Chapter 4

NUCLEAR WORLD

"Three great forces rule the world: stupidity, fear, and greed"
Albert Einstein

"The woods are lovely, dark and deep,
But I have promises to keep,
And miles to go before I sleep,
And miles to go before I sleep."
Robert Frost, American poet

"I know not with what weapons World War III will be fought,
but World War IV will be fought with sticks and stones."
Albert Einstein

4.1 INTRODUCTION

The success of the first man made self-sustained chain reaction in the Chicago Pile Number 1 (CP1) was followed by the Manhattan Project, which culminated into the Trinity first nuclear test (Fig. 1) then the first use of nuclear weapons by the USA against Japan. This was succeeded by a frantic period of atmospheric nuclear testing and a nuclear arms race, then by attempts by humans, who have come to realize its tremendous energy release potential, at:

1. Sublimating the new state of knowledge, or: "Turning their swords into plowshares," toward the peaceful applications of nuclear energy.
2. Containing the possible, yet improbable, use of nuclear weapons through different treaties and international agreements.

The accumulated knowledge about nuclear phenomena is the "Aladdin's Genie" that is out of its bottle, or oil lamp in the story. It could be made as humanity's servant, or allowed to become its worst nightmare, and like other knowledge, it cannot be imprisoned into the lamp again. In fact humanity needs it to preserve its existence, since it constitutes the only way to defend life on Earth against possible future meteorites impacts that have led to major extinctions in the past. It is also the only hope for humanity for becoming a space civilization, using nuclear propulsion for freeing itself from being planet bound and spreading life throughout the known universe.

4.2 THE NEW WORLD

In January of 1946, The First General Assembly of the United Nations met and created the United Nations Atomic Energy Commission precursor of the International Atomic Energy Agency (IAEA) with a charge of eliminating all weapons of mass destruction.

However, nuclear testing continued. In Operation Cross Roads on July 1, 1946, in the Bikini Atoll in the Pacific Ocean an air drop test designated as the Able test was conducted. An underwater device designated as the Baker test, sunk 16 out of 95 World War II decommissioned ships including the American Saratoga and Arkansas, the German Prinz Eugen and the Japanese Nagato. Military personnel were trained at watching the tests wearing goggles protecting their eyes from the ensuing intense ultraviolet radiation, yet not from the neutron, gamma and x-ray radiation. Air burst shots were fired from an artillery cannon. The effect of the nuclear blast shock wave and x rays on engineering structures were studied.

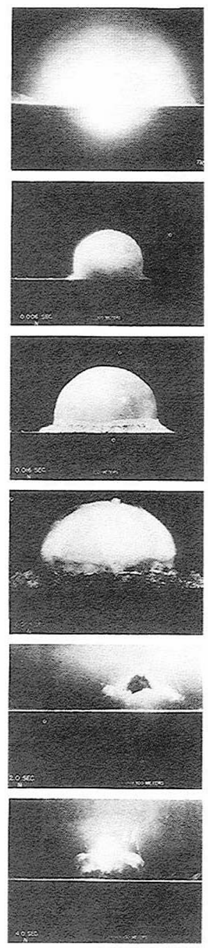


Figure 1. Sequence of photographs taken of the Trinity nuclear test. Only color photo of the event, said to have been taken by environmental physicist Jack Aeby.

Figure 2. Atomic explosions night sight-seeing from the hills of Las Vegas, at a safe distance 65 miles away from the Nevada Test Site. Over the period 1951 – 1992, 928 tests were conducted there. Mother and son watching nuclear test at Las Vegas, 1953.

Figure 3. Glamorous Atomic Bomb Ballet, and Lee Merlin Miss Atomic Bomb in the Nevada Desert.

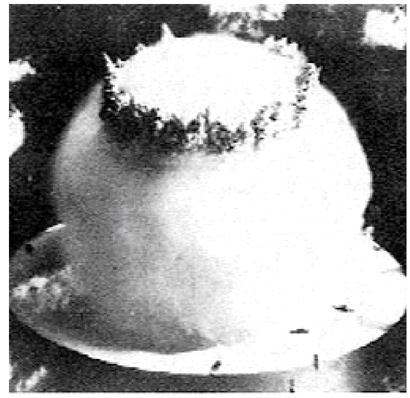


Figure 4. The underwater 21 kT of TNT-equivalent, July 24, 1946, Crossroads-Baker test surrounded by a fleet of 96 decommissioned naval vessels at the Bikini Atoll, Marshall Islands.

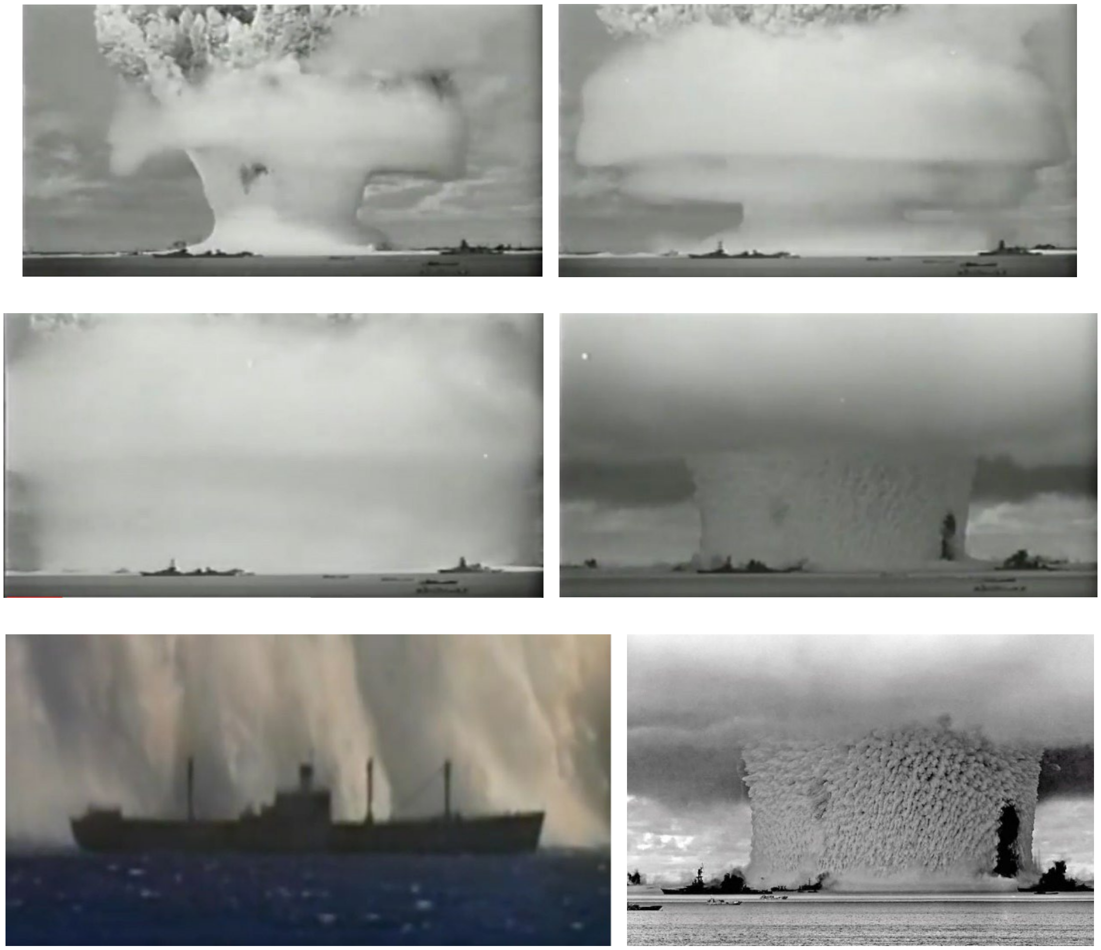


Figure 5. Crossroads under water Baker test sequence. The water column was hollow in the center and 610 meters in width. It lifted 2 million tons of sea water which created a base surge 274 meters in height and a tsunami 5 meters in height as it reached the Bikini beach 6 kms away. The Japanese battleship Nagato survived for 5 days then capsized and sun in the lagoon. Many ships could not be decontaminated and a planned third test after the Able air burst and the Baker underwater tests in the series was cancelled. Five vessels were put back into service.

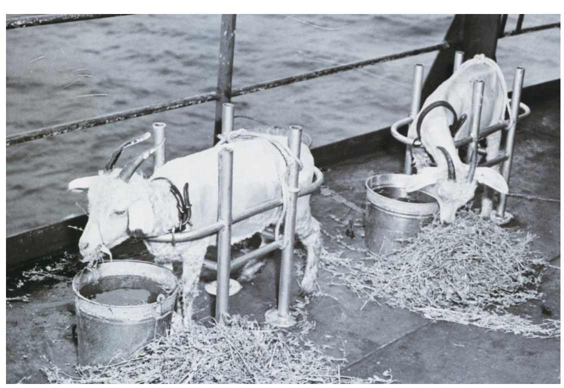


Figure 6. Goats used in atomic testing on ships.

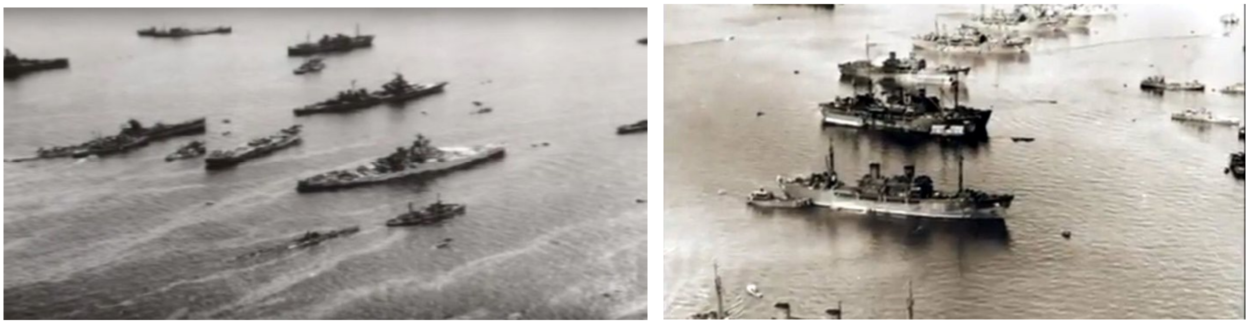


Figure 7. Bikini Atoll fleet of decommissioned ships used in nuclear testing.

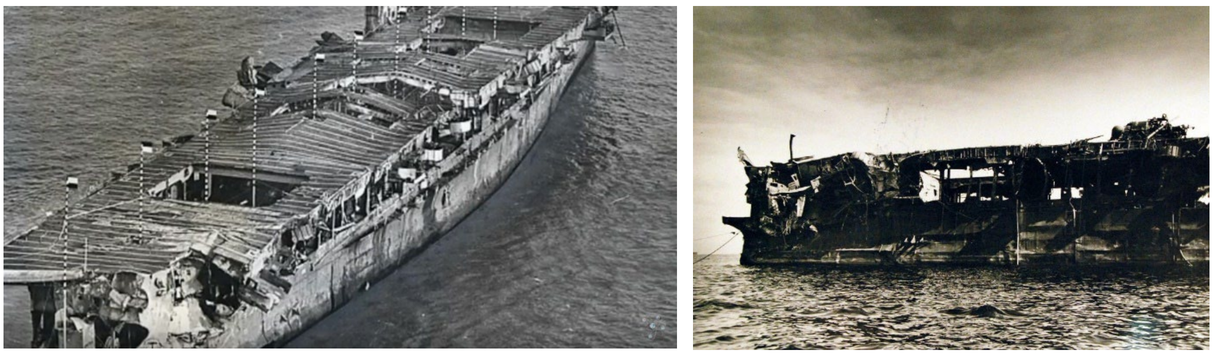


Figure 8. Crossroads test remnant of the Independence aircraft carrier. Gilda device was exploded 150 m above deck, November 2, 1952.

Figure 9. Crossroads USS Saratoga aircraft carrier sunk after 8 hours.

Figure 10. Crossroad test battle ship Pennsylvania.

Figure 11. Crossroads test Japanese ship Sakawa.

Figure 12. Crossroads test Japanese ship Nagato.

Figure 13. Crossroads test German Prinz Eugen ship survived the testing but was later sunk in the Kwajalein atoll. It is sought now by scuba diving enthusiasts.

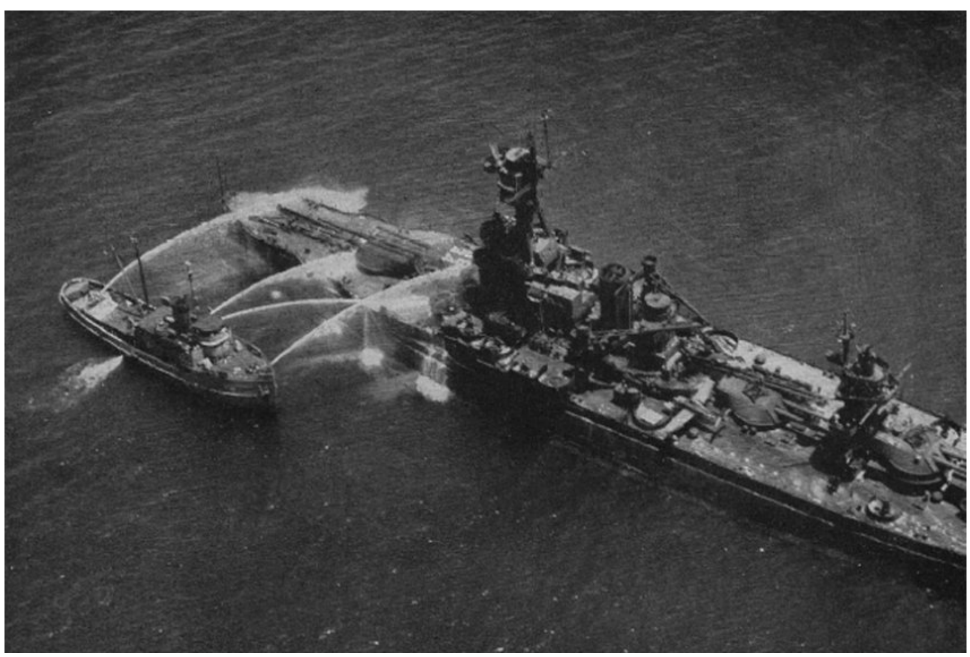


Figure 14. Radiation decontaminating of the USS New York using water jets.

Figure 15. Above ground testing using troops and mannequins.

Figure 16. Laboratory and Navy personnel observing a nuclear detonation using ski goggles to protect against ultraviolet radiation.

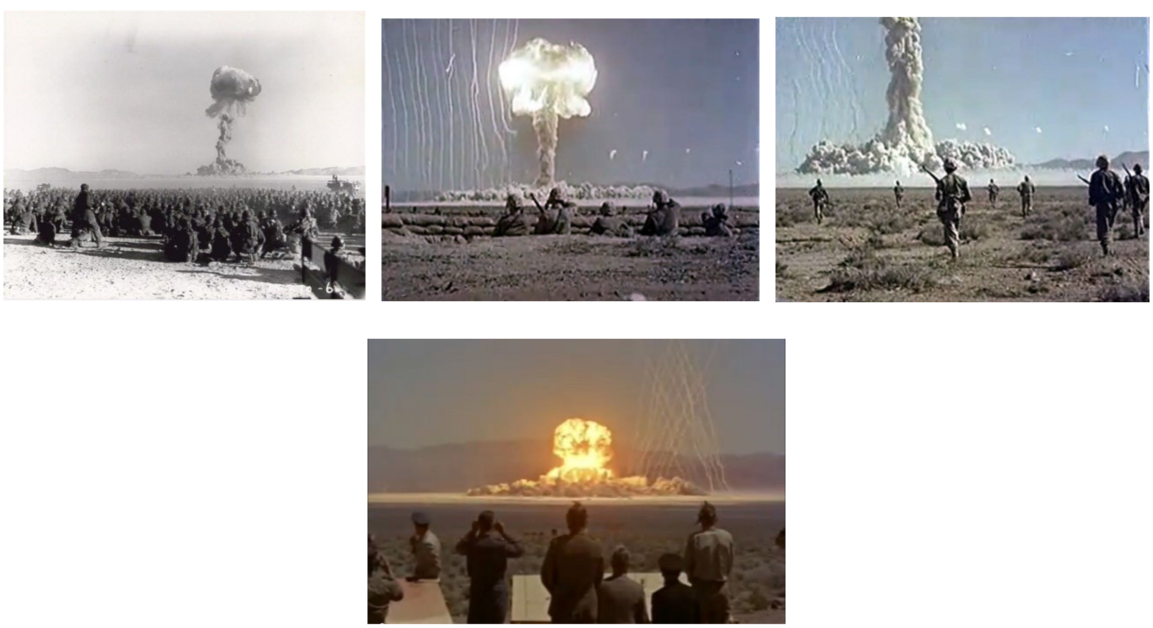


Figure 17. Army infantry troops being trained to operate in a nuclear war environment in the Nevada Desert.

Figure 18. High altitude air burst sequence.

