TIMELINE: Bohr, Heisenberg and The Bomb

October 7, 1885: Niels Bohr Born in Copenhagen, Denmark

1895: J.J. Thomson discovers the electron, the extremely light, negatively charged particles orbiting inside the atom which give it its chemical properties.

1896: First Nobel Prizes Established. "Near the end of the nineteenth century many physicists believed that physical theory had been virtually completely discovered." Website: http://www.benbest.com/science/quantum.html

1900: Quantum Theory - Energy as Discrete Packets
Max Planck discovers that heat energy is not continuously variable, as classical physics assumes. There is a smallest common coin in the currency, the quantum, and all transactions are in multiples of it.

1905: Einstein's Photoelectric Effect
Albert Einstein realizes that light, too, has to be understood not only as waves but as quantum particles, later known as photons.
"Einstein sent to the Annalen der Physik, the leading German physics journal, a paper with a new understanding of the structure of light...." Website:
http://www.aip.org/history/einstein/great1.htm

December 5, 1901: Werner Heisenberg Born in Wurzburg, Germany

1910: Ernest Rutherford shows that the electrons orbit around a tiny nucleus, in which almost the entire mass of the atom is concentrated.
"By the early 20th century, there was rather compelling evidence that matter could be described by an atomic theory...." Website: http://www.lbl.gov/abc/wallchart/chapters/02/1.html

May 1911: Bohr Receives Doctorate from University of Copenhagen

August 1, 1912: Niels Bohr and Margrethe Norlund married in a brief civil ceremony. Their marriage would produce six sons.

1913: Niels Bohr realizes that quantum theory applies to matter itself. The orbits of the electrons about the nucleus are limited to a number of separate whole number possibilities, so that the atom can exist only in a number of distinct and definite states.

June 28, 1914: Archduke Ferdinand assassinated in Sarajevo. World War I begins, casualties quickly mount.

1915: Einstein Postulates General Theory of Relativity

November 11, 1918: Armistice, Germany surrenders

October 1920: Werner Heisenberg Enters University of Munich.

1922: Mussolini Marches into Rome and Forms Fascist Government

June 1922: Bohr and Heisenberg meet for first time when Heisenberg challenges Bohr during Gottingen lecture series.

December 11, 1922: Bohr Receives Nobel Prize: "For his services in the investigation of the structure of atoms and of the radiation emanating from them." Website:
http://nobelprize.org/physics/laureates/1922/index.html

September 1924: Heisenberg Works in Copenhagen
Heisenberg begins research fellowship at Bohr's institute in Copenhagen.

1924: Louis de Broglie in Paris suggests that, just as radiation can be treated as particles, so the particles of matter can be treated as a wave formation.

1925: Quantum Mechanics Formulated: Werner Heisenberg abandons electron orbits as unobservable, completing paper on quantum mechanics. Max Born finds a mathematical formulation in terms of matrices for what can be observed -- the effects they produce upon the absorption and emission of light.
"Quantum mechanics is a mathematical theory that can describe the behavior of objects that are roughly 10,000,000,000 times smaller than a typical human being...." Website:
http://rugth30.phys.rug.nl/quantummechanics/

1926: The Wave Equation Solution
Erwin Schrodinger finds the mathematical equation for the wave interpretation, and proves that wave and matrix mechanics are mathematically equivalent

1927: Heisenberg's Uncertainty Principle
Heisenberg demonstrates that all statements about the movement of a particle are governed by the uncertainty relationship: the more accurately you know its position, the less accurately you know its velocity, and vice versa.
"The more precisely the position is determined, the less precisely the momentum is known in this instant, and vice versa -- Heisenberg, uncertainty paper, 1927" Website:
http://www.aip.org/history/heisenberg/p08.htm

1928: The Copenhagen Interpretation: Bohr relates Heisenberg's particle theory and Schrodinger's wave theory by the complementarity principle, according to which the behavior of

an electron can be understood completely only by descriptions in both wave and particle form. Uncertainty plus complementarity become established as the pillars of the Copenhagen (or 'orthodox') interpretation of quantum mechanics.

