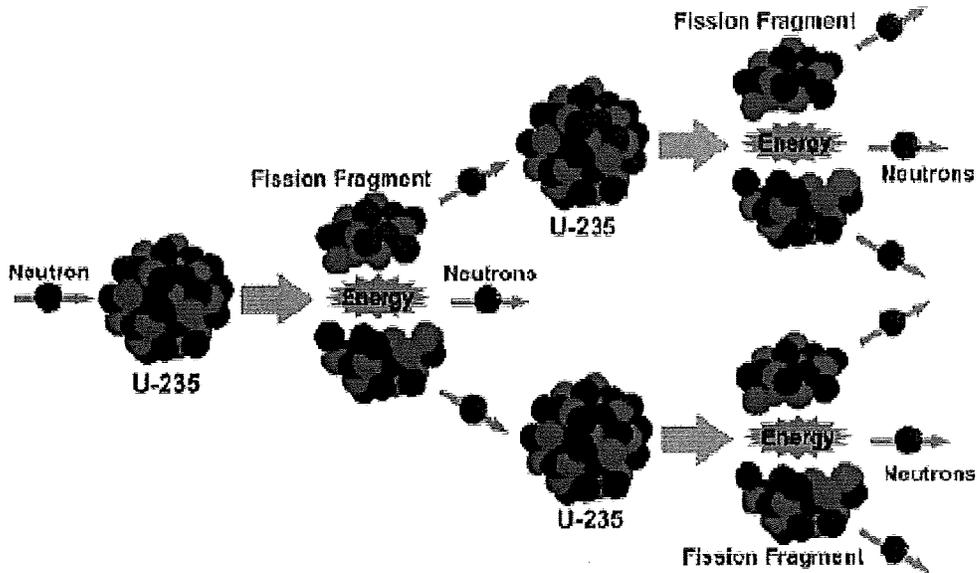


Chart explaining the process of self-sustaining nuclear fission, the long sought after information that was harnessed, and was the power behind weapons made during the Manhattan Project.

Appendix III

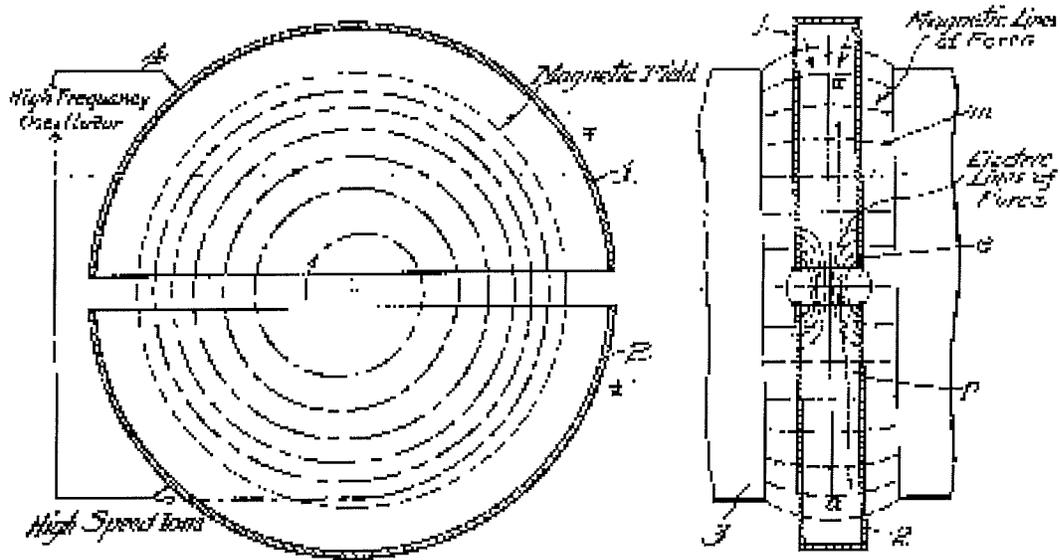


Chart of the original cyclotron developed by Ernest Lawrence at the University of California, Berkeley.