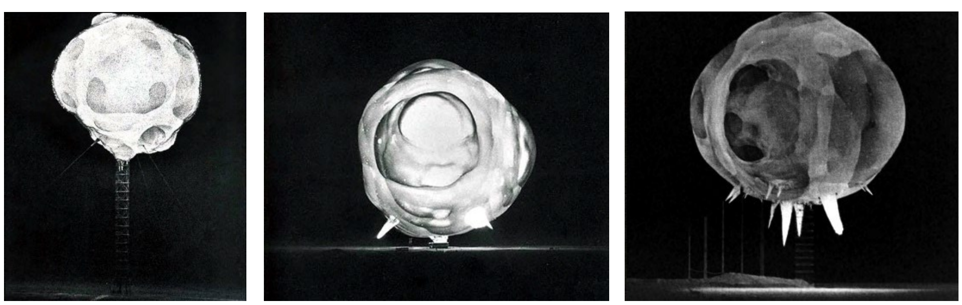


Figure 19. Low altitude nuclear blast effects on top of a steel tower.

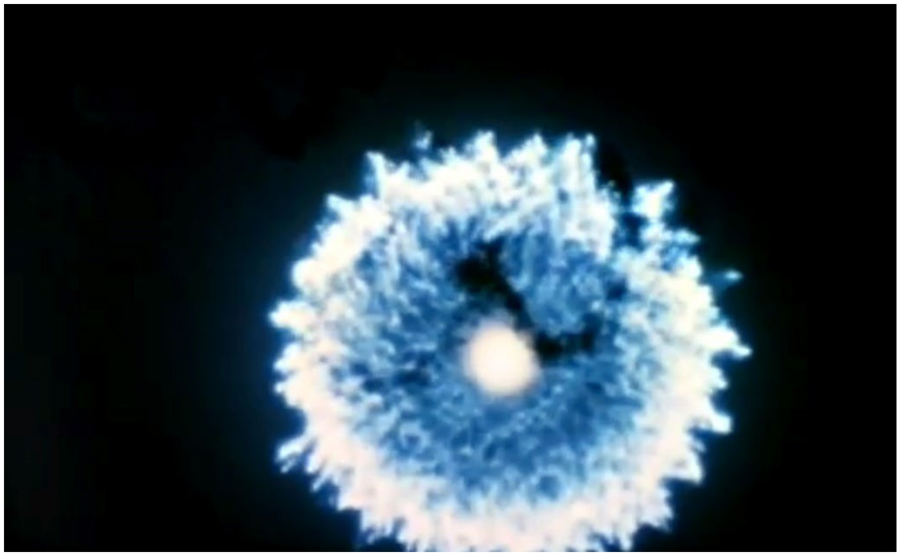


Figure 20. High altitude test fireball can cause an Electro Magnetic Pulse, EMP.

Figure 21. Auroral effect of nuclear blasts in Hawaii.

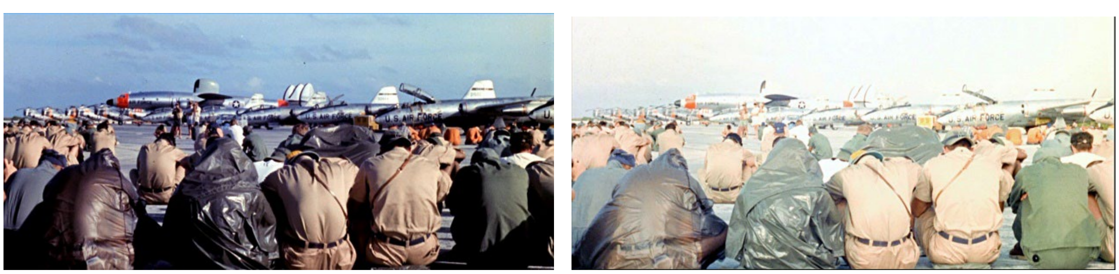
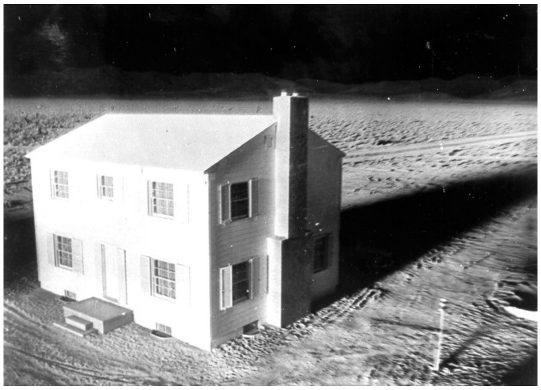
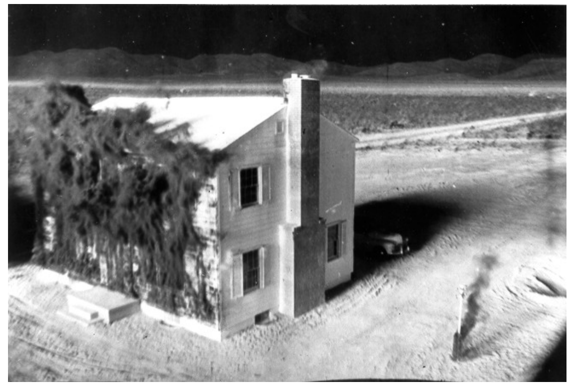
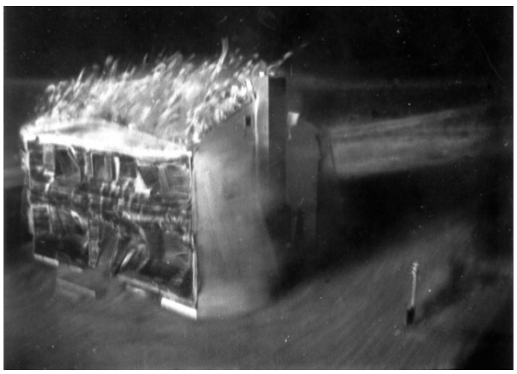
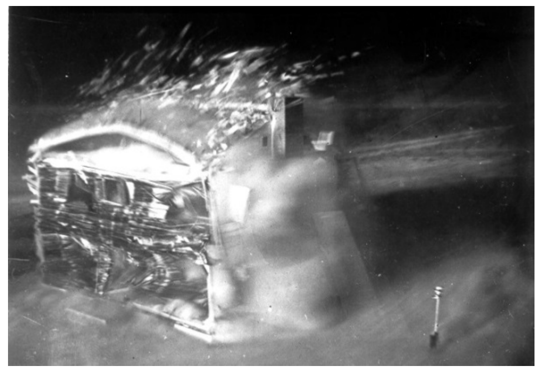
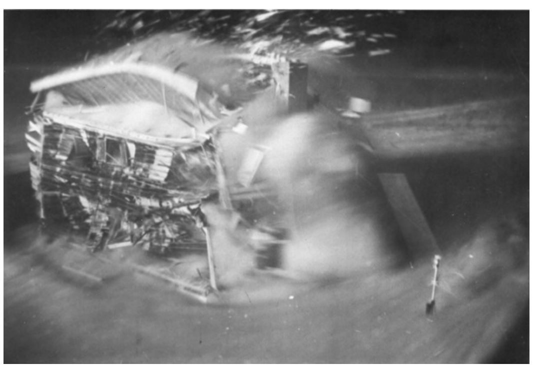


Figure 22. Air Force personnel testing.

Figure 23. “Ground Zero Population” underneath the Genie Shot: Gamma, x-rays, ultraviolet, light, then infrared radiations, followed by shock wave exposure from an F89 Scorpion fighter jet missile-launched 2 kT overhead air burst at 10,000 ft [5].

Figure 24. Grable event as part of operation Upshot-Knothole was an air detonation fired from an 289 mm artillery gun on May 25, 1953. It yielded 15 kT of TNT-equivalent at the Nevada Proving Grounds (left). A W-79, 8 in, shell artillery projectile is shown (top right). Source: National Nuclear Security Administration / Nevada Site Office.

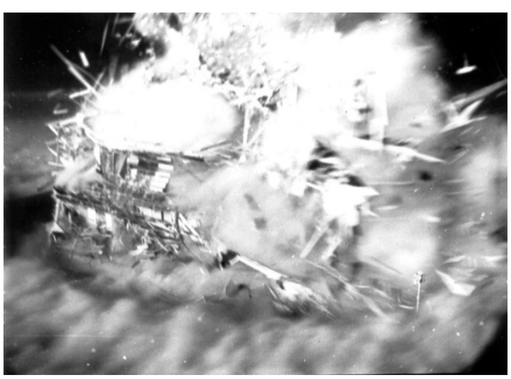
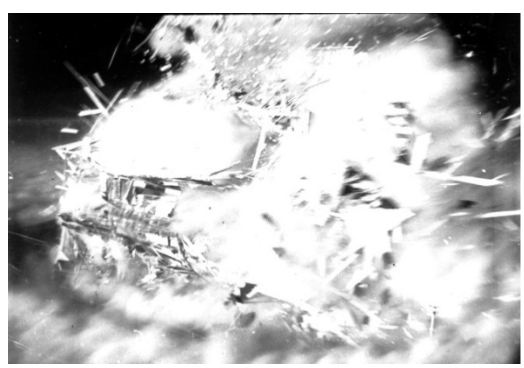



Figure 25. Effects of the x-rays then blast wave on house located 3,500 ft from ground zero. March 17, 1953 at Yucca Flat during the Upshot-Knothole operation. Photo courtesy of National Nuclear Security Administration / Nevada Site Office.

The Soviet program, limited in scope during the war starting in 1943 under I. V. Khurchatov, moved forward. Their first reactor was built in 1947, and their first nuclear device was tested on August 29, 1949.

The United States found its monopoly on atomic weapons lost. This led to the Super Program advocated by Edward Teller to build a thermonuclear or hydrogen Bomb. Robert Oppenheimer, then Director of the Los Alamos Laboratory, as well as Enrico Fermi and Rabi, opposed the program initially, on the basis that fission weapons boosted with tritium can generate explosive yields in the range of 100 kT TNT. The argument was that such a yield was sufficient for all tactical purposes, that the megaton yield level of thermonuclear weapons was militarily unusable, and that they amounted to city busters: "Since no limit exists to the destructiveness of this weapon, its existence is a danger to humanity as a whole". The argument was also made that the acquired advantage would be temporary, in that it will induce an arms race. There ensued a personality clash between Edward Teller and Robert Oppenheimer. Robert Oppenheimer's reputation was smeared. Having had some communist friends he was viciously accused of treason, his security clearance was revoked by the Atomic Energy Commission in 1953, as the Super Program proceeded forward. His innocence was recognized and reputation was later restored, but he was by then a broken and sick man.

Figure 26. Blast effect on trees.

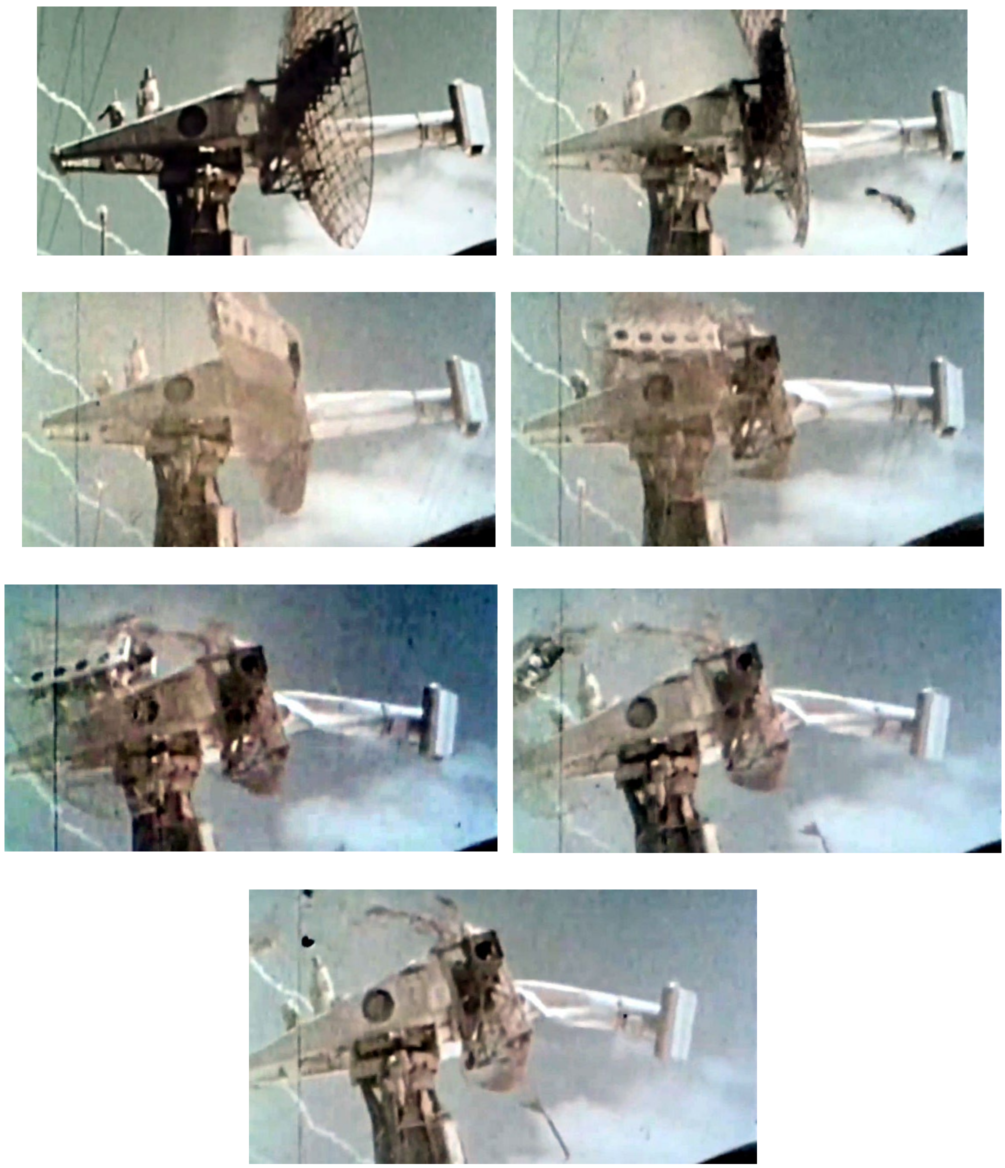


Figure 27. Blast effects on naval radar structures.

4.3 THE SUPER PROJECT

Further momentum was acquired when it was discovered that Manhattan Project British scientist Klaus Fuchs had passed nuclear secrets, including concepts of a hydrogen device, to Russia. On January 31, 1950, President Truman gave the go ahead to intensify the effort in the pursuit of a thermonuclear device. The Air Force specifically established the Lawrence Livermore National Laboratory (LLNL) for Edward Teller to pursue the Super project.

The first fusion device conceptualized the use of a fission device to heat a cylinder of liquid deuterium to start a fusion reaction. The concept stalled initially when calculations indicated that it is unlikely that a fission weapon could generate by itself the hundreds of millions of degrees of temperature needed to trigger significant fusion reactions. The reason was that at such high temperatures, most energy will appear as escaping radiation rather than in the form of usable kinetic energy of the nuclei. Some calculations suggested that using a mixture of deuterium and tritium could help the reaction proceed much faster than for deuterium alone before a lot of radiation is emitted and equilibrium with radiation is established. It was quite difficult to postpone radiation equilibrium and obtain a long enough energy confinement time for thermonuclear reactions to proceed.

4.4 RADIATION AND MATERIAL ENERGY DENSITIES OF A BLACK BODY RADIATOR

According to the Stefan Boltzmann law, the total amount of energy of all wavelengths contained per cubic centimeter, or radiation energy density, of a black body is related to the absolute temperature, T in kelvin, K = 273 + °C, by the equation:

$$E_{radiation} = \sigma T^4 \left[\frac{ergs}{cm^3}\right] \tag{1}$$

where: σ is the Stefan-Boltzmann constant = 7.65×10^{-15} [ergs/(cm^3.K^4)].

On the other hand, the material energy density is related to the temperature by:

$$E_{material} = \frac{3}{2} f\, NkT \left[\frac{ergs}{cm^3}\right], \tag{2}$$

where: k is the Boltzmann constant = 1.38×10^{-16} [erg/K],

f = 1 + r, r = average degree of ionization,

$N = \frac{\rho}{M}.A_v$, = atomic density in [nuclei/cm^3],

$A_v = 0.6025 \times 10^{24}$ [nuclei/mole] = Avogadro's number,

M is the molecular or atomic weight [amu],

ρ is the material density [gm/cm^3].

The total energy density is the sum of radiation and material energy densities and is given by:

$$E_{total} = E_{radiation} + E_{material}$$
$$= \sigma T^4 + \frac{3}{2} f\,NkT \left[\frac{ergs}{cm^3}\right]$$

Of particular interest is the ratio of the radiation energy density to the material energy density, which can be deduced as:

$$\frac{E_{radiation}}{E_{material}} = \frac{2}{3}\frac{\sigma M}{f.A_v.k}\frac{T^3}{\rho}\ . \tag{3}$$

Or, by substituting the values of the physical constants:

$$\begin{aligned}\frac{E_{radiation}}{E_{material}} &= \frac{2}{3}\frac{\sigma M}{f.A_v.k}\frac{T^3}{\rho}\\ &= \frac{2}{3}\frac{7.65\times 10^{-15} M}{6.025\mathrm{x}10^{23}\times 1.38\times 10^{-16} f}\frac{T^3}{\rho}\\ &= 6.134\times 10^{-23}\frac{M}{f}\frac{T^3}{\rho}\end{aligned} \tag{4}$$

A critical temperature of:

$$T_c = 3.5 \text{ x } 10^7 \text{ K} = 6.3 \text{ x } 10^7\ {}^oF, \tag{5}$$

must be attained in the fusion fuel with the aid of a fission device for the fusion reaction to be self-sustaining.