1927: Bohr and Heisenberg Defend Principles of Complementarity at Volta Conference, Lake Como

October 1929: New York Stock Market Crashes
The Great Depression starts.

August 1931; Ernest Lawrence and M. Stanley Livingston of the University of California at Berkeley develop the first cyclotron for smashing atoms.
"The First Cyclotron" Website: http://www.aip.org/history/lawrence/first.htm

February 1932: James Chadwick discovers the neutron - a particle which can be used to explore the nucleus because it carries no electrical charge, and can penetrate it undeflected.

1932: Heisenberg opens the new era of nuclear physics by using neutron theory to apply quantum mechanics to the structure of the nucleus.

January 1933: Adolph Hitler becomes Chancellor of Germany.

November 9, 1933: The 1932 Nobel Prize in Physics was announced on November 9, 1933. Werner Heisenberg receives Nobel Prize for Physics."For the creation of quantum mechanics, the application of which has, inter alia, led to the discovery of the allotropic forms of hydrogen...." Website: http://nobelprize.org/physics/laureates/1932/

1934: The Transmutation of Uranium: Enrico Fermi in Rome bombards uranium with neutrons and produces a radio-active substance which he cannot identify.

1937: Bohr explains the properties of the nucleus by analogy with a drop of liquid.

January 1939: Splitting the Atom – Fission: Lise Meitner and Otto Frisch in Sweden apply Bohr's liquid drop model to the uranium nucleus, and realize that it has turned into barium under bombardment by splitting into two, with the release of huge quantities of energy.

February 1939: Fission Produces Neutrons: Bohr and John Wheeler at Princeton realize that fission also produces free neutrons. These neutrons are moving too fast to fission other nuclei in U-238, the isotope which makes up 99% of natural uranium, and will fission only the nuclei of the U-235 isotope, which constitutes less than 1% of it.

"It is well known that the discovery of nuclear fission in 1938 had far reaching, even revolutionary effects on world politics. It certainly led to a change of thinking about warfare...."
Website: http://www.physics.ucla.edu/~moszkows/np30/fission2.htm

1939: Nuclear Chain Reaction Possible
Frederic Joliot and Irene Joliot-Curie in Paris and Fermi in New York demonstrate the release of two or more free neutrons with each fission, providing the possibility of a chain reaction in pure U-235.

May 1939: Bohr leaves safety of US to return home and organize help for fleeing German-Jewish scientists.

August, 1939: Einstein writes letter to President Roosevelt warning that Germany may be developing atomic weapons.
Read "Einstein's Letter to FDR" Website: http://www.atomicmuseum.com/tour/aa3.cfm

September 1939: World War II Begins
Germany invades Poland. Nazis commence serious research into the military possibilities of fission."When Germany invaded Poland in 1939, Heisenberg was already drafted into a reserve mountain infantry unit..." Website: http://www.aip.org/history/heisenberg/p11.htm

1940: Critical Mass is Calculated
Otto Frisch and Rudolf Peierls in Birmingham calculate, wrongly but encouragingly, the minimum amount of U-235 needed to sustain an effective chain reaction.

April 1940: Germany Invades Denmark
Germany invades and occupies Denmark.
"German troops occupied Denmark within a few hours on the morning of 9 April 1940." Website

January 1941: Plutonium Discovered
Glenn Seaborg and others at the University of California at Berkeley discover Plutonium, a man-made heavy metal ideal for use in nuclear weapons.
"The Discovery and Isolation of Plutonium" Website: http://chemcases.com/nuclear/nc-04.htm

September 1941: Meeting in Copenhagen
Heisenberg travels to occupied Copenhagen to meet with Bohr.

December 7, 1941: Japan Attacks Pearl Harbor
United States enters the war.