Annotated Bibliography

Primary Sources

Anderson, Elda "Education and Training of Health Physicists." *Radiology* (January 1945): 83-87. Center for the History of Physics at the American Institute of Physics in New York City. Web. 10 Dec. 2012.

-Journal Entry of Elda Anderson, part of the Los Alamos team responsible for creating the atomic bomb. She measured particles produced by the cyclotron and later became interested in the health effects of radiation and health physics.

Boyce, Westray Battle. "A Message to The Members of the Women's Army Corps Assigned to the Manhattan Project." Letter to Women's Army Corps. 6 Sept. 1945.

-A Congratulatory message from Col. Boyce of the Women's Army Corps thanking one of the 425 enlisted women in the corps for their service. This was important to my project because it helped demonstrate the increase of female involvement in the military due in part to the Manhattan Project.

Einstein, Albert. "The Einstein- Szilard Letter". Letter to Franklin D. Roosevelt. 2 Aug. 1939. MS National Archives, Washington, D.C.

-Message that motivated the U.S. Government to start conducting research in the field of Nuclear Science. This was what originally sparked the interest in forming a government sponsored experiment such as the Manhattan Project, the basis for my project.

Einstein, Albert. *Ist Die Trägheit Eines Körpers Von Seinem Energieinhalt Abhängig?* Publication. 13th ed. Vol. 323. Berlin: Annalen Der Ohysik, 1905. *Ist Die Trägheit Eines Körpers Von Seinem Energieinhalt Abhängig?* Annalen Der Physik, 10 Mar. 2006. Web. 12 Jan. 2013.

-This source is the original journal in which Albert Einstein first states his theory of Mass-Energy Equivalence and is used in reference to the explanation of nuclear fission that pertains to the bombs made in the Manhattan Project.

Fermi, Enrico. "My Observations During the Explosion at Trinity". 16 July. 1945. National Archives. Washington, D.C.

-Provides a description of an eyewitness of the Trinity Test on the day it occurred. This shows one of the main parts of the Manhattan Project, and would also be the basis for other

nationally funded laboratories dedicated to pursuing experiments similar to that of the Trinity Test.

Graves, Elizabeth Riddle “Energy Release from Be 9 (d,a) Lit and the Production of Lit”. Physical Review (1940) Ph.D. Dissertation.

-The thesis of a dissertation of Elizabeth Riddle Graves which granted her a Ph.D. in Physics. Graves was a member of the Metallurgical Laboratory with Enrico Fermi in 1943. She and her husband measured radioactive fallout from the Trinity Test. This reference was important to my project because it is an example of the kind of work that helped make women more respected in the field of science through the Manhattan Project.

Harrison, George L. “Trinity Test”. Letter to Henry L. Stimson. 17 July, 1945. MED Records.

-Government record of the importance of the Trinity Test. This shows that the government was significantly involved with the project, and felt the need to utilize the military in their pursuits (including women.)

Joliot-Curie, Frederic and Irene “Chemical Evidence of the Transmutation of Elements” Lecture. 12 Dec. 1935. www.nobelprize.org.

-Speech given by Irene and Frederic Joliot-Curie after being awarded the Nobel Prize for Chemistry for their discovery of Artificial Radioactivity. This is an example of the beginning of women being recognized for their scientific achievements.

Lawrence, Ernest O. Method and Apparatus for the Acceleration of Ions. Patent 1948384. 20 Feb. 1934. Print.

-This source provided the image of the Ernest Lawrence original cyclotron (seen in Appendix III) at the University of Berkeley which helped base motives for and the beginning of initial research of the Manhattan Project,

Marshall, Leona W., and Enrico Fermi. “On the Interaction Between Neutrons and Electrons”. A Physical Review (1947):1139-1146. Physical Review Online Archive. Web. Nov. 24, 2012 <http://Prola.aps.org/lababstract/RRIV721pl139_1>.

-A Journal article published by Fermi with contribution from Leona Woods Marshall, one of the female scientists involved with the Manhattan Project. She was one of the key women in the movement of the female acceptance of female scientists.

Mayer, Maria G. “On Closed Shells in Nuclei” U.S. Atomic Energy Commission (1948). Research and dEvelopment of the U.S. Department of Energy. Web. Nov. 24, 2012.

