

## Technical Milestones in Nuclear Weapons Development

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**1932**-L. Szilard-Invents and patents in UK Neutron Chain Reaction Concept, including reactors and bombs

**1938**-Hahn & Strassman-Discover Uranium fission by neutrons and subsequent large energy release

**1939**

- All physicists aware of potential extra neutrons from Uranium fission that could sustain chain reaction, and thus potential for a “gun-type” assembly design of Uranium fission bombs (Szilard, Bohr, F. Joliot, Heisenberg, etc.)
- F. Joliot and H. Halban-French Patent of Uranium gun-type fission bomb (wrong isotope:U238 not fissile)
- N. Bohr clarifies only U-235 is fissile (0.7% in Natural U)

**1940**

- Frisch-Peierls memorandum at University of Birmingham: seminal paper describing design, manufacture and effects of fission “Uranium Bomb”
- G. Seaborg discovers Plutonium, a man-made element, a better bomb material than Uranium (by factor of ~3)

**1941**

- M. Szilard and E. Fermi prove emission of multiple neutrons per fission, making chain reaction a reality
- M. Szilard and E. Fermi invent and file patent on the first neutron fission reactor (pile)
- E. Fermi and E. Teller propose a “super” bomb based on the ignition of a cylinder of cheap deuterium by a fission bomb at one end

**1942**

- E. Fermi demonstrates the first neutron chain reactor, CP-1 at the University of Chicago
- E. Konopinski suggest that a mixture of Deuterium and Tritium burns more readily (100 times faster and at lower temperature) than pure Deuterium. The mixture is added as a primer to the super (known now as “Classical Super”).

**1943**

- S. Nedermeyer invents the implosion concept of fast assembly of fissile material to supercriticality
- L. Alvarez proposes external neutron initiator using linear accelerator; tested 1951; rediscovered by E. Tsukerman

**1944**

- E. Teller and J. Von Neumann discover Plutonium compression by implosion reduces critical mass and increases explosion efficiency by a factor of 20
- L. Alvarez invents explosive bridgewire (EBW) detonator for microsecond simultaneity
- J. Von Neumann suggests the use of HE “Lenses” to get spherical symmetry
- K. Fuchs and R. Sherr invent the internal Po-Be neutron initiator (urchin)

**1945**-First demonstration experiment of an atomic explosion using implosion of Plutonium, Trinity, with yield of ~20kT

**1945**-E. Teller invents the “Booster” which increases yield of fission bombs by a factor of 2 or more using small amounts of D+T in the center of a fission core; tested in 1951

**1946**

- K. Fuchs and J. Von Neumann invent and patent the “ionization implosion” method of igniting a “Super” hydrogen bomb; tested concept as the Greenhouse “Cylinder” in 1951; re-discovered by A. Sakharov in 1948 as “Sakharization” for “Sloika”.
- E. Teller invents the “Alarm Clock” Uranium/deuterium layered cake boosted bomb; rediscovered in 1948 by A. Sakharov as “Sloika”, and tested in 1953.
- E. Teller proposes the use of solid Lithium Deuteride instead of liquid Deuterium and Tritium; rediscovered in 1949 by Vitaly Ginsburg in USSR for the “Sloika”

**1948**

- LASL tests “Levitated” bomb, using flyer impact concept which doubles yield; invented in a more refined form by E. Zababakhin
- LASL tests “Composite Pu-U Core” bomb, to even out burn-up which doubles yield; invented in a more refined form by E. Zababakhin and L. Altshuler

**1950**-Stanislaw Ulam invents the concept of staging to obtain high "cold" compressions by fission explosive hydrodynamic shock; rediscovered by Viktor Davidenko in 1952

**1951**

- E. Teller invents the concept of thermal X-ray radiation driven implosion of a secondary bomb containing TN fuel for faster and longer sustained compression using Ulam’s staging; rediscovery in 1954 incorrectly attributed to Y. Zeldovich and A. Sakharov: actually result of spying
- E. Teller invents the concept of fission “sparkplug” initiator in the center of the fusion fuel to ignite the cold compressed fusion fuel
- E. Teller invents the “equilibrium burn super” where the radiation implosion compression is compensated by the explosion of the fission sparkplug for a longer lasting and more complete burn of thermonuclear fuel in the secondary

**1952**- LASL tests the Teller-Ulam configuration’s “3 concepts” (separation of stages, radiation driven compression, sparkplug ignition) in 10.4 MT Mike test shot using liquid Deuterium thermonuclear fuel

**1954**- LASL test of E. Teller “dry” Lithium Deuteride fueled thermonuclear explosives in Castle series (Bravo shot of 14.7MT)

**1953-1956**-US Transition to Hollow Core Boosting and external neutron initiation, providing safe, lightweight, and high yields in compact package

**1956**-C Haussmann, J. Foster and associates at LLNL invent the concept of linear implosion, permitting ultra-compact devices fitting in 6” and 8” artillery shells

**1956-** E. Teller proposes miniaturization of thermonuclear warheads at Nobska, resulting in Polaris W-47, through extensive use of hollow boosting, Beryllium reflectors, Tritium, or alloy and Plutonium

**1956-1960-** LLNL-Development of 2 detonator primary bomb

**1956-1960-** LLNL-Accidental discovery of ablation providing for more compression of TN secondary compared with energized plastic foam plasma. Fortuitous use of a Be reflector for the HEU secondary produced strong Be ablation by x-rays and higher implosion pressures and compression, enhancing TN burn

**1962-** LLNL-John Nuckolls invents and tests the isentropic compression of the TN fusion package using layered profiled ablaters for higher TN burn efficiency and lighter weight. Later extended to primary X-ray output pulse shaping. Rediscovered in USSR in 1977.

**1962-** VNIIEF-V. Mokhov proposes and tests TN secondary bomb ignition by fast compression without a sparkplug; similar to "fast ignition" concept in laser fusion ICF targets