APPENDIX B
A CHRONOLOGY OF THE NUCLEAR ARMS RACE

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1919
--June; Rutherford creates oxygen from nitrogen. "Talk softly please. I have been engaged in experiments which suggest that the atom can be artificially disintegrated. If it is true, it is of far greater importance than a war." ($He^4 + N^{14} \rightarrow H^1 + O^{17}$)

1920
--Rutherford speculates on the existence of the neutron at the Royal Society.

1931
--November; Urey discovers deuterium.

1932
--February; Chadwick discovers the neutron; ($He^4 + Be^9 \rightarrow 3He^{4'} + n^1$)

1933
--January 28; Hitler becomes Chancellor of Germany.
--March 4; Roosevelt becomes President of the U.S.
--April; Born, Courant, Franck and many other scientists were compelled to leave the University of Gottingen because of their "Jewish physics;" The "Aryan physics" of Stark and Lenard was not widely accepted by physicsts.
--October; Szilard recollects that "it occurred to me in October, 1933 that a chain reaction might be set up if an element could be found that would emit two neutrons when it swallowed one neutron." This idea was classified as a British patent in 1934 before fission was discovered.

1934
--Artificial radioactivity discovered by Curie/Joliet (with alpha particles) and by Fermi (with neutrons).

1938
--December; Fermi receives the Nobel prize for the discovery of the transuranic elements (actually fission of uranium) and departs for the "new world."
--December 22; Hahn, Strassman, Meitner, and Frisch conclude that the indentifiction of barium implies that the uranium nucleus has been been fissioned by neutrons.

1939
--January to May; Many experiments on uranium fission (a brief list is at the end of this appendix);
--April 29; Conference in Berlin to consider the German

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uranium burner and bomb.
--August 2; Szilard and Teller obtain a letter from Einstein on the possibility of a uranium weapon; Roosevelt receives the letter on October 11, 1939 from Sachs.
--September 1; Hitler invades Poland.

1940
--June 3; Hartek fails to observe neutron multiplication with his reactor in Hamburg (185 kg of uranium oxide, 15 tons of CO_2 ice).

1941
--January; Using the natural uranium (300 kg) reactor in the "virus house" in Berlin, the Germans reject graphite as a moderator since neutrons did not diffuse adequately through the graphite. This mistake caused by impurities in the graphite forced the German program to rely only on the heavy water from Vermork, Norway.
--July; British "Maud" Committee reports that a weapon could be made with 10 kg of U-235; U.S. National Academy of Sciences endorses bomb program.
--August; Hamburg group begins construction of the ultracentrifuge to obtain U-235; some centrifuges explode in April, 1942, but they did obtain 7% enrichment levels by March, 1943.
--October; Bohr and Heisenberg indirectly discuss termination of uranium research.
--December 6; Roosevelt directs substantial financial and technical resources to construct the uranium weapon.
--December 7; Japan attacks Pearl Harbor.

1942
--May; Heisenberg and Dopel observe the first multiplication of neutrons (13%) in Leipzig using 570 kg of uranium and 140 kg of heavy ice.
--December 2; First nuclear chain reaction at Chicago's Stagg Field by Fermi.

1943
--February 28; Vermork heavy water factory destroyed by the allies; the attack of November 19, 1942 failed.
--March 15; Oppenheimer moves to Los Alamos.
--March; Seaborg suggests Pu weapons might be jeopardized by Pu^{240} if it is a spontaneous neutron emitter.
--Resumption of Soviet nuclear experiments.

1944
--August 26; Bohr presents his memorandum on international control of nuclear weapons to Roosevelt (and Churchill).
--November; First batch of spent fuel obtained from Hanford reactors.

--November; Goudsmit's Alsos mission obtains documents in Strasborg from the German bomb project which implied that their rate of progress had diminished.

1945
--January; First Pu reprocessing production run at Hanford.
--January 20; First U-235 seperated at the K25 gaseous diffusion plant, Oak Ridge.
--April 25; U.N. Charter signed by 50 nations in San Francisco.
--May 4; End of war in Europe.
--June 11; The Franck Report on the demonstration of the bomb and its international control was sent to the Secretary of War.
--July 16; U.S. explodes first atomic bomb, Trinity, at Alamogordo, N.M. Electronics equipment shielded by Fermi to avoid EMP pulse.
--August 6, 9; Atomic bombs dropped by U.S. on Hiroshima ("thin man," uranium, 9000 pounds, 10 feet by 28 inches in diameter) and Nagasaki ("fat man," plutonium, 11 feet by 5 feet in diameter).
--August 15; End of war in the Pacific.