-Report by prominent female physicist Maria Goeppert-Mayer. She was awarded the Nobel Prize for Physics in 1963. This was an important reference piece because it showed the use of information from the Manhattan Project to bring further notoriety to women scientists.

Meitner, Lise and Otto R. Frisch. "Disintegration of Uranium by Neutrons: A New Type of Nuclear REaction." *Nature*. 123.3615 (1939):239-40. Library of Congress. Web. 10 Dec. 2012.

-Letter written by Lise Meitner, the first to explain Nuclear Fission. She is an important figure to recognize because she was Germany's first female Professor of Physics. Artificial Element 109 is named for her.

Reactor Team from the University of Chicago. 1946. Photograph. Los Alamos National Laboratory, Los Alamos, NM. lanl.gov. Web.

-Photograph of the Chicago team showing Leona Woods Marshall as the only female amongst 14 other male physicist working on the Manhattan Project. This gives a visualization of how outnumbered female scientists were at this time.

Stockton, Bill. "Dr. Jane Hamilton Hall." *Schenectady Gazette* [Schenectady] 13 Nov. 1970: 19. Print

-This source provided information about Jane Hall, one of the most prominent female scientists of the Manhattan Project.

United States Defense Nuclear Agency. Project Trinity, 1945-1946. Washington, D.C. Agency, 1946. Print

-Gives accounts of the military and civilian proceedings of the Trinity Test. This was important to my project because it also gives testimonies from female members of the military.

Quimby, Edith H. "Physical Factors in Interstitial Radium Therapy" *American Journal of Roentgenology and Radium Therapy*: 306-316. UCLA. Web. Nov. 24, 2012. <http://cwp.library.ucla.edu/Phase2/Quimby,_Edith_Hinkley@842345678.html>

-Proposes different uses for information discovered in the Manhattan Project. This was important because it shows the use of information from the Manhattan Project being utilized for further female scientific study.

Wu, Chien-Shiung "Experimental Test of Polarity Conservation in Beta Decay" *A Physical Review* (1957): 1413-1415. *Physical Review Online Archive*. Web. Nov. 24, 2012. <http://prola.aps.org/abstract/PR/v051,i41p1413_1>

-Journal article published by scientist inspired by female involvement in Manhattan Project.

Secondary Sources

Howes, Ruth, and Caroline L. Herzenburg. "Their Day In the Sun: Women of the Manhattan Project". Philadelphia: Temple UP, 1999. Print.

-Provides information about how the Manhattan Project changed the face of American

science, and the women who helped make this possible. This book was important to my project because it helped to highlight certain female scientists and the works that helped make them a success.

Kelly, Cynthia C. "The Manhattan Project". New York: Black Dog & Leventhal, 2007. Print.

-This source provides information about the scientists, historians, and eyewitnesses of the Manhattan Project. This was important to my project because it helped me recognize the lack of female scientists while researching scientists involved in the Manhattan Project.

Kelly, Cynthia C. Oppenheimer and the Manhattan Project. Singapore. World Scientific, 2005. Print.

-Provides information about the forming of the Manhattan Project. This resource helped me to recognize key points and causes of the formation of the Manhattan Project,

MacPherson, Malcolm. Time Bomb: Fermi, Heisenberg, and the Race for the Atomic Bomb. New York: Dutton, 1986. Print.

- This source provides material about the scientists involved with the Manhattan Project. This source also brought to my attention the low number of female scientists involved in the Manhattan Project.

Rhodes, Richard. The Making of the Atomic Bomb. New York: Simon & Schuster, 1986. Print.

- This source provided information about the atomic bomb and the effects it had.

Rodden, Clement J. Analytical Chemistry of the Manhattan Project. New York: McGraw-Hill. 1950. Print.

-This information provided information about the chemistry behind the Manhattan Project. This resource was important to my project because it helped me understand the process behind the Manhattan Project and the chemists that had a hand in making it possible.

World Mysteries. N.p., 25 Apr. 2005. Web. 30 Jan. 2013.

-This source provided an image used in Appendix II, and helped further explain the process of Nuclear Fission that was experimented with in the Manhattan Project.