Substituting this value in the ratio of energy densities yields:

$$\begin{aligned}\frac{E_{radiation}}{E_{material}} &= 6.134\times 10^{-23}\ \frac{M}{f}\ \frac{(3.5\times 10^7)^3}{\rho}\\ &= 2.63\ \frac{M}{f}.\frac{1}{\rho}\ .\end{aligned} \tag{6}$$

To attain an equilibrium between the radiation energy density and material energy density,

$$\frac{E_{radiation}}{E_{material}} \approx 1, \tag{7}$$

suggests that a condition is imposed on the nuclear density as:

$$\rho \approx 2.63\frac{M}{f} \tag{8}$$

This implies that the fusion fuel has to be compressed to higher than normal density if the material energy density would be in equilibrium with the radiation energy density.

The implication for the design of the Super is that pre-compression of the fusion fuel to higher density is necessary to obtain a thermonuclear burn. There exists an urgent need to strongly compress the thermonuclear fuel, and, in the compressed fuel, radiation would be less important and would not inhibit the reaction.

4.5 INITIATION OF THERMONUCLEAR REACTION

Several ideas aroused on how to initiate a thermonuclear reaction, including:

1. One due to Gamow, referred to as: “Squeezing the cat's tail.”
2. One due to Stanislav Ulam, referred to as the “Spittoon.”
3. One due to Edward Teller, referred to as the “Womb.”

In a drawing by Gamow, the Russian leader Josef Stalin is shown carrying the Russian bomb, Robert Oppenheimer, dressed as an angel and a halo above his head, is watching Gamow squeezing a cat’s tail, while Edward Teller is wearing an American Indian fertility necklace in the form of a womb and Stanislav Ulam is spitting into a spittoon.

None of these concepts was feasible all by itself, and a test by the Livermore Laboratory of the Teller's womb collimation idea failed to initiate a thermonuclear reaction. Hans Bethe and Enrico Fermi contributed to the effort. John von Neumann, developed one of the first computers, the Eniac to carry out the tedious computations needed to study the process. A new numerical methodology, Monte Carlo sampling was developed to simulate the particles and radiation interactions in such a device.

Initially Stanislav Ulam thought that he could use neutrons from a primary fission device to compress the fusion fuel in a secondary charge. Calculations showed this was not feasible.

4.6 HOHLRAUM CONCEPT

HOHLRAUM

The breakthrough came when Edward Teller suggested the use of radiation from the primary instead of neutrons to compress and implode the fusion fuel in the secondary charge.

In this process, the x rays from the primary fill up a cavity filled with a material that is transparent to x rays such as polystyrene foam. This forms a hohlraum where the x rays uniformly irradiate the fusion fuel casing.

The surface of the fusion fuel casing absorbs the x rays ablating its outer surface and generating an inverse rocket driving it inwards. The ablating surface sends a compression shock wave into it. This compression wave propagates into the casing then reflects back as a rarefaction wave further sputtering the surface.

The implosion process compresses the fusion charge to a high density, which makes possible the ignition and effective burn of fusion fuel, and prevents radiation from escaping.

SPARK PLUG

A further embellishment is to include a spark plug at the center of the fusion charge consisting of a subcritical mass of Pu^{239} becoming upon reaching criticality under compression a source of neutrons to breed fusile fuel such as $_1T^3$ from a fusile breeding material such as natural Li or its isotope $_3Li^6$.

Shaping the spark plug as a long cylinder increases the surface leakage of neutrons and allows the use of a large mass of plutonium without initially reaching criticality.

DUAL CORE

The primary device was later built with a composite inner core of Pu^{239} and an outer core of U^{235}. This had two reasons. The U^{235}, even though possessing a larger critical mass than Pu^{239}, was cheaper to produce at the time than Pu^{239}, and the cost advantage compensated for the increased critical mass. In addition, its use to substitute for then scarce Pu^{239} provided a tamper as well as a material with a lower level of spontaneous fission neutrons, avoiding a serious pre-detonation problem occurring in pure Pu^{239} cores and in plutonium cores tamped with U^{238}. The Pu^{239} would also contain some Pu^{240} adding to the neutron source from the (α, n) reactions with low Z elements impurities such as O and F from the fuel reprocessing process, as well as from spontaneous fission reactions.

Table 1. Partition of the energy release from the fission process.

Distribution of Fission Energy	Energy (MeV)	Fraction, percent
Kinetic energy of fission fragments	165	81.3
Prompt gamma rays energy	7	3.4
Kinetic energy of fission neutrons	5	2.5
Beta particles from fission products	7	3.4
Delayed gamma rays from fission products	6	3.0
Antineutrinos from the fission products	10	4.9
Gammas from radiative capture in structure	3	1.5
	______	______
Energy release per fission event	203	100

FISSION ENERGY PARTITION

The fission process in the primary device generates fission products, neutrons and prompt and delayed beta and gamma radiation. Some 3 - 5 MeV of energy release per fission event is produced by radiative capture (n, gamma) reactions with the structural material.

The energy from the antineutrinos and the beta and gamma particles from the fission products appear at a later time, and are not available to the immediate yield. Thus only 203 – 10 – 6 -7 = 180 MeV are immediately available to the fission yield.

The fission products carry 81.3 percent of the approximate energy release of 203 MeV/fission or 165 MeV, and deposit it in the device materials melting and vaporizing them into an ionized state of a high temperature plasma.

The ionized plasma ions and electrons radiate their energy in the form of x-rays. In addition, the prompt gamma radiation interacts with materials through the processes of pair production, Compton scattering, the photo electric effect, and for high energy gammas, through photo fission and photo nuclear reactions. The gamma radiation interacts with materials, loses its energy and turns into x rays. The generated positrons and electrons can annihilate into lower energy gamma rays. The electrons lose their energy through the generation of bremstrahlung x-rays. Overall most of the primary device energy at the high obtained temperatures is in the form of x ray radiation.

IMPLODING FUSION CHARGE

The intense electromagnetic radiation in the form of x rays from the primary fission device permeates almost instantaneously at the speed of light a foam surrounding the secondary fusion device, generating a plasma that encloses the imploding fusion charge fuel liner also called a pusher and compressing it to a higher than normal density. The neutrons contribute to breeding tritium in the fusion fuel in the form of lithium deuteride powder, LiD, from the lithium contained in it. The reaction with the Li^6 isotope, is exothermic:

$$ {}_0n^1 + {}_3Li^6 \rightarrow {}_1T^3 + {}_2He^4 + 4.78\,MeV \tag{9} $$

If natural lithium is used, part of the energy is lost to the endothermic Li^7 reaction, but more neutrons are produced:

$$ {}_0n^1 + {}_3Li^7 \rightarrow {}_0n^1 + {}_1T^3 + {}_2He^4 - 2.47\,MeV \tag{10} $$

However, a radiative capture reaction with the Li^6 isotope would turn it into the Li^7 isotope, resulting in overall comparable heating at high neutron energies from the Li^6 and the Li^7 isotopes.

4.7 ABLATIVE IMPLOSION, EQUILIBRIUM THERMONUCLEAR REACTION

The complex phenomena involved in the energy transfer from the primary device to the secondary device designated as hetero catalytic processes are almost instantaneous, but they can be sequenced into several modes:

1. The initial impingement of the prompt gamma rays. These constitute just 3.5 percent of the energy release, and to avoid preheating, the secondary material must be shielded from them by interposing a shield along the line of sight between the primary and the secondary.
2. The heated plasma’s x rays constitute the major part of the 82.5 percent of the energy release in the fission products, and must be considered as the main component in the compression of the secondary.
3. The blast energy in the form of a shock wave carried out by the expanding plasma shell and ionized debris.

The x rays move at the speed of *light* of electromagnetic radiation and deposit their energy before the arrival of the third blast component at the speed of *sound* in the surface of the secondary and the hohlraum casing surrounding it. The x rays deposit their energy at the surface of the secondary. This deposited radiation forms a shock wave that propagates into it while vaporizing part of the pusher container ablating part of the surface. The shock wave propagates into the pusher and reflects from the free surface of the material's interior as a rarefaction wave causing spallation. The ablation and spallation combine to form an inverse rocket inwardly imploding the secondary container surface and achieving the needed compression and increase in the density of the fusion charge.

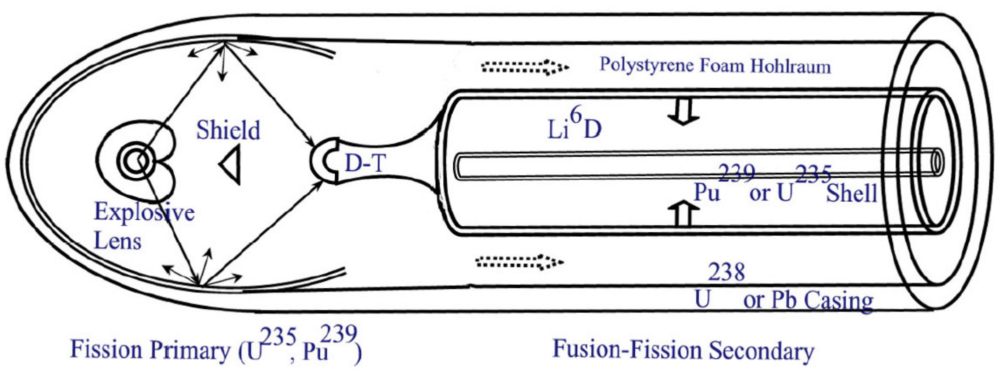
Figure 28. Drawing by Gamow sketching the three processes involved in the design of the Super. Stanislav Ulam is spitting into a spittoon. Edward Teller is wearing a Navajo Indian Naja fertility necklace in the form of an inverted Moor crescent. Gamow is squeezing the tail of a cat. Observing them are: Joseph Stalin carrying the Russian atomic device and Robert Oppenheimer as a saint with a halo above his head. Source: Gamow, "The Curve of Binding Energy."

Edward Teller describes the realization of the possibility of this development as:

> "By the end of 1950, I had the novel and positive answer. Because of the wartime work, we knew how to strongly compress the thermonuclear fuel, and, in the compressed fuel, radiation would be less important and would not inhibit the reaction."

Figure 29. Crescent shaped Naja Navajo necklace worm by Edward teller showing a squash blossom and healing hands.

This was the concept of an equilibrium thermonuclear reaction.



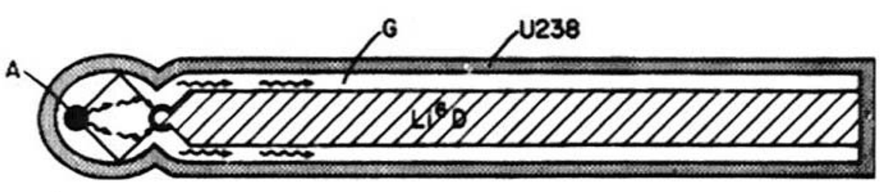


Figure 30. Schematics of the assumed Ulam-Teller configuration, using a fission primary and a fusion-fission secondary. The use of the Li^6 isotope can be replaced by natural Li.

It must be noted that it is "pressure generated by radiation" rather than just "radiation pressure" that is the key to the fusion fuel's compression. This is an esoteric distinction that is important for understanding the process. It is not just the x-rays from the primary device that compress the fusion fuel. An analogy has been suggested here to boiling water. Water like radiation, does not turn the blades of a turbine. Instead, it is the steam generated by the boiling water that generates the torque that rotates the blades.

4.8 ULAM TELLER CONFIGURATION

In February 1951, Stanislav Ulam came out with the idea that he described in his book "Adventures of a Mathematician" as:

> "Perhaps the change came with an idea I contributed. I thought of a way to modify the whole approach by injecting a repetition of certain arrangements. Unfortunately the idea or set of ideas involved is still secret and cannot be described here."

This repetition of "certain arrangements" came to be known as the Ulam Teller configuration and became the turning point for thermonuclear reactions work.

Weapons designers in a handful of other nations have conceived other or similar iterative schemes still shrouded in secrecy. This conveys the immeasurable privilege and prestige to the USA, United Kingdom, France, Russia, and China as Super Powers Status in the World, and reserves them permanent seats and the much desired veto power on the Security Council of the United Nations. Other countries such as India, Pakistan and Israel have developed similar schemes using tritium boosted devices. Those that mastered the knowledge assure their cultures' invincibility against conventional and nuclear attack and survival against any opponents in any potential future conflicts.

Such a configuration would be an extremely complex set of components acting in perfect sequencing as a multistage energy and neutron amplifier. One possibility involves a succession of fission then fusion then fission again amplification stages.

A drawing by Gamow sketches the three processes involved in the design of the Super. Stanislav Ulam is shown to the left spitting into a spittoon. Edward Teller in the middle is wearing a Navajo Indian Naja fertility necklace in the form of an inverted crescent. Gamow, to the right, is squeezing the tail of a cat. Observing them is Joseph Stalin carrying the Russian first atomic device as well as Robert Oppenheimer as a saint with a halo hovering above his head.

A pendant worn by Edward Teller displays the classic squash blossom necklace features a crescent shaped pendant, called a Naja, which is the Navajo word for "crescent," and beads with a design resembling a squash blossom. Both the Naja and squash blossom beads designs were adapted from the early Spanish settlers of the American Southwest. The Naja motif was borrowed from the Spanish horse bridle. The Spanish had adopted the Naja design from the crescent moon motif of the Moors of North Africa. The crescent design was common to many early civilizations, particularly the Islamic civilization.

The squash blossom design is based on a pomegranate blossom motif originally worn as silver trouser ornaments by the Spanish and, later, by the Mexicans who populated the American Southwest. The Navajo do not use the term "squash blossom," instead referring to it as "the bead that spreads out."

While the squash blossom necklace is still thought of as primarily a Navajo art form, other Native American silversmiths, including the Zuni, also craft squash blossom necklaces in their own styles.

In the Trinity test, electrically fired detonators surrounding a fission primary in a soccer ball configuration with twenty hexagons and twelve pentagons, are set off. They drive shock waves in explosive lenses that convert the spherically divergent waves from the detonators into a spherically convergent shock wave. These convergent shocks simultaneously compress a hollow shell tamper made of high temperature and strength beryllium, which also acts as a neutron multiplier and U^{238} as an energy multiplier. The tamper is driven inward by the implosion shock toward the fissile core of the primary device. The core is compressed to super criticality by the tamper.

It takes a few minutes for a stray neutron from cosmic rays and background radiation to initiate a chain reaction in a critical assembly. For reliability considerations, a neutron source is needed to initiate the reaction once the configuration has reached its supercritical state.

An urchin shaped neutron source used the alpha particles generated from Po^{210} to generate a reaction with beryllium producing neutrons once they came into contact with each other. In modern weapons, for higher reliability, when super-criticality is reached, an accelerator tube generates a beam of high energy charged particles in the form of deuterons that impinge on a target made of tungsten loaded with tritium. The DT reaction releases a pulse of 14.06 MeV DT fusion neutrons that start the chain reaction in a Pu^{239} fissile pit. A layer of U^{235} may surround the central Pu^{239} pit for a dual core configuration, initially reducing the spontaneous fission source from U^{238}. Upon compression, it contributes a neutron source that flattens the neutron flux in the core plutonium region leading to a maximum level of burnup with increased efficiency and yield.

4.9 BOOSTER CHARGE AND NEUTRON MULTIPLICATION

The energy release may ignite a thermonuclear reaction in a capsule containing a booster charge of deuterium and tritium gas under high pressure. The energy release from the fission process initiates the DT fusion reaction:

$$ {}_{1}D^{2} + {}_{1}T^{3} \rightarrow {}_{0}n^{1}(14.06\ MeV) + {}_{2}He^{4}(3.54\ MeV) \tag{11} $$

The fusion 14.06 MeV neutrons have a much higher energy than fission neutrons with an average energy of just 1.99 MeV. The fusion neutrons fission plutonium and release an average 4.5 neutrons per reaction at high energy compared with about 2.9 for fission induced neutrons.

The fusion neutrons amplify the energy release by increasing the fissioning of fissile isotopes in both the Pu^{239} and the U^{235} or U^{238} tamper. The energy release from these second generation neutrons reactions exceeds the ones from the initial fission process. This made possible the design of devices having yields in the range of 100 kT. Robert Oppenheimer argued that this was sufficient to destroy any conceivable strategic target. This led to a vicious personality clash with Edward Teller who kept pushing for the Super with its potential megaton level energy release. Modern weapons have a yield in the range of 100 kT vindicating Robert Oppenheimer's perspective.

The beryllium used to contain the tritium could also be a source of neutron multiplication through the (n, 2n) reaction:

$$ {}_0n^1 + {}_4Be^9 \rightarrow 2\,{}_0n^1 + 2\,{}_2He^4 \tag{12} $$

which can be conceived as a fission of the beryllium nucleus.

The generated gamma rays are absorbed in the device casing and are reemitted as x rays in addition to the x rays generated from the primary device's hot plasma.

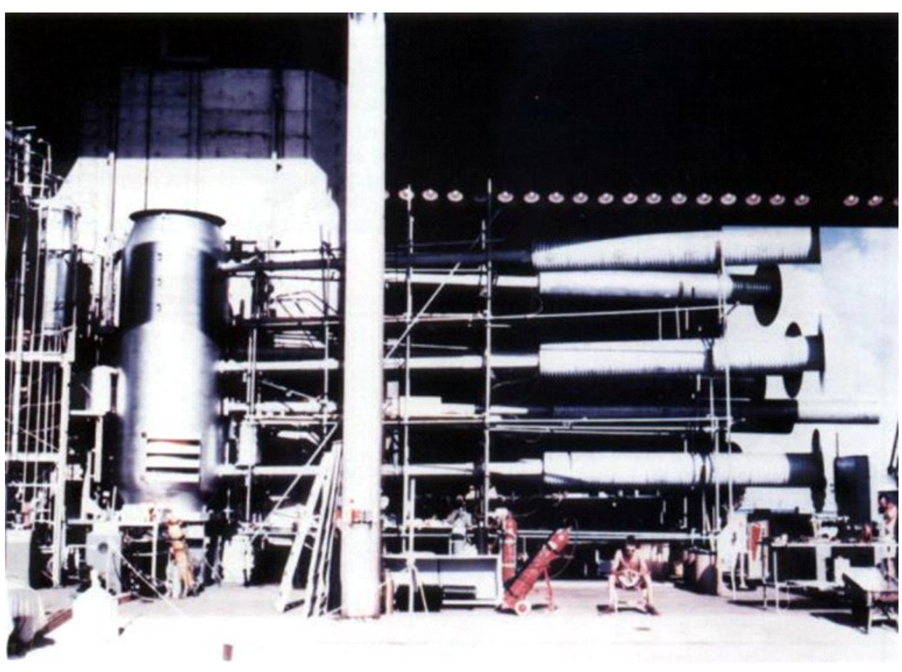
The collimation process may use the concept of a whispering gallery to collimate the soft x rays from the primary at the focus of an ellipsoid of revolution to the other focus containing a DT charge that can be ignited and propagate a thermonuclear burn wave into a cylindrical fusion charge.

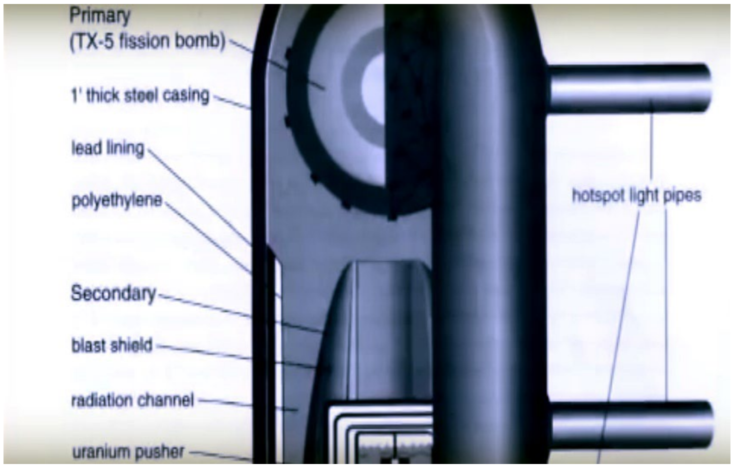
The hohlraum cylinder length can be arbitrary in length, suggesting that there is no limit on the possible yield that can be generated from such devices; which act like a cigarette ignited at its tip. In fact long cylindrically shaped thermonuclear devices have been used in the Plowshare peaceful nuclear explosives program, in which they were brought down drill holes and exploded to enhance the production from hydrocarbon gas and oil reservoirs.

The x rays permeate a paper honeycomb shield to a special polystyrene foam channel filler. The hohlraum is fabricated from foam containing a high Z element, possibly thin sheets of U^{238} that are 5/1000 of an inch thick.

A plasma forms, compressing through inverse rocket action the secondary device composed of a lithium^6 deuteride compressed powder encased in a U^{238} pusher. The compressed plasma in turn compresses an internal core of U^{235} or Pu^{239}. Neutrons from the internal core transmute the Li^6 component of the lithium^6 deuteride into tritium, which would interact as a plasma under compression with deuterium. The reaction proceeds under equilibrium since the highly compressed fusion fuel now absorbs the emitted radiation and does not allow it to escape. In addition, the reaction proceeds faster between the deuterium and tritium nuclei with a substantial energy confinement time, leading to a high efficiency in burning the fusion fuel.

The high-energy 14.06 MeV neutrons from the DT fusion reaction are capable of fissioning the U^{238} pusher, generating about 90 percent of the released energy. Thus the secondary contains its own fission trigger in the center.





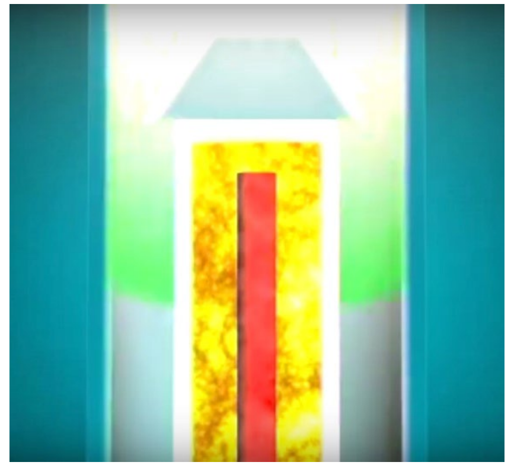


Figure 31. Setup for the cryogenic liquid deuterium Mike device showing the experimental measuring tubes. The device was 22 ft in length and 5 ft in diameter and an inch steel lining housing polyethylene foam, gold sheet reflectors, lead lining, a radiation shield and canisters of liquid deuterium. The He-filled tube carried the gamma rays resulting from the interaction of gamma rays resulting from the interaction of neutrons with an iron shield plate to the diagnostics instrumentation.

Figure 32. The 1952 Ivy-Mike thermonuclear test whose yield at 10.4 Mt TNT, at the Eniwetok Atoll was 500 times the yield from the Hiroshima device and occurred on October 31, 1952. The cloud reached a height of 100,000 feet. Photo: National Nuclear Security Administration / Nevada Site Office.

In enhanced radiation weapons such as a neutron device, no U^{238} casing is used, and is substituted for with Pb, Be, tantalum, or tungsten. If Be is used the DT fusion 14.6 MeV neutrons do not slow down through radiation capture reactions, and are not lost in fissioning the casing and multiply the neutron flux through (n , 2n) reactions with Be, and possibly to a lesser extent with Pb.

The system in fact acts as a multistage energy converter and amplifier of neutrons, electromagnetic radiation and kinetic energy. Designing enhanced radiation devices with different conversion efficiencies and different forms of energy releases in the form of neutrons, x rays, gamma rays, charged particles, and blast, becomes a design possibility, according to the intended usage of the devices. Directed energy devices also have been designed by channeling the device plasma into a heavy or light element propellant disc that under free expansion in space, can evolve into a directed energy cylindrical plug shape. Such process could become useful for pulsed nuclear rocket propulsion for planetary travel.

An important application came through a plan of placing such devices in rockets carried by submarines. This suggestion made it impossible for an attack to be launched on the USA without retaliation. A small and efficient primary fission device and a small and efficient secondary fusion device were designed.

Since the production of the hydrogen isotope tritium (${}_1T^3$) was needed for the Super program, president Harry S. Truman assigned the Savannah River Laboratory in South Carolina as a site for producing tritium in 1950.

4.10 ATMOSPHERE IGNITION AND NUCLEAR TESTING, MIKE SHOT, OPERATION IVY

The first Super apparatus weighted 65 tons and was practically a deuterium cryogenic plant built at the Eniwetok Atoll in the South Pacific. On Oct. 31, 1952, the Mike test was conducted and yielded 10.4 Megatons (Mt) of TNT equivalent. The Mike test yield was so unexpectedly large that the director of the Los Alamos Laboratory considered keeping the results of the test secret.

President Dwight Eisenhower was informed that: “The island of Elugelab is missing!” Elugelab was vaporized. The resulting crater could accommodate several pentagon-size buildings. It was deep enough to hold the Empire State Building.

There was a fear that such a thermonuclear reaction could ignite the Earth's atmosphere and turn the Earth into a new star, which obviously did not occur. The reaction in question was the fusion of the nitrogen in the Earth’s atmosphere according to the reaction:

$$_{7}N^{14} + {}_{7}N^{14} \rightarrow {}_{2}He^{4} + {}_{12}Mg^{24} + 17.7 MeV$$

which was determined to have no ignition point in the encountered range of temperature.

What happened is that the island of Elugelap in the Marshall Islands in the Pacific Ocean was practically vaporized. The Mike test used the hydrogen isotope deuterium in the form of a cryogenically cooled liquid with the fusion reaction ignited by a fission explosion. This arrangement is fine for a physics experiment but does not yield a deliverable weapon system.

The Mike test was followed on November 15, 1952 by the King shot, the larger implosion fission device ever tested producing 500 kT of TNT equivalent.

LITHIUM DEUTERIDE, BRAVO TEST

In a subsequent deliverable device test designated as Bravo, lithium[6] deuteride (Li^6D) as a compressed white powdered substance was used. The test was conducted on March 1, 1954, and exceeded its calculated yield by yielding 14.8 Mt TNT, triple its expected release of 5 Mt.



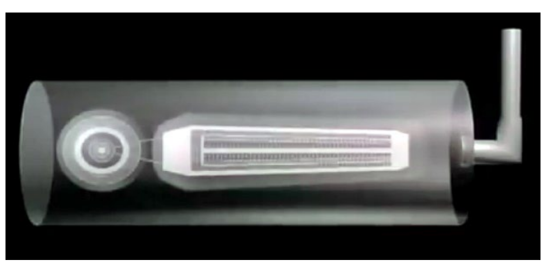


Figure 33. Castle Bravo device used the Ulam-Teller configuration with a uranium tamper generating 80 percent of the yield.

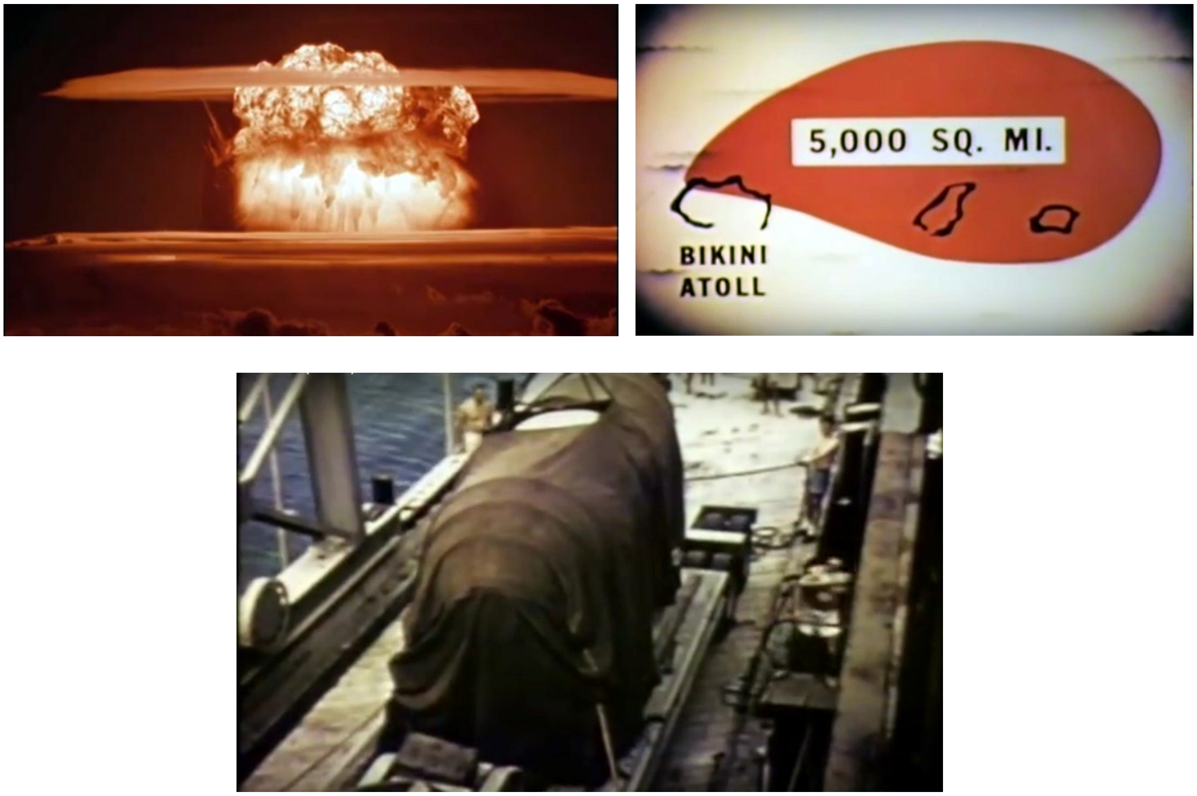


Figure 34. Bravo Test mushroom cloud, fallout extent and barge firing.

Figure 35. Personnel firing and monitoring Bravo test were evacuated by helicopter from their observation bunker.

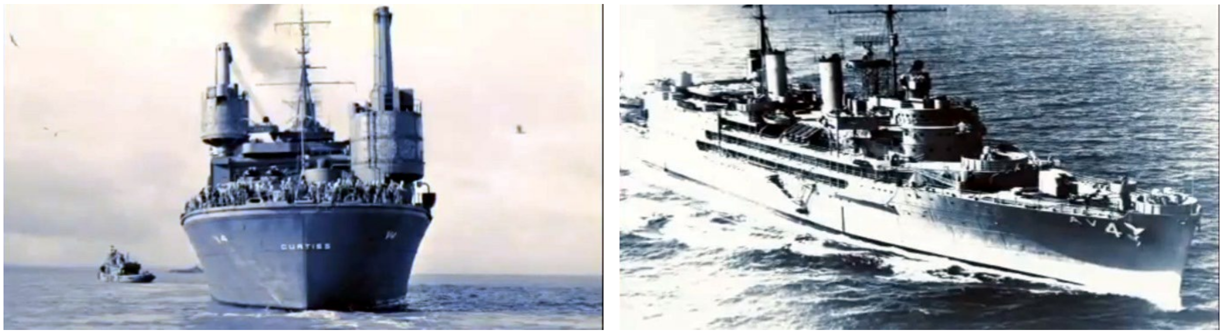


Figure 36. USS Curtiss monitoring and weapon assembly ship was affected by the fallout from the Bravo Test.

Figure 37. The "Lucky Dragon" Japanese fishing boat was affected by the Bravo Test fallout.

Figure 38. Relocation of Marshall Island population from the Bikini Atoll.

TENTATIVE EXPLANATION OF THE TRIPLED YIELD OF THE BRAVO TEST

The Castle Bravo yield of 15 megatons was triple that of the 5 megatons predicted by its designers, due to a miscalculation.

The unexpectedly high yield of the device severely damaged many of the permanent buildings on the control site island on the far side of the atoll.

Little of the desired diagnostic data on the shot was collected; many instruments designed to transmit their data back before being destroyed by the blast were instead vaporized instantly, while most of the instruments that were expected to be recovered for data retrieval were destroyed by the blast.

In an additional unexpected event, albeit one of far less consequence, X-rays traveling through line-of-sight (LOS) pipes caused a small second fireball at Station 1200 with a yield of 1 kiloton of TNT

A tentative explanation for the higher yield is worthwhile for the benefit of future fusion and fusion-fission hybrid reactor designs. The Li in the LiD in the device was intentionally enriched in the Li^6 isotope and was composed of about 30 percent of the Li^6 isotope and 70 percent of the Li^7 isotope. Both Isotopes would lead to the breeding of tritium that would interact with deuterium through the DT reaction:

$$ {}_1D^2 + {}_1T^3 \rightarrow {}_0n^1 + {}_2He^4 + 17.6MeV \tag{13} $$

The reasoning for the enrichment in Li^6 probably was, at the time, that the neutron reaction with the Li^6 isotope is exothermic, whereas the neutron reaction with the Li^7 isotope is endothermic:

$$ \begin{aligned} &{}_3\mathrm{Li}^6 + {}_0\mathrm{n}^1(\text{thermal}) \rightarrow {}_2\mathrm{He}^4(2.05\ \mathrm{MeV}) + {}_1\mathrm{T}^3(2.73\ \mathrm{MeV}) + 4.78\ \mathrm{MeV} \\ &{}_3\mathrm{Li}^7 + {}_0\mathrm{n}^1(\text{fast}) \rightarrow {}_2\mathrm{He}^4 + {}_0\mathrm{n}^1 + {}_1\mathrm{T}^3 - 2.47\ \mathrm{MeV} \end{aligned} \tag{14} $$

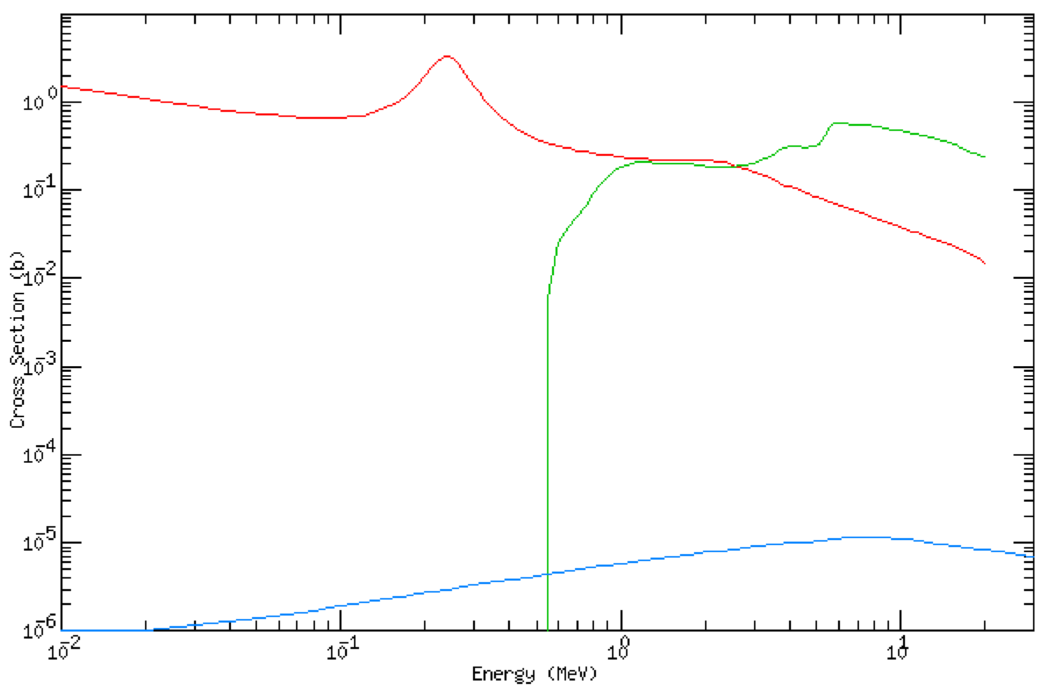


Figure 39. Tritium production cross sections for Li^6 (red), Li^7 (green) and D^2 (blue). The tritium production cross section of Li^7 exceeds that of Li^6 at high neutron energies.