1942: Enrico Fermi in Chicago achieves the first self-sustaining chain reaction, in a prototype reactor.

"In 1942 the Italian-born American physicist Enrico Fermi and his coworkers at the University of Chicago produced the first controlled self-sustaining fission reaction. ..." Website:
http://search.eb.com/nobel/micro/431_68.html

September 1942: Manhattan Project Gets Director: Colonel Leslie R. Groves appointed Director of the Manhattan Project. Atomic bomb program given top priority.
"The quest for nuclear explosives, inspired by the fear that Hitler's Germany might invent them first, was an epic, top-secret engineering and industrial venture in the United States during World War II..." Website

March, 1943: Dr. J. Robert Oppenheimer arrives at Los Alamos as director of new lab. Responsible for designing and building the atomic bomb.

September 1943: Bohr and family escape from Denmark by fishing boat.

February 1944: Niels Bohr arrives in Los Alamos to work on atomic bomb.

June 6, 1944: D-Day
Normandy invasion by Allied forces.

August 1944: Bohr and Roosevelt Talk. Bohr advises President Roosevelt that atomic energy should be developed with close international cooperation, or an arms race will result. His advice is ignored.

May 3, 1945: Heisenberg is arrested by invading U.S. forces at his home in Urfeld, Germany.
May-October 1945: Heisenberg held in custody with other German atomic scientists at Farm Hall, an estate in England. Their conversations are secretly taped.
"The Secret Recordings at Farm Hall" Website:
http://www.childrenofthemanhattanproject.org/MP_Misc/Bohr_Heisenberg/bohr_3.htm

May 8, 1945: War Over in Europe
Germany surrenders. German nuclear scientists are rounded up and held in custody.
"When the Nazi government collapsed in May, 1945, an Allied intelligence mission took into custody nine of the German scientists..." Website:
http://jchemed.chem.wisc.edu/Journal/issues/1997/feb/abs204.html

July 16, 1945 The Trinity Test first atomic explosion
At about 5:29 in the morning the first atomic bomb is exploded near Alamogordo, New Mexico.
"Fifty Years from Trinity. On July 16, 1945, everything changed. Forever." Website:
http://seattletimes.nwsource.com/trinity/

August 6, 1945: Hiroshima Bombed
Atomic bomb dropped on Hiroshima, Japan. 140,000 casualties result.

"Two atomic bombs made by the allied powers (USA and UK) from uranium-235 and plutonium-239 were dropped on Hiroshima and Nagasaki..." Website

August 9, 1945: Nagasaki Bombed

August 10, 1945: U.S. President Harry Truman announces Japan's surrender.

1950: Outbreak of Korean War

1952: US Explodes First Hydrogen Bomb
The "H-Bomb" is 700 times more powerful than the Hiroshima atomic bomb.

1956: Heisenberg's version of 1941 meeting with Bohr is published in Jungk's "Brighter Than a Thousand Suns."
Read "Letter From Werner Heisenberg to Author Robert Jungk" Website:
http://www.childrenofthemanhattanproject.org/MP_Misc/Bohr_Heisenberg/bohr_2.htm

1957-1958: Bohr Reads Heisenberg's Account in Jungk's book and drafts response. Letter is never sent.

November 18,1962: Niels Bohr Dies and is buried in Copenhagen.

1962: Cuban Missile Crisis
US President Kennedy forces Soviet Union to remove nuclear missiles from Cuba.

January 1, 1976; Werner Heisenberg Dies at home in Munich with family and friends.

1995: Nuclear Non-Proliferation Treaty Ratified
US, USSR, and 133 other nations ratify the treaty.

February 6, 2002: Bohr family publishes Niels Bohr's circa 1957 unsent letter to Heisenberg.
"Release of documents relating to 1941 Bohr-Heisenberg meeting" Website:
http://www.nbi.dk/NBA/papers/introduction.htm