1946
--June 14; Baruch presents the Acheson-Lilenthal plan to internationalize the atom to the U.N. "We are here to make a choice between the quick and the dead."
--June 30; First subsurface detonation by U.S. at Bakini.
--July; Demonstrations in Times Square, New York, against nuclear testing.
--December 31; AEC takes over nuclear weapons program from the army.

1948
--April, May; U.S. atomic tests, Eniwetok Atoll.
--November 4, 1948; U.N. General Assembly adopts, 40 to 6, U.S. plan for international atomic control; U.S.S.R opposed.

1949
--April 4; NATO established.
--August 29; First Soviet atomic detonation, in the Ustyurt desert.
--October 30; General Advisory Committee on the AEC recommends that the more powerful atomic bombs should be built rather than the hydrogen bomb.

1950
--January 27; Fuchs confessed that he transmitted atomic secrets to the Soviets.
--January 31; Truman announces the descion to proceed with the H bomb.

--March; Worldwide peace offensive to "ban the bomb" (the Stockholm Appeal) signed by more than 500 million people.
--June 25, 1950 - July, 1953; North Korean army crosses the 38th parallel.

1952
--January; U.N. Security Council establishes Disarmament Committee.
--June; Lawrence-Livermore Laborary established.
--October 3; First British atomic detonation, Monte Bello Islands, Australia.
--October 31; U.S. explodes first fusion device, Mike, of 10.4 Mt at Eniwetok (liquid deuterium, not deliverable).

1953
--March; U.S. above-ground tests start in Nevada.
--May; Representative Springfellow of Utah asks AEC to stop tests at the Nevada Test Site because of public alarm over fallout.
--August 12; First Soviet fusion device exploded on a tower in Siberia (relatively low yield, probably not deliverable, but used LiD).
--Fall; India and Australia propose to U.N. a total ban on nuclear weapons.
--December 8; "Atoms for Peace" speech by Eisenhower at U.N.

1954
--January 21; USS Nautilus, first atomic-powered submarine, launched.
--March; The "Bravo" event; Marshall Islanders affected by fallout from large U.S. tests.
--April; British Parliment petitions Churchill, Eisenhower, and Malenkov to meet on the control of nuclear weapons.
--April 12 to May 6; Oppenheimer hearings that resulted in his denial of access to atomic secrets.
--August 30; Atomic Energy Act of 1954 to emphasize peaceful uses of atomic energy.

1955
--January-December; Reports of increasing fallout.
--May 6; W. Germany joins NATO.
--May 14; Warsaw Pact Organization established.
--August 8-20; First International Conference on Peaceful uses of atomic energy, Geneva.
--November 23; First relatively high yield deliverable Soviet H bomb.

1956
--U.S. National National Academy of Sciences panel finds genetic effects of fallout from nuclear testing to be slight compared with natural radiation background;

Stevenson makes fallout an issue in the U.S. Presidential campaign.

1957
--May 15; First British H bomb exploded at Chirstmas Island.
--July 6-11; First Pugwash Conference advocates test ban; Soviet scientists attend.
--August; AEC inaugurates Plowshare Program for peaceful uses of nuclear explosions.
--September 19; First underground test, Ranier, 1.7 kt.
--October 1; IAEA inaugurated in Vienna.
--October 4; First artificial Earth satellite, Sputnik I, put into orbit by the U.S.S.R.
--December 2; Shippingport reactor reached full power of 60 MW.

1958
--January 1; Euratom (European Atomic Energy Community) established.
--January 31; Explorer I, the First U.S. satellite.
--November, 1958 to September, 1961; U.S., U.K., and U.S.S.R. agree to a moratorium on atomospheric tests.

1959
--June 12; Results on Panel on Seismic Improvement made public; Geneva system assessed effective only above 20 kt; bold research program in seismology recommended.
--September 2; Vela Uniform seismic project established with Department of Defense.
--November 24; U.S. and U.S.S.R. sign a memorandum of cooperation for the utilization of atomic energy.

1960
--February 13; First nuclear test by France, Sahara desert.
--May 1; U.S. spy plane (U-2) shot down over the U.S.S.R.
--July 26; U.S.S.R. sugggets 3 on-site inspections/year as part of a test ban.
--November 15; First Polaris missile launched from a sub.

1961
--January 17; Eisenhower's farewell address.
--February 1; U.S. launched Minuteman I.
--March 31; Pravda suggests use of H bombs to obtain fresh water from Soviet glaciers.
--April 12; Gagarin becomes the first cosmonaut in orbit.
--May 29; U.S. and U.K. agree to draft CTB treaty with 12 on-site inspections/year.
--August; Installation by U.S. of first seismic stations of a network in 60 countries.
--September 1; U.S.S.R. resumes nuclear tests, including a 58 Mt explosion on October 31.

--September 15; U.S. resumes nuclear tests.

1962
--February 20; Glenn becomes the first U.S. astronaut in orbit.
--July 6; Sedan excavation experiment by Plowshare; 10.4 Mt of earth displaced.
--July 8; Electromagnetic pulse (EMP) from the high altitude (400 km above Johnston Island) "Fishbowl" test (1.4 Mt) destroys 300 streetlights on Oahu, Hawaii (1200 km away).
--September 3-7; Tenth Pugwash Conference proposed "black box" for complete test ban (CTB) verification.
--October; U.S. reduces requirement to 8-10 inspections/year.
--October 23 to November 20; Cuban missile crisis and blockade.
--December 19; Khrushchev accepts 2-3 inspections/year and 3 unmanned seismographic stations (black boxes) in the U.S.S.R.

1963
--January; Secret test-ban talks between U.S. and U.S.S.R.
--February 19; U.S. accepts 7 inspections/year provided any mysterious event can be challenged.
--April; Khrushchev withdraws offer of 3 inspections/year.
--June 20; US/USSR sign "hot line" agreement.
--August 5; Limited Test Ban Treaty signed in Moscow by U.S., U.S.S.R. and U.K.; bans nuclear explosions in atmosphere, in space, and underwater.

1964
--August 2; "Gulf of Tonkin" resolution allows U.S. troops to be sent to Vietnam.
--October 16; China (PRC) expodes first atom bomb.
--October 22; U.S. muffling experiment Salmon in a salt dome in Mississippi.

1965
--June; Large Seismic Array (LASA) opened in Montana for nuclear detection.

1966
--January 17; U.S. B-52 bomber crashes near Palomares, Spain with 4 unarmed H bombs.
--September 24; First French H bomb, Tuamoto Islands.

1967
--January 27; Outer Space and Celestial Bodies Treaty bans nuclear weapons being placed in orbit.
--February 14; Treaty for Prohibition of Nuclear Weapons

in Latin America signed in Mexico City (Tlatelolco); all the Latin nations must ratify for the treaty to entr into force.
--June 17; First Chinese H bomb exploded in the atmosphere.
--June 23-25; Johnson and Kosygin hold talks in Glassboro, N.J.
--December 10; Gasbuggy Plowshare explosion for gas production, New Mexico.

1968
--July 1; The Non-Proliferation Treaty on nuclear weapons (NPT) opened for signature.
--August; Soviet GALOSH ABM system deployed around Moscow.

1969
--July 20; U.S. Appollo 11 landed on moon.
--November 3; Committee on Disarmament reports to U.N. on comprehensive test ban; proposes worldwide exchange of seismological data.
--November to December; Preliminary SALT talks in Helsinki.

1970
--January; Nixon administration cuts Plowshare budget.
--March 2-6; Talks by 21 nations at the IAAEA on peaceful uses of nuclear explosions.
--March 5; NPT entered into force; 50 nations ratified the NPT by 1970, over 100 by 1980.
--November 30; Atlantic-Pacific Interoceanic Canal Study Commission rejets use of nuclear explosives.

1971
--March 30: U.S. deploys Poseidon SLBM.
--June 15; Izvestia mentions three Russian nuclear charges exploded in oil fields to increase productivity.