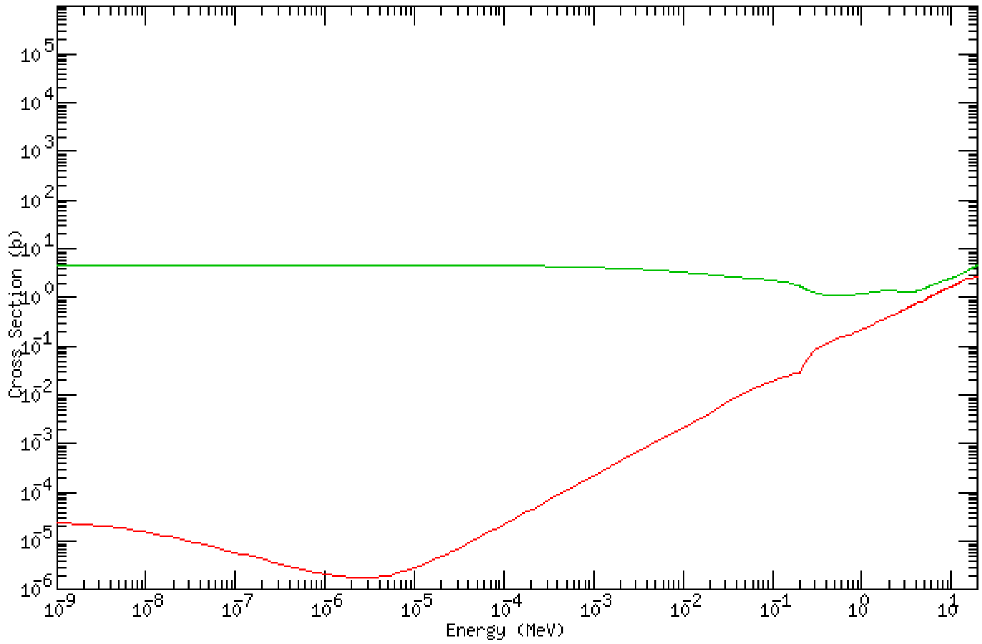


Figure 40. The neutron heating cross sections of Li^6 (green) and Li^7 (red) are comparable at high neutron energies even though the one for Li^7 is much lower than for Li^6 at low neutron energies.

What was not realized at the time is that the Li^7 isotope has a larger tritium production cross section than the Li^6 isotope at higher neutron energies. Further, the neutron produced by the reaction with Li^7 is available for breeding extra tritium from Li^6 exothermally.

$$
\begin{array}{l}
{}_3\mathrm{Li}^7 + {}_0\mathrm{n}^1(\mathrm{fast}) \rightarrow {}_2\mathrm{He}^4 + {}_0\mathrm{n}^1 + {}_1\mathrm{T}^3 - 2.47\ MeV \\
{}_3\mathrm{Li}^6 + {}_0\mathrm{n}^1(\mathrm{thermal}) \rightarrow {}_2\mathrm{He}^4 + {}_1\mathrm{T}^3 + 4.78\ MeV \\
2\,{}_1D^2 + 2\,{}_1T^3 \rightarrow 2\,{}_0n^1 + 2\,{}_2He^4 + (2\times 17.6)\,MeV \\
\hline
2\,{}_1D^2 + {}_3Li^6 + {}_3Li^7 \rightarrow {}_0n^1 + 4\,{}_2He^4 + 37.51\,MeV
\end{array}
\tag{17}
$$

The result is that at high neutron energies, the heating from Li^7 is comparable to that of Li^6, which was not known at the time of the initial calculations, and hence was ignored. Since the heating from the Li^7 isotope is comparable to that of the Li^6 isotope, and the concentration of the Li^7 isotope (70 percent) is about twice that of the Li^6 isotope (30 percent), hence this could alone explain the tripling of the generated energy release from the fusion component of the reactions.

$$0.7\,{}_3\mathrm{Li}^7 + 0.7\,{}_0\mathrm{n}^1(\text{fast}) \rightarrow 0.7\,{}_2\mathrm{He}^4 + 0.7\,{}_0\mathrm{n}^1 + 0.7\,{}_1\mathrm{T}^3 - (0.7 \times 2.47)\ MeV$$
$$0.3\,{}_3\mathrm{Li}^6 + 0.3\,{}_0\mathrm{n}^1(\text{thermal}) \rightarrow 0.3\,{}_2\mathrm{He}^4 + 0.3\,{}_1\mathrm{T}^3 + (0.3 \times 4.78)\ MeV$$
$${}_1D^2 + {}_1T^3 \rightarrow {}_0n^1 + {}_2He^4 + 17.6\,MeV \tag{18}$$

$${}_1D^2 + 0.3\,{}_3Li^6 + 0.7\,{}_3Li^7 \rightarrow 0.7\,{}_0n^1 + 2\,{}_2He^4 + 17.305\,MeV$$

This suggests the interesting implication that there was no need to enrich the used Li in the Li^6 isotope, and that natural lithium with 92.5 percent Li^7 and 7.5 percent Li^6 could have been used with a moderate decrease in energy release from 17.3 MeV to 15.7 MeV.

$$0.925\,{}_3\mathrm{Li}^7 + 0.7\,{}_0\mathrm{n}^1(\text{fast}) \rightarrow 0.925\,{}_2\mathrm{He}^4 + 0.925\,{}_0\mathrm{n}^1 + 0.925\,{}_1\mathrm{T}^3 - (0.925 \times 2.47)\ MeV$$
$$0.075\,{}_3\mathrm{Li}^6 + 0.075\,{}_0\mathrm{n}^1(\text{thermal}) \rightarrow 0.075\,{}_2\mathrm{He}^4 + 0.075\,{}_1\mathrm{T}^3 + (0.075 \times 4.78)\ MeV$$
$${}_1D^2 + {}_1T^3 \rightarrow {}_0n^1 + {}_2He^4 + 17.6\,MeV \tag{19}$$

$${}_1D^2 + 0.075\,{}_3Li^6 + 0.925\,{}_3Li^7 \rightarrow 0.925\,{}_0n^1 + 2\,{}_2He^4 + 15.674\,MeV$$

One can also attempt an explanation on the basis of the secondary fusion reactions that could not have been accounted for in the initial calculations. These would occur at the very high temperatures attained in thermonuclear weapons, but not necessarily under laboratory conditions.

For instance, the TT fusion reaction is an efficient neutron multiplier that releases two neutrons per reaction:

$${}_1T^3 + {}_1T^3 \rightarrow 2\,{}_0n^1 + {}_2He^4 + 11.3\,MeV \tag{20}$$

At some point in time the two emitted neutrons were thought to be a "dineutron."

The increased neutron multiplication would have increased the neutron flux, efficiently fissioning the fissile material releasing about 180 MeV per fission event.

In addition, the DHe^3 reaction releases a significant 18.3 MeV per reaction in the form of charged particles:

$${}_1D^2 + {}_2He^3 \rightarrow {}_1H^1 + {}_2He^4 + 18.3\,MeV \tag{21}$$

The THe^3 reaction has three branches occurring with different branching ratios:

$$\begin{aligned}{}_1T^3 + {}_2He^3 &\xrightarrow{51\%} {}_1H^1 + {}_2He^4 + {}_0n^1 + 12.1\,MeV \\ &\xrightarrow{43\%} {}_1D^2(9.5\,MeV) + {}_2He^4(4.8\,MeV) \\ &\xrightarrow{6\%} {}_1H^1(11.9\,MeV) + {}_2He^5(2.4\,MeV)\end{aligned} \tag{22}$$

The presence of Li^6 can also lead to the reaction with deuterium:

$$ {}_1D^2 + {}_3Li^6 \rightarrow 2\,{}_2He^4 + 22.4\,MeV \tag{23} $$

and the reaction with the hydrogen ions:

$$ {}_3Li^6 + {}_1H^1 \rightarrow {}_2He^3(2.3MeV) + {}_2He^4(1.7\,MeV) \tag{24} $$

If Li^7 is present a branching reaction could occur:

$$ \begin{aligned} {}_1H^1 + {}_3Li^7 &\xrightarrow{80\%} {}_0n^1 + {}_4Be^7 - 1.6\,MeV \\ &\xrightarrow{20\%} 2\,{}_2He^4 + 17.3MeV \end{aligned} \tag{25} $$

One can even envision the occurrence of the He^3He^3 reaction:

$$ {}_2He^3 + {}_2He^3 \rightarrow 2\,{}_1H^1 + {}_2He^4 + 12.9\,MeV \tag{26} $$

POTENTIAL LOWEST ENERGY FUSION REACTION

It is possible that the p-Li^7 reaction is the nuclear reaction that occurs at the lowest temperature among the other fusion reactions with its two branches:

$$ \begin{aligned} {}_1H^1 + {}_3Li^7 &\xrightarrow{20\%} 2\,{}_2He^4 + 17.3MeV \\ &\xrightarrow{80\%} {}_4Be^7 + {}_0n^1 - 1.6MeV \end{aligned} $$

If this is the case, it must be seriously considered as a potential future fusion reactor fuel, possibly ahead of the contemplated fusion reactor designs using the DT and DD reactions. The Li^7 isotope occurs in natural Li with an atomic abundance of 92.5 percent, whereas the Li^6 isotope occurs with an abundance of 7.5 percent.

In stellar interiors Li occurs in one of the less common branches in the conversion of H into He, known as the p-p-II chain reaction. Li^7 could be present from the time of star birth, or could be produced from the fusion of the two He^3 and He^4 isotopes producing Be^7 which is a proton rich nuclide decaying through electron capture into Li^7:

$$ \begin{aligned} &{}_2He^3 + {}_2He^4 \rightarrow {}_4Be^7 \\ &{}_4Be^7 + {}_{-1}e^0 \xrightarrow{53.29d} {}_3Li^7 \\ \hline &{}_2He^3 + {}_2He^4 + {}_{-1}e^0 \rightarrow {}_3Li^7 \end{aligned} $$

In this overall reaction, Be^7 acts as a catalyst. It is thought to be the first to occur in the formation of young proto stars. It could be the sole reaction occurring in brown dwarf stars.

In the first branch of the pLi^7 reaction, 20 percent of the time the following overall reaction would be expected:

$$
\begin{aligned}
&{}_{2}He^{3} + {}_{2}He^{4} \rightarrow {}_{4}Be^{7} \\
&{}_{4}Be^{7} + {}_{-1}e^{0} \xrightarrow{53.29d} {}_{3}Li^{7} \\
&{}_{1}H^{1} + {}_{3}Li^{7} \xrightarrow{20\%} 2\,{}_{2}He^{4} \\
\hline
&{}_{2}He^{3} + {}_{2}He^{4} + {}_{-1}e^{0} + {}_{1}H^{1} \rightarrow 2\,{}_{2}He^{4}
\end{aligned}
$$

In this case both Li^7 and Be^7 act as catalyst in the reaction.

In the second branch of the pLi^7 reaction, 80 percent of the time the following overall reaction may occur:

$$
\begin{aligned}
&{}_{2}He^{3} + {}_{2}He^{4} \rightarrow {}_{4}Be^{7} \\
&{}_{4}Be^{7} + {}_{-1}e^{0} \rightarrow {}_{3}Li^{7} \\
&{}_{1}H^{1} + {}_{3}Li^{7} \rightarrow {}_{4}Be^{7} + {}_{0}n^{1} \\
&{}_{4}Be^{7} + {}_{-1}e^{0} \rightarrow {}_{3}Li^{7} \\
&{}_{1}H^{1} + {}_{3}Li^{7} \rightarrow {}_{4}Be^{7} + {}_{0}n^{1} \\
&\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\
\hline
&{}_{2}He^{3} + {}_{2}He^{4} + m\,{}_{-1}e^{0} + m\,{}_{1}H^{1} \rightarrow {}_{4}Be^{7} + m\,{}_{0}n^{1}
\end{aligned}
$$

This chain reaction, if energetically possible, that once started cycles and perpetuates itself as long as a supply of m electrons and m protons are available from a hydrogen plasma, turning them into a supply of m neutrons, through the intermediary of Li^7 and Be^7 as catalysts for the reaction.

THE P-P-I, P-P-II and P-P-III REACTION CHAINS

These reactions in stellar atmospheres essentially convert H into He^4. The p-p-I branch proceeds as follows:

$$
\begin{aligned}
&{}_{1}H^{1} + {}_{1}H^{1} \rightarrow {}_{1}D^{2} + {}_{+1}e^{0} + \nu \\
&{}_{+1}e^{0} + {}_{-1}e^{0} \rightarrow 2\gamma \\
&{}_{1}D^{2} + {}_{1}H^{1} \rightarrow {}_{2}He^{3} + \gamma \\
&{}_{2}He^{3} + {}_{2}He^{3} \xrightarrow{69\%} {}_{2}He^{4} + 2\,{}_{1}H^{1}
\end{aligned}
$$

The p-p II branch is:

$$
\begin{aligned}
&{}_1H^1 + {}_1H^1 \to {}_1D^2 + {}_{+1}e^0 + \nu \\
&{}_{+1}e^0 + {}_{-1}e^0 \to 2\gamma \\
&{}_1D^2 + {}_1H^1 \to {}_2He^3 + \gamma \\
&{}_2He^3 + {}_2He^4 \xrightarrow{31\%} {}_4Be^7 + \gamma \\
&{}_4Be^7 + {}_{-1}e^0 \xrightarrow{99.7\%} {}_3Li^7 + \nu \\
&{}_3Li^7 + {}_1H^1 \to 2\,{}_2He^4
\end{aligned}
$$

With a branching ratio of 0.3 percent the p-p-III branch can occur:

$$
\begin{aligned}
&{}_1H^1 + {}_1H^1 \to {}_1D^2 + {}_{+1}e^0 + \nu \\
&{}_{+1}e^0 + {}_{-1}e^0 \to 2\gamma \\
&{}_1D^2 + {}_1H^1 \to {}_2He^3 + \gamma \\
&{}_2He^3 + {}_2He^4 \xrightarrow{31\%} {}_4Be^7 + \gamma \\
&{}_4Be^7 + {}_1H^1 \xrightarrow{0.3\%} {}_5B^8 + \gamma \\
&{}_5B^8 \to {}_4Be^8 + {}_{+1}e^0 + \nu \\
&{}_{+1}e^0 + {}_{-1}e^0 \to 2\gamma \\
&{}_4Be^8 \to 2\,{}_2He^4
\end{aligned}
$$

ANOMALOUS MISSING LITHIUM IN THE UNIVERSE

Studies of the old stars that surround the Milky Way in a halo show that they have at most 1/3 the amount of the Li^7 isotope predicted by models of what happened in the newborn universe according to the Big Bang theory. Some stars in the Milky Way's disk do have more Li^7, but such stars are generally thought to be younger than the halo stars and are therefore polluted by heavy elements created through the nucleo-synthesis process later in the universe's history.

Other elements match the predictions and any process that could destroy the Li^7 isotope would have to leave the other elements unaffected. J. Christopher Howk from the University of Notre Dame measured the Li content outside the Milky Way galaxy [6, 7]. He directed the high-resolution UVES spectrograph on the 8.2-meter Very Large Telescope at a massive, young star in the Small Magellanic Cloud, a dwarf galaxy orbiting the Milky Way. Light from the star passes through the gas and dust lying surrounding the star and picks up its spectral signature. Such interstellar material has about 1/4 the amount of heavy elements as the sun. The concentration is at least 10 times higher than the heavy-element levels in many halo stars, but it is useful studying primordial abundances. The effort detected an amount of Li^7 that is substantially lower than predicted but that could be consistent with the theory of big bang nucleosynthesis. The amount of Li should only go up with time as more stars create heavy elements and then spew those elements into space as the stars age and die. If the Small Magellanic Cloud now has about the same amount of lithium as big bang nucleosynthesis predicts, it had to begin with a lower amount. In addition, the actual level of the rarer Li^6 isotope in the interstellar cloud is reported to be 1,000 times more than is predicted by Big Bang nucleosynthesis.

RADIOACTIVE FALLOUT

The radioactive fallout from the test, carried by winds beyond its expected range and in an unexpected direction, fell on nearby islands forcing the evacuation of their local inhabitants. The crew of a Japanese fishing vessel, ironically called "Lucky Dragon," was also affected by the fallout. Figure 41 shows the Mk-17 device, which was the first deliverable thermonuclear weapon. This device required the use of a large bomber to deliver it. This size has been substantially reduced in size as shown in Fig. 42 for the W80-0 device and Fig. 43 for the W85 device.

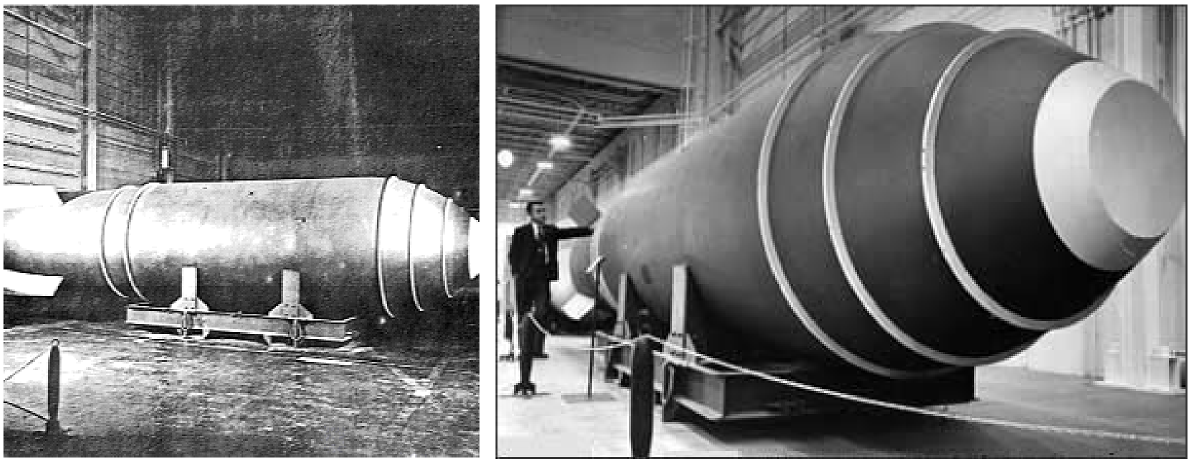


Figure 41. The Mk-17 device, 25 ft in length, 3 ½ in thickness and 21 tons casing, was the first deliverable thermonuclear weapon.

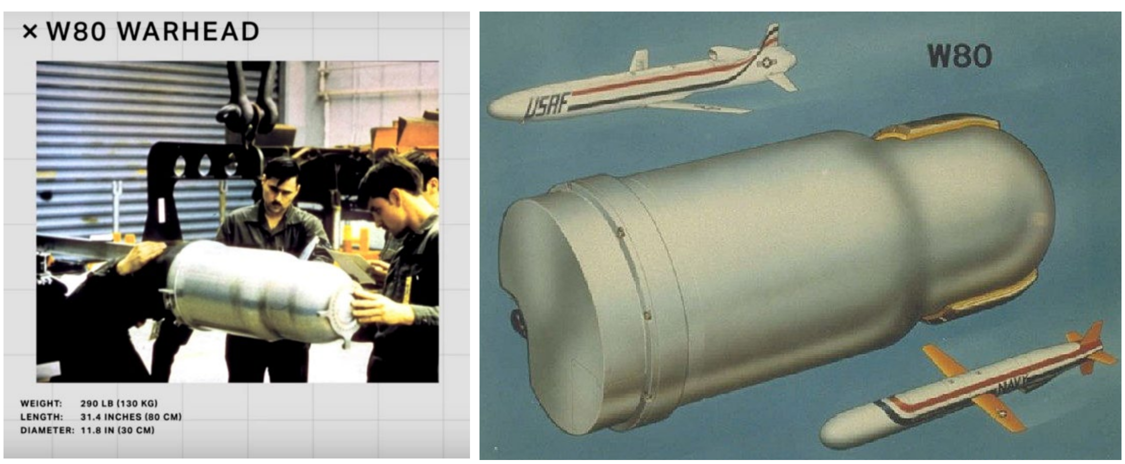


Figure 42. The W80-0, 5-170 kT thermonuclear device was used on cruise missiles.

Figure 43. The B53 9 Mt of TNT equivalent device being moved at the Pantex plant. Source: USDOE

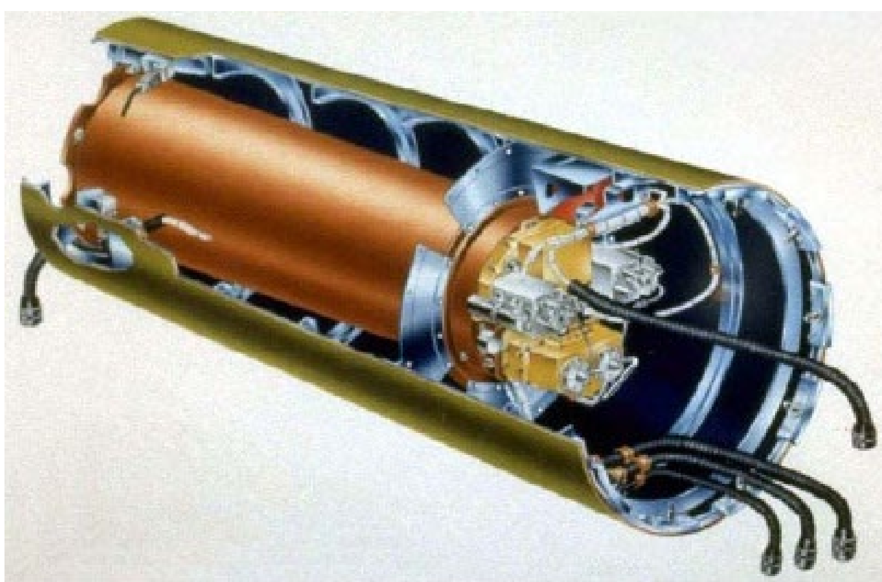
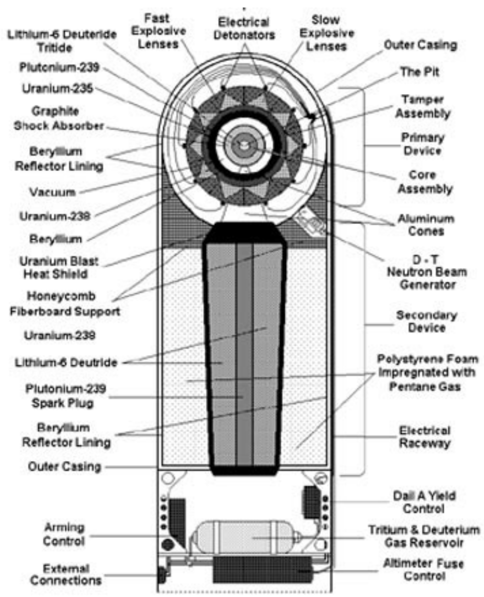


Figure 44. Schematic of variable yield (5-80 kT) W85 device. Variable yield is achieved through the control of its tritium content. Source: USDOE.

Figure 45. Components of the B-83 device are manufactured by a large number of suppliers.



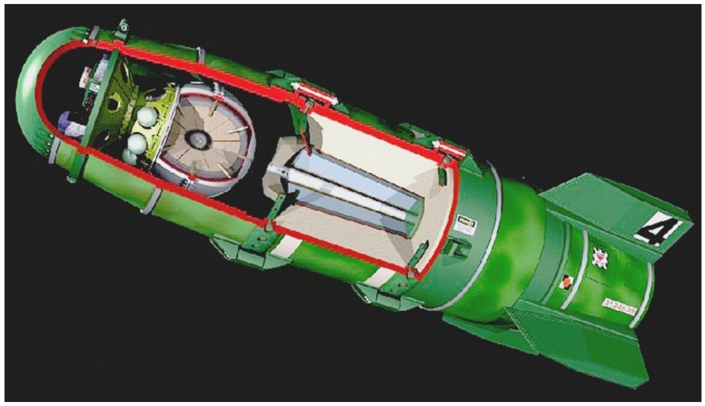


Figure 46. Assumed schematic of a thermonuclear device and Mark 15 Mod 3 cutout. Source: Moreland, “The Secret that Exploded.”

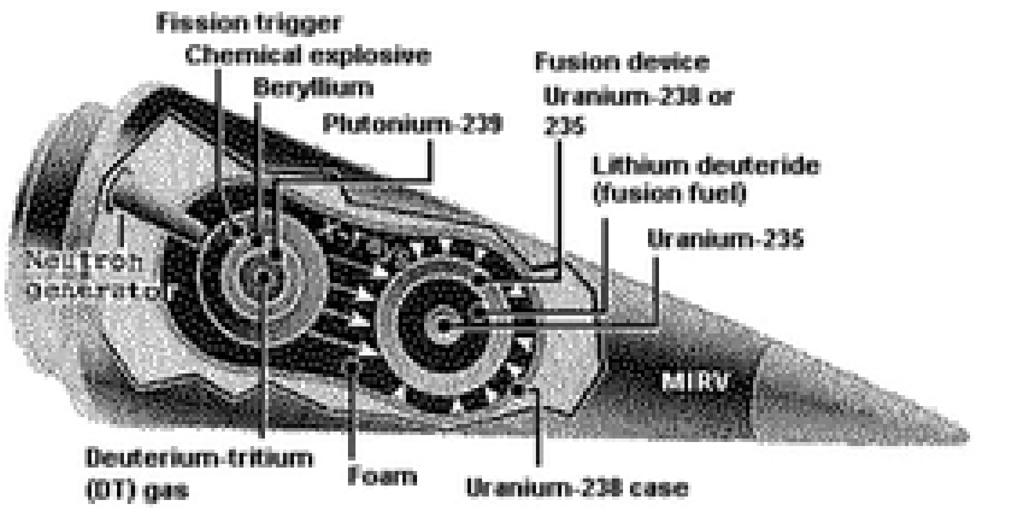
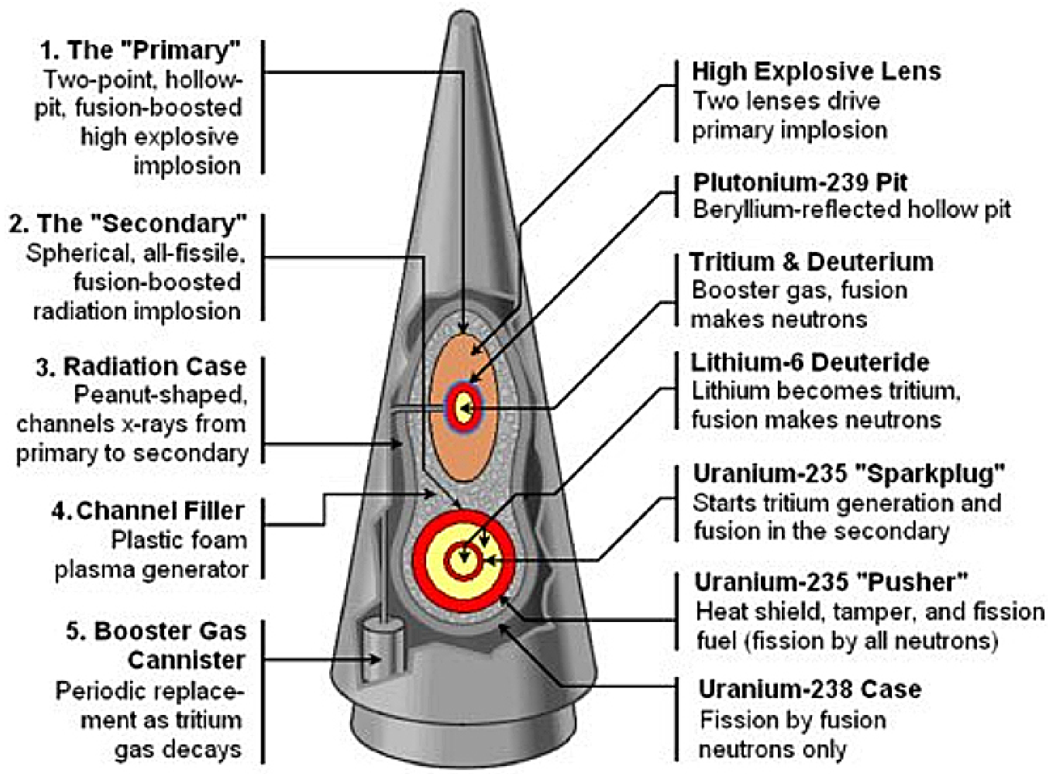


Figure 47. Assumed configuration of W87 warhead. Shows the secondary emplacement at the tip of the MIRV reentry vehicle in contrast to the W88 design in which it is emplaced at the back end. Used on MX intercontinental missile. Length: 5.7 feet, diameter of base: 1.8 feet. Yield: 300 kT of TNT equivalent.



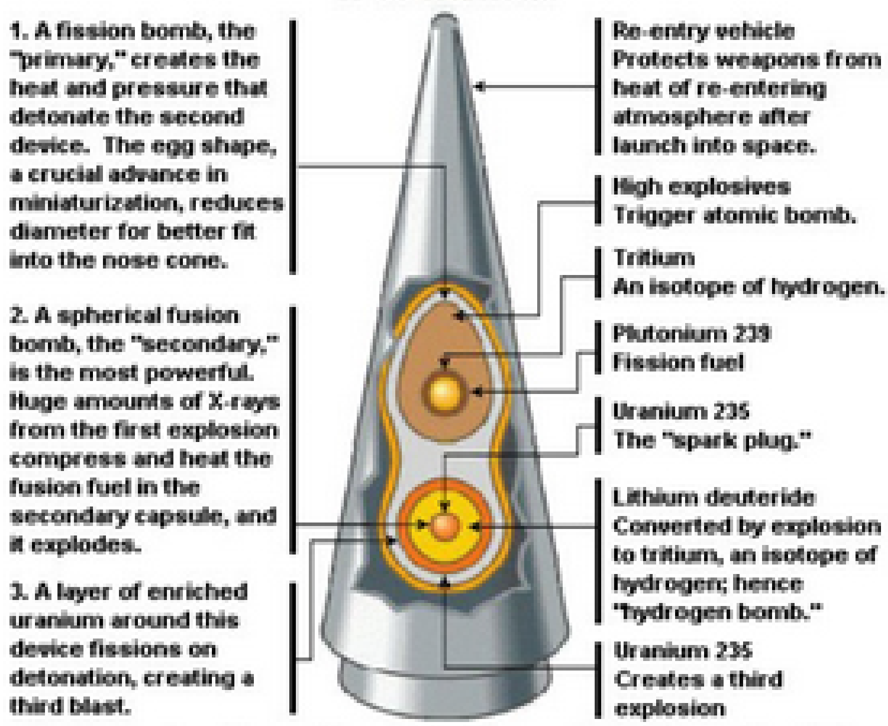


Figure 48. Assumed published configurations of W88 500 kT warhead for the Trident D-5 ballistic missile with a spherical rather than a cylindrical secondary. Miniaturization of the forward placed primary is attempted by an ellipsoidal or egg-shaped explosive lenses

configuration. The primary uses a dense but less stable explosive for compactness and to fit it into the narrow tip. The warhead has a center of gravity shifted to the back resulting in flight stability issues necessitating the use of dead weight ballast in the nose of the reentry vehicle.

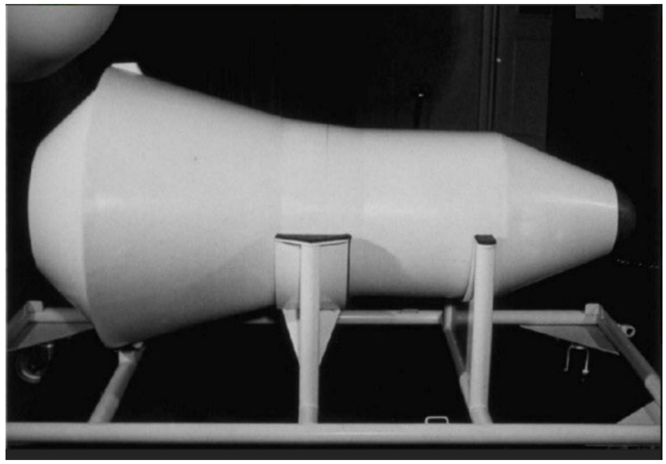


Figure 49. The W59 1 Mt of TNT equivalent for Minuteman I ballistic missile casing.

Figure 50. Museum replica of W80 variable 5-170 kT of TNT equivalent thermonuclear warhead.

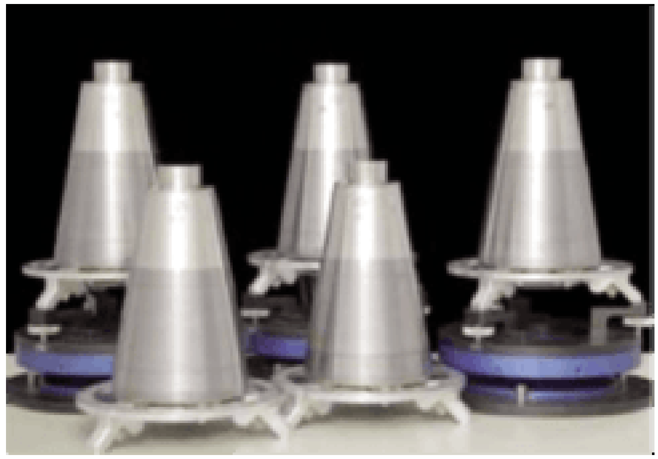


Figure 51. USA nuclear warheads.

Figure 52. W-45 Medium Atomic Demolition Munition, MADM.

These devices are equipped with sophisticated safety, arming and fusing parts as shown for the B83 device using the skills of thousands of engineers and technicians used by tens of suppliers constituting a whole industrial suppliers complex. An assumed schematic for the contents is shown. Inter-Continental Ballistic Missiles (ICBMs) can carry Multiple Independently Released Vehicles (MIRVs).

Table 2. Technical Specifications of the LGM-30 Minuteman III ICBM. Source: Federation of American Scientists, FAS.

Primary function	Inter-Continental Ballistic Missile, ICBM.
Contractor	The Boeing Company.

Power plant	Three solid-propellant rocket motors stages: First stage, Thiokol Second stage, Aerojet-General Third stage, United Technologies Chemical Systems Division
Thrust	First stage, 202,600 pounds, 91,170 kilograms
Length	59.9 feet, 18 meters
Weight	79,432 pounds, 32,158 kilograms
Diameter	5.5 feet, 1.67 meters
Range	6,000-plus miles, 5,218 nautical miles
Speed	Approximately 15,000 mph, Mach 23 or 24,000 kph at burnout
Ceiling	700 miles, 1,120 kilometers
Guidance systems	Inertial System: Autonetics Division of Rockwell International Ground electronic/security system: Sylvania Electronics Systems and Boeing Co.
Load	Re-entry vehicle: General Electric MK 12 or MK 12A
Warheads	Three (downloaded to one as required by the Washington Summit Agreement, June 1992)
Yield	-
Circular Error Probable, CEP	-
Unit cost	$7 million
Date deployed	June 1970, production cessation: December 1978
Inventory	Active force, 530; Reserve, 0; ANG, 0

The value of the ICBM speed at burnout is intriguing. If the Earth's radius is R = 4,000 miles, its circumference is:

$$\begin{aligned} C &= 2\pi R \\ &= 2 \times 3.1415 \times 4{,}000 \\ &= 25{,}133\, miles \end{aligned}$$

The distance to be travelled by a typical ICBM would be less than half this circumference or:

$$\begin{aligned} d &\leq \frac{C}{2} \\ &\leq \frac{25{,}133}{2} \\ &\leq 12{,}566 \ miles \end{aligned}$$

This is double the reported range of $d' = 6{,}000$-plus miles. The reported time for an ICBM to travel from the continental USA to its assigned target is about t = ½ hour. To cover the distance d, the speed of travel of the missile would have to be:

$$
\begin{aligned}
V &= \frac{d}{t} \\
&= \frac{6,000-12,566}{0.5} \\
&= 12,000-25,132 \frac{miles}{hour}
\end{aligned}
$$

An average value of this speed would be:

$$
\begin{aligned}
\bar{V} &= \frac{12,000+25,132}{2} \\
&= \frac{37,132}{2} = 18,566 \frac{miles}{hour}
\end{aligned}
$$

At Standard Sea Level conditions corresponding to a temperature of 15 degrees Celsius, the speed of sound S is:

$$
\begin{aligned}
S &= 340.3 \frac{m}{\sec} = 340.3 \times 10^{-3} \times 60 \times 60 = 1,225 \frac{km}{hour} \\
&= 1,225 \times 0.62137 = 761.2 \frac{miles}{hour}
\end{aligned}
$$

The Mach number is:

$$
M = \frac{\bar{V}}{S} = \frac{18,566}{761.2} = 24.4\, M
$$

This checks the magnitude of M = 23 reported as the speed at burnout in Table 2.

4.11 NUCLEAR ARMS RACE

OPEN TESTING

The nuclear arms race continued escalating. Russia caught up with the American effort and exploded its first fusion device in central Siberia on August 12, 1953. One of the Russian tests at Novaya Zemlya Island on October 23, 1961 yielded a record yield of 58 Mt of TNT. Nikita Khruschchev, the Russian leader boasted about it: "It could have been bigger, but then it might have broken all the windows in Moscow, 4,000 miles away." In fact, the yield was reduced at the last moment by halving the size of the thermonuclear fuel charge. Khruschchev's boasting notwithstanding, it was a situation where the actual yield exceeded the expected one.

Britain caught up and detonated an atomic device on Monte Bello Island off the Australian coast on October 3rd, 1952, which yielded 25 kT of TNT. It conducted 9 more tests in the Great Victoria Desert in Australia from 1952 to 1957. It tested its first hydrogen weapon over the Christmas Island in the Pacific on May 15, 1957.

Figure 53. Multiple Independently Released Vehicles (MIRVs) W87 300-475 kT TNT devices upgraded by adding HRU rings to the secondary. The warhead yield can be upgraded from 300 kT TNT to 475 kT TNT by adding rings or a sleeve of Oralloy of Highly Enriched Uranium (HEU) to the second stage. This entails replacing depleted uranium rings used in a cylindrical fusion tamper so that less energetic neutrons can produce additional fissions.

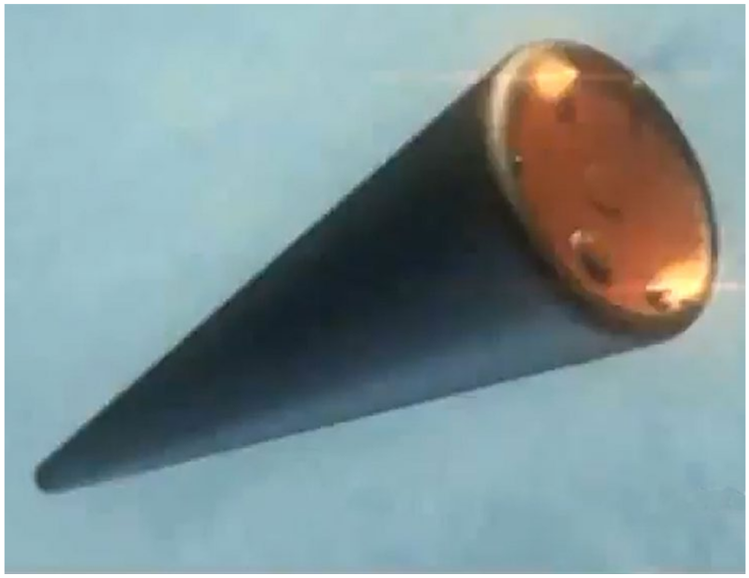


Figure 54. Spin gas generators impart a stabilizing gyroscopic motion to reentry vehicles.

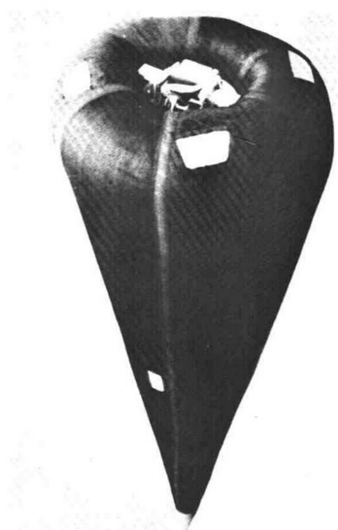


Figure 55. Inflatable decoy re-entry vehicle for the Minuteman missile.

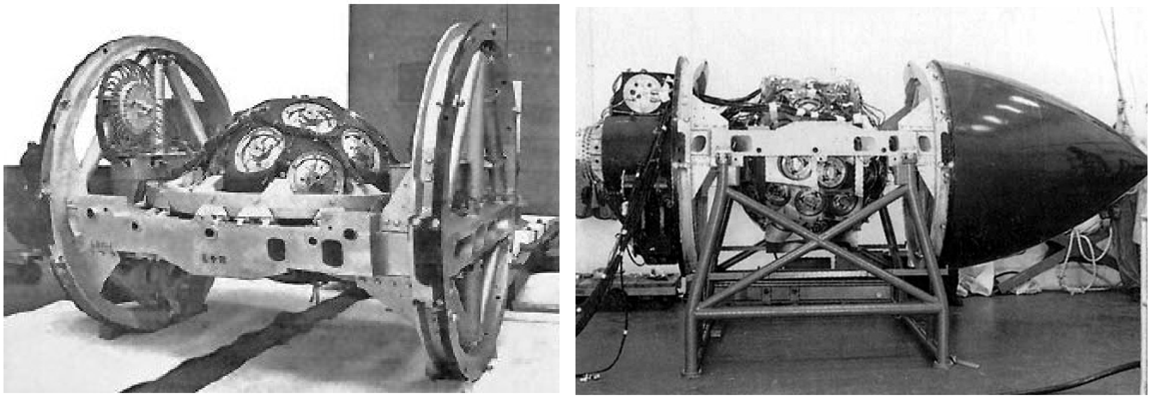


Figure 56. British 32 explosive lenses Orange Herald second Grapple test, May 1957, 720 kT device assembly.

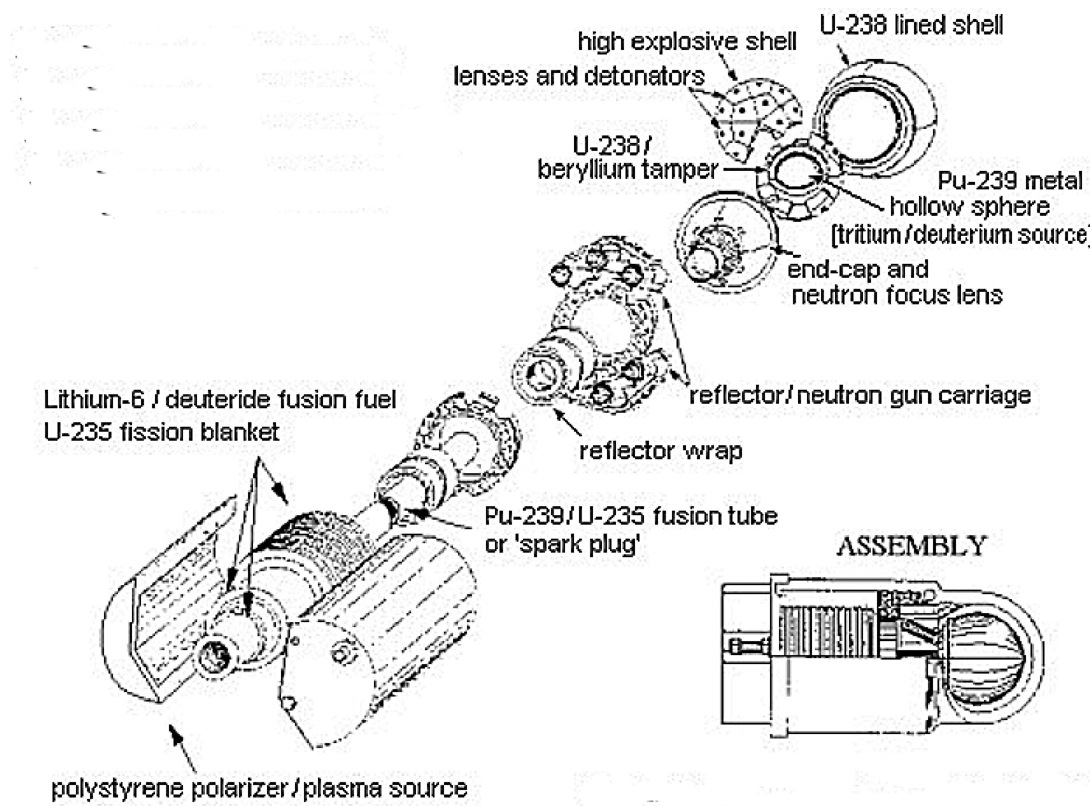


Figure 57. UK assumed design of a staged thermonuclear device. WE117B nuclear Missile.Source: Greenpeace.

France used the Sahara Desert in its previous colony, Algeria, for testing its first device on February 13, 1960. It then exploded its first fusion device above the Fangataufa Island in the Pacific on Aug. 24, 1968.

Figure 58. France’s atmospheric testing in the South Pacific. Source: BBC.

China's first weapon was exploded at Lop Nor on October 16, 1964. Its first hydrogen bomb was tested in 1967.

The world came close to a nuclear exchange between Russia and the USA in the Cuban missile crisis in 1962, when Russia positioned missiles with nuclear warheads close to the USA’s mainland. Russia withdrew its missiles after a naval blockade of Cuba by then President John F. Kennedy, in a horse trade for an already planned closing of American listening posts in Turkey, close to the Russian border. The mutual threats of an unprecedented nuclear exchange generated more efforts towards controlling the spread of nuclear weapons. The Limited Test Ban Treaty (LTBT) was signed in 1963, and was followed by the Comprehensive Test Ban Treaty (CTBT).

Figure 59. Indian ship-launched Dhanush missile.

Figure 60. Pakistani nuclear delivery rocket launch.

Figure 61. DPRK, North Korea nuclear delivery missile launch using Ukrainian Yuzmash Design Bureau RD-250 4-stage rocket system. Estimated “yield-adjustable” 120 kT of TNT equivalent workable Ulam-Teller hohlraum configuration thermonuclear warhead that has an eventual potential of Mt of TNT yield similar to the Trident W-88 warhead with a 475 kt of TNT yield. The “physics” trigger component is shown. The diagram on the wall shows how it would be fitted into an Inter-Continental Ballistic Missile (ICBM) design. On August 28, 2017 test launch overflying Japan suggests that the missile's

structure was made of carbon fiber, in that it did not reflect radar so that a radar lock was not obtained for interception by the Patriot land-based nor the Naval Aegis RIM-161 Standard Missile SM-3. Japan has three batteries with 48 missiles each of Aegis SM-3 Block IIA capable of reaching 1,500 km altitudes.

Figure 62. Hwasong-14 mobile launch ICBM, DPRK.

The radioactive fallout from nuclear testing in the atmosphere spread worldwide, and generated wide protests. Nuclear testing in the atmosphere was replaced by atmospheric and underground tests at the Nevada test site in the USA. Lately, underground testing has been replaced by computer simulations and laser physics experiments at the National Ignition Facility at Livermore, California and other supercomputing sites worldwide.

Figure 63. Social hierarchy as a matter of life or death. President John F. Kennedy nuclear war fallout bunker known as Detachment Hotel on Peanut Island near Riviera Beach, Florida, a 10-minute journey from a Palm Beach house where Kennedy often stayed (top). Blast door of nuclear bunker at Greenbrier resort near White Sulphur Springs, West Virginia with code name Project Greek Island for Congress (bottom). President Donald Trump has a range of places at his disposal. One is located under the White House, a fortified area built in the 1950s. Another is “Doomsday City” in the Blue Ridge Mountains, at Mount Weather, a 1,754-ft (534m) peak near Bluemont, Virginia, fifty miles from Washington D.C. He also has a rudimentary bunker at his Florida estate, Mar-a-Lago, and one originally used to store bombs at his golf course in West Palm Beach under the second hole. Access arrangements exist for the president and a group of individuals deemed to be at the "top of the food chain". Shelters and bunkers make it easier for Americans to talk about atomic or nuclear warheads and help make the unthinkable global nuclear war, thinkable.

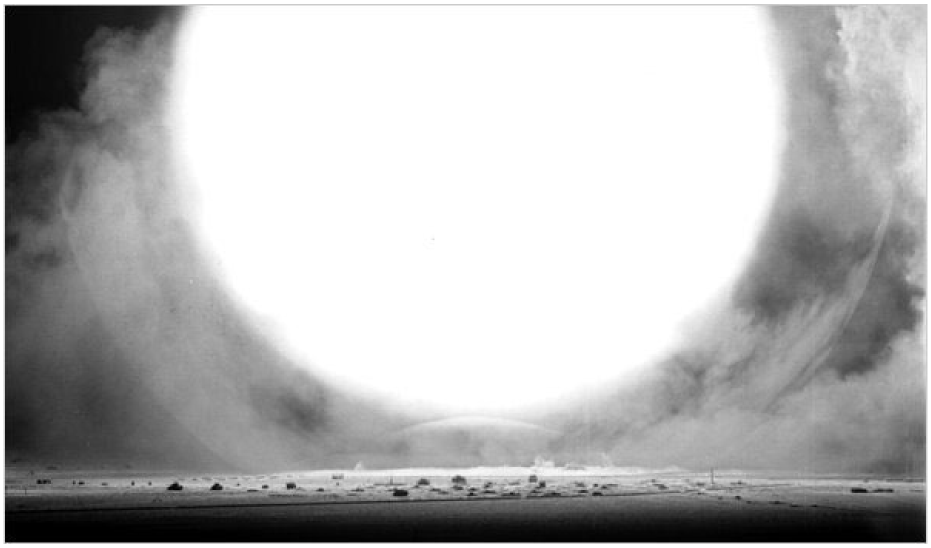


Figure 64. Fireball surrounded by blast wave and its reflection off the ground tested atop military vehicles.

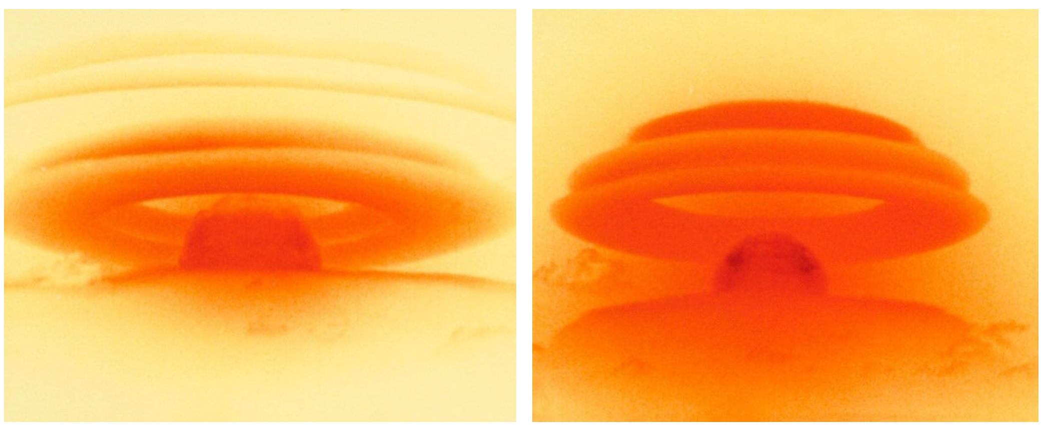


Figure 65. Toroidal magnetic field configurations resulting from the electromagnetic pulse arising from nuclear tests into the troposphere.

Figure 66. Underground nuclear test at the Nevada test site in the USA.

PLOWSHARE PROGRAM

Peaceful uses of nuclear explosives have been studied for a variety of purposes, such as the terraforming of Mars by melting its polar ice-caps. The USA Atomic Energy Commission launched Project Plowshare in 1958 to pursue peaceful applications of the technology.

Some proposed civil nuclear engineering uses of nuclear blasts: harbor, canal, dam construction, fracking, railroad cuts; waste disposal; and generating steam for geothermal power. The Plowshare program produced some three dozen explosive experiments.

The Russians tried using nukes for mining purposes, detonating hundreds of devices up until the late 1980s, including a 200-300 kiloton explosion set off in a coal mine located in Eastern Ukraine in 1979.

The Soviet Union capped leaking and on-fire natural gas wells with nuclear detonations a few times, and President Barack Obama's administration considered that course briefly as a speedy way to plug the Deepwater Horizon spill in 2010.

The Atomic Energy Commission thought about carving a sea-level Panama Canal using a long chain of nuclear blasts. An alternate Suez Canal was planned going through Israel instead of Egypt.

In the early 1960s, Manhattan Project scientist Edward Teller worked on using a nuclear explosion to create an artificial harbor at Cape Thompson, along Alaska's northwest coast. Radioactive experiments were conducted in anticipation of the plan to detonate a 200 kiloton device.

Project Carryall idea was to carve a new path for the Santa Fe Railway Company and an adjacent public roadway through the Bristol Mountains in California's Mojave desert by simultaneously detonating 22 nuclear devices, each with varying yields of up to 200 kilotons, along a two-mile stretch of California's Mojave desert.

Taking out an asteroid with nuclear devices sounds reasonable, and there are active efforts to design a system to do that in case a planetary killer heads our way. Some recent studies have shown that blowing up an asteroid could be largely ineffective, like turning a giant space rock into thousands of smaller space rocks. Comets and asteroids on a collision course with Earth could have their course altered just enough so as to avoid the collision.

Restoring the Earth to a geologically earlier mild temperate climate in case of a runaway anthropogenic global warming by reinstating the circumglobal equatorial current has been proposed by Ragheb by reconnecting the Atlantic and Pacific Oceans using a sea-level canal excavated using peaceful nuclear explosives.

Figure 67. The Sedan underground 105 kT TNT equivalent cratering explosion, July 6, 1962. The release of Cesium^{135} and Argon^{37} are indicative of underground nuclear explosions.

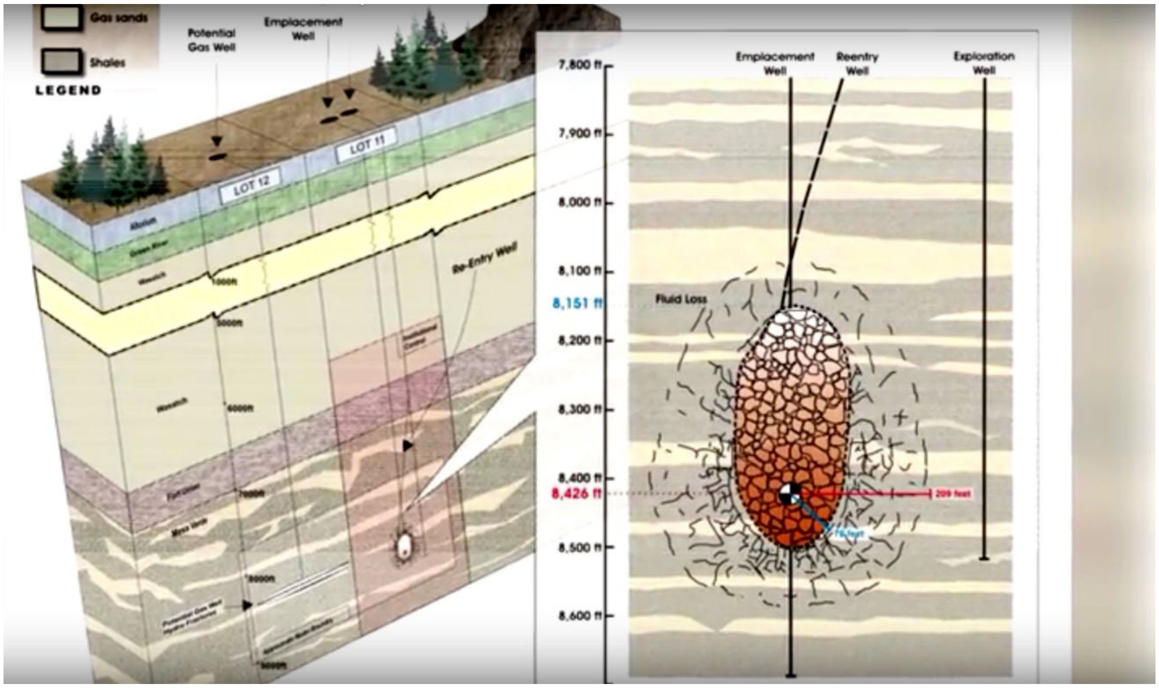


Figure 68. The "Plowshare" program used peaceful nuclear explosions to stimulate the production of natural gas by fracturing the medium and creating a large well radius. The Gasbuggy and Rulison experiments predated the techniques of horizontal well drilling and hydraulic fracturing or fracking.

Figure 69. The Plowshare Project considered the nuclear excavation of a sea-level canal instead of the existing locks and dams at the Isthmus of Panama.

However, nuclear weapons continued to proliferate. India tested a 10-15 kT of TNT yield equivalent fission device in the Rajasthan desert on May 18, 1974. On May 11, 1998, it tested new 20 kT tactical devices using fusion boosted devices, and was followed promptly by its neighbor Pakistan on May 28, 1998 with its own 36-40 kT fission test.

COMPREHENSIVE TEST BAN TREATY

The Comprehensive Test Ban Treaty is an international treaty that would ban all nuclear explosions, whether for military or for peaceful purposes. The treaty has never been ratified by all the signatories, including the USA, and many potential nuclear-capable countries have not signed it. But all nations except North Korea have abided by their interpretation of the treaty since 1999. The proposed treaty was partly in response to protests which converged on the Nevada Test Site in the waning years of full-scale nuclear testing to protest and hold vigils at Peace Camp, near the road leading to the Nevada National Security Site's Mercury entrance. More than 15,740 protesters were arrested in civil disobedience trespass actions from 1986 through 1994.

The USA interprets the treaty to allow for only "zero-yield" tests, such as subcritical experiments. But because those words are not in the treaty or agreed to in negotiations, the possibility exists that other countries have been conducting tests that produce low yields.

Since the last, "Divider" full-scale test at the sprawling Nevada site on September 23, 1992, scientists have certified the safety and reliability of USA nuclear weapons with physics tools and by detonating tiny bits of plutonium in underground subcritical experiments.

The moratorium on full-scale testing announced by President George H.W. Bush after Divider has been extended by all presidents through the Obama administration, meaning a generation of Americans has grown up without ever hearing or reading reports of a domestic nuclear test.

The most palpable reminders of that bygone arms race era are the National Atomic Testing Museum in Las Vegas and the tower for the test that was to have followed Divider, known as Icecap, standing forlornly amid tumbleweeds on the security site's desolate Yucca Flat.

Some nuclear policy experts believe testing should resume, though on a smaller scale than the big underground blasts and preceding atmospheric tests conducted at the site and over the Pacific Ocean in the 1950s. They advocate the need to break the moratorium with low-yield testing on the order of a kiloton of TNT equivalent

Such a test would be about 1/150th the size allowed under the 1974 Threshold Test Ban Treaty. The plutonium in America's last-generation weapons continues to degrade, as well as the initiating chemical explosive, so at some point testing will be needed to assure the stockpile is reliable. The testing moratorium has stifled research of new nuclear weapons, noting that Russia claims to have developed a new family of nuclear warheads that are supposedly pure fusion.

The USA already has embarked on a 30-year, $1 trillion effort to design, develop and produce new and modified nuclear warheads and delivery systems.

CLANDESTINE TESTING

Israel is reported as having conducted on a barge or a balloon, jointly or with support from South Africa, 3 tactical device tests around September 1979. South Africa and Israel had a joint biological and nuclear weapons program. At the end of apartheid

South Africa had 6 nuclear bombs. They collaborated on nuclear and biological weapons programs with one another, A test on September 22, 1979 was inconclusively identified, possibly because of an ingenious disguise of the event to resemble a lightning discharge, by surrounding the exploding device by a Mylar balloon. The balloon would have absorbed the prompt gamma rays emissions from the device and re-emitted them with a time delay.

A nuclear explosion is characterized by two gamma ray pulses. One prompt pulse from the fission process, and a delayed pulse from the fission products of the explosion, whereas a lightning pulse involves only a single pulse. The Mylar balloon surrounding the device would have merged the two pulses into a single pulse, disguising the explosion to look like a lightning's pulse. One of the tests was corroborated by being detected concurrently by the Vela-6911 Satellite and by USA Navy bottom of ocean hydrophones monitoring naval traffic (SOSUS) with a tactical yield of 2-4 kT TNT.

It is also suggested that it was a testing of a fission primary or trigger for a thermonuclear device. Fission triggers on a cruise missile are in the 2-4 kT range and detonate the 150 kT thermonuclear warhead. In a USA Tomahawk Missile the Warhead is a 150 kT Thermonuclear Warhead with a 5 kT Fission Trigger for a total explosive power of 155 kT. The Blast is distinctly 2 blasts, milliseconds apart. The two explosions are close together that it seems like one.

Israel and South Africa had some issues which required them to test the fission trigger, but not an actual warhead. South Africans dismantled its nuclear devices and their laboratories and enrichment centrifuges before ending apartheid. Israel has a lot riding on their Nuclear weapons program and their falling out with the French required them to look elsewhere in the late 1970's to test their triggers. The French South Pacific Tests aroused World outrage.

Atomic devices signatures include x-rays and gamma rays, neutrons and fission products. None of these were noted by any of the other detection instruments. The USA sent airplanes and ships into the 3000 miles in radius area, the distance from Japan to the USA, with equipment to detect radiation, cesium, strontium and other fission isotopes created by the tests. None were reported other than the other than the double flash. This was the only known time Vela picked up the optical flashes that was not confirmed by detection of radiation or fission product isotopes. The weather satellite "Tiros-N" detected strong electromagnetic and auroral activity two minutes before the Vela satellite would pick up the flashes. An airplane pilot reported seeing a dirty brown mushroom cloud out of his cockpit near this area a year earlier, suggesting that other tests may have been conducted.

The absence of radioactivity signatures is contested by an account by an unwitting witness, “Sir Lantz”:

> “I was at OSAN AB Korea September 22/23, 1979. I was ordered to report to the flight line to wash a plane in the early morning with a water truck and a bucket of soap. I was in Civil Engineering, It was an odd order but I did as I was told. When I get to the flight line I see a U-2 spy plane sitting in the middle of a roped off area with security guards in weird suits. There were security police everywhere but a distance from the plane. I showed my ID and told them I was there to wash the plane. I was allowed

to drive right up to the plane, put on my rain suit, gloves and rubber boats, take out some soap and turn the pump on for water to wash the plane. It took me 10/12 minutes to preset. I finally spray the plane with water- the water turned to steam and disappeared. I feel a heat coming off the plane, it is pretty hot. I don't think really anything about the heat. I take out the soap and toss some on the plane - it turned to glue...I take the brush with soap and stick it to the plane and the brush sticks to the plane. it is glued to the fuselage. I am now 20 or 30 minutes into the attempt to wash the plane when one of the security guards runs up to me in a special suit.. He screams at me wanting to know where my radiation suit is? I don't have one. He screams for me to leave immediately that the plane was hot because it had just flown threw a nuclear explosion. I said really and he said yea China exploded their "First Nuclear Bomb" I pack up what I can and leave the scene. Summer 2014, I decided to look up the incident at the Nuclear Regulatory Agency. There was only one explosion in September 1979 on the 22nd and it said it was Israel. I don't recollect any mention of South Africa. I felt this information was Odd due to the Cover story I was told on September 1979. I sure would like to talk to someone about this info..."

An airline pilot flying on a routine commercial flight from New Zealand to Africa reported to the newspapers noticing the mushroom cloud. The authorities all scoffed at him but to he swore by what he saw. Documents have been released indicating that Israel was willing to sell nuclear weapons to South Africa. Israel was allowed to transport and prepare a nuclear device on South African soil and then detonate it at sea off the coast. The payoff to South Africa was that Israel was going to share nuclear weapons technology with it or sell them the devices.

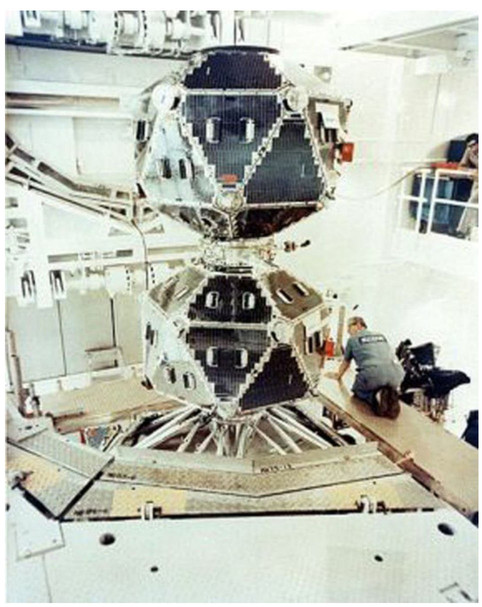
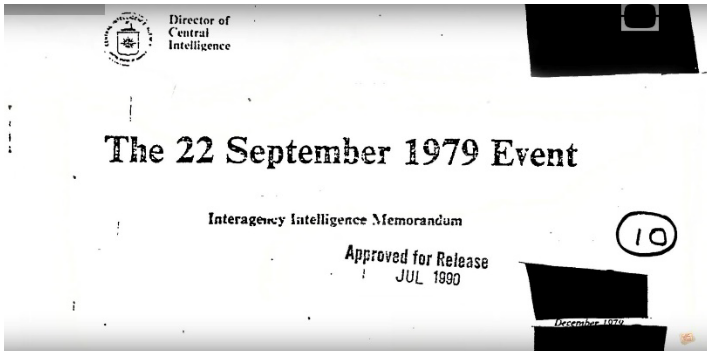


Figure 70. Vela-5 surveillance satellite. Vela is "sail" in Albanian.


Director of
Central
Intelligence

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The 22 September 1979 Event

Interagency Intelligence Memorandum

Approved for Release
JUL 1990

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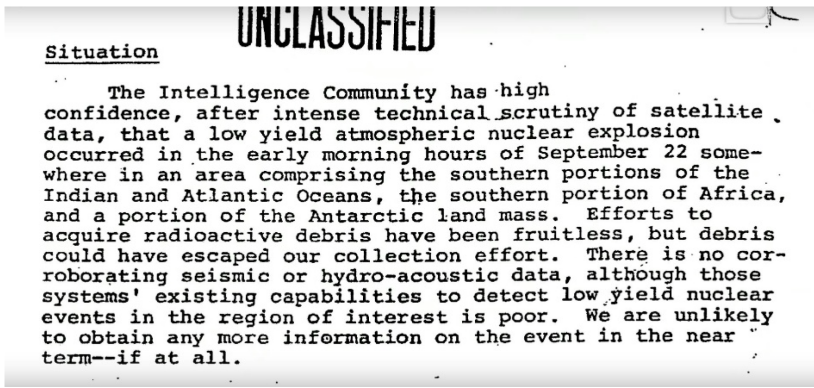
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