1972
--May 26; SALT I Treaties limiting ABM and offensive missiles signed by Nixon and Brezhnev in Moscow.
--June; U.N. Environmental Conference in Stockholm votes 48 to 2 to halt all testing of nuclear weapons; France and China against, U.S. and U.K. abstain, U.S.S.R absent.
--October; First U.S. detection of flight test of Soviet SS-18 ICBM.

1973
--June 22; World Court issues injunction to France not to carry out Mururoa tests.
--October 17, 1973 to March 17, 1974; OPEC embargos petroleum to U.S. and the Nethererlands.

1974
--May 18; India sets off a low-yield device (10-15 kt) under Rajasthan desert, expanding the nuclear club beyond the "big five" of World War II.
--November 24; U.S./U.S.S.R. agree to limit the number of strategic launchers (2400) and MIRV launchers (1320).

1975
--January 19; AEC reorganized into the NRC (regulatory) and ERDA (developmental, later DOE on August 4, 1977).

1976
--January 29; The order for the South Korean reprocessing plant from France was cancelled. (Pakistan plant cancelled in 1978)
--October 28; Ford postpones reprocessing of spent fuel to obtain commercial Pu.

1977
--April 7; Carter postpones indefinitely reprocessing of commercial spent fuel, slows progress on the Clinch River Breeder Reactor, and calls for an International Fuel Cycle Evaluation (INFCE) to investiate ways to make the nuclear cycle more resistant to proliferation.
--October 19, 1977 to February 26, 1980; Over 40 nations prepare a report at INFCE.

1978
--January 11, The Guidelines of the Nuclear Suppliers (London meetings) were forwarded to the IAEA.
--March 10, The Nuclear Nonproliferation Act of 1978 (NNPA) was signed into law.
--April 4; Camp David Accord signed by Egypt and Isreal in Wshington.
--April 27; Carter issues an Executive Order to export low-enriched uranium fuel to India; this was the first override of the NRC as allowed for in the NNPA; the Congress did not veto this action.
--July 13; Euratom ended the the embargo of nuclear fuel from the U.S. (required by NNPA) and agreed to discuss renegotation of the US-Euratom agreement on the issue of retranfer and reprocessing rights.

1979
--April, 6; The U.S. cut off economic and military aid to Pakistan after concluding that Pakistan was building an enrichment plant to produce weapons grade uranium.
--June 8; First Trident SLBM launched.
--June 18; The SALT II Treaty was signed in Vienna by Brezhnev and Carter.
--December 26; U.S.S.R. invades Afganistan; SALT II treaty removed from consideration by the Senate.

1980
--July 15; Presidential Office of Science and Technology Policy reported that the light signals recorded by a VELA satellite over the South Atlantic on September 22, 1979 was probably not from a nuclear explosion.
--December; Tomahawk submarine lauched cruise missile flies out to sea and returns 600 miles to land; later it obtains an accuracy of about 5 meters on a flight from Pt. Mugu to Nevada.

1981
--April 12-14; Space shuttle Columbia flies 36 orbits.
--June 7, Isreal destroys Iraq's Osirak reactor.
--November 13; Senate ratifies Protocol I of Tlatelolco Treaty; U.S. cannot store, deploy, or use nuclear weapons in Puerto Rico, Virgin Islands, or Guantanomo Naval Base.

1982
--June 29; START talks begin in Geneva.
--1982; U.S.S.R. places about 300 SS-20 missiles on its western border.
--November; Reagan adopts the dense pack basing mode for the MX missile.

ACKNOWLEDGEMENT AND REFERENCES

In preparing this list of chronological data, we would like to acknowledge the lists and suggestions of others; in particular we would like to thank Bruce Bolt, Prentice Dean, Warren Donnelly, and Spencer Weart. Some references that we have found to be useful are as follows:

1. B. Bolt; Nuclear Explosions and Earthquakes, Freeman, San Francisco, 1976.
2. P. Dean, Energy History Chronology from World War II to the Present, U.S. Dept. of Energy, DOE/ES-0002, Washington, D.C., 1982.

3. W. Donnelly and D. Kramer, Nuclear Proliferation Factbook, Congressional Research Service, Library of Congress, 1980.

4. B. Goldschmidt, The Atomic Complex, Am. Nuc. Soc., La Grange Park, IL, 1982.

5. R. Hewlett and O. Anderson, A History of the U.S. Atomic Energy Commission; The New World: 1939-46, Penn. St. Univ. Press, University Park, PA, 1962. R. Hewlett and F. Duncan, Atomic Shield: 1947-52, Penn. St. Univ. Press, University Park, PA, 1969.

6. D. Irving, The German Atom Bomb, Simon and Schuster, NY, 1967.

7. D. Kevles, The Physicsts, Vintage, N.Y., 1979.

8. H. Smyth, "Atomic Energy for Military Purposes," Rev. Mod. Phys. 17, 351 (1945).

9. H. York, Race to Oblivion, Simon and Schuster, NY, 1970.

ADDITIONAL REFERENCES ON URANIUM FISSION (1939):
(Dates will be in the order of submitted/published)

November 3, 1938/January 15, 1939; Nier (Phys. Rev. 55, 150 (1939)); "A mass spectrographic determination ... found U-238/U-235 = 139 ± 1 percent."

February 16/March 1; Fermi, et al (Phys. Rev. 55, 511 (1939)); "If we assume that the energy release in the fission is approximately 200 Mev, and that the two fragments may have somewhat different masses, then fragments with energies up to 120 or 130 Mev might be expected in some cases."

March 8/March 18; Joliot, et al (Nature 143, 470 (1939)); "...more than one neutron must be produced. This seems to be the case..."

March 10/April 1; Roberts, et al (Phys. Rev. 55, 664 (1939)); "direct neutron emission is responsible for the delayed neutrons)."

March 16/April 15; Fermi, et al (Phys. Rev. 55, 797 (1939)); "...it would correspond to a yield of about two neutrons..."

March 16/April 15; Szilard and Zinn (Phys. Rev. 55, 799 (1939)); "...we find the number of neutrons emitted per fission to be about two."

April 6/June 1; W. Furry, R. Clark, and L. Onsager (Phys. Rev. 55, 1083 (1939)); "On the Theory of Isotope Seperation by Thermal Diffusion."

April 7/April 22; Joliot, et al (Nature 143, 680 (1939)); the number of neutrons emitted per fission = ν = 3.5 ± 0.7

May 20/June 3; Joliot, et al (Nature 143, 939 (1939));

"...neutrons possessing an energy of at least 11 Mev are liberated in uranium irradiated with thermal neutrons."

May 31/August 1; J. Beams and C. Skarstrom (Phys. Rev. 56, 266 (1939)); "The Concentration of Isotopes by the Evaporative Centrifuge Method."

July 3/August 1; H. Anderson, E. Fermi, and L. Szilard (Phys. Rev. 56, 284 (1939)); "Neutron Production and Absorption in Uranium... It has been found that there is an abundant emission of neutrons from uranium under the action of slow neutrons."

June 28/September 1 (the day Hitler invaded Poland); N. Bohr and J. Wheeler (Phys. Rev. 56, 426 (1939)); "The Mechanism of Nuclear Fission;" includes theory of fission by fast neutrons.

July 10/September 1; J. Oppenheimer and H. Snyder (Phys. Rev. 56, 455 (1939)); "On Continual Gravitational Contraction... When all thermonuclear sources are exhausted a sufficiently heavy star will collapse."

SIPRI: LIST OF FIRST NUCLEAR EXPLOSIONS

Fission devices				Thermonuclear devices		
Country	Year of first explosion	Fissile material	Source of fissile material	Year of first explosion	Fissile material	Source of fissile material
USA	1945	Pu-239	Reactor	1952	U-235	Gaseous diffusion
USSR	1949	Pu-239	Reactor	1952	U-235	Gaseous diffusion
UK	1952	Pu-239	Reactor	1957	U-235	Gaseous diffusion
France	1960	Pu-239	Reactor	1968	U-235?	Gaseous diffusion
China	1964	U-235	Gaseous diffusion	1967	U-235	Gaseous diffusion
India	1974	Pu-239	Reactor	-	-	-

Source: Stockholm International Peace Research Institute, Nuclear energy and other nuclear weapons proliferation. London: Taylor and Francis Ltd., 1979, p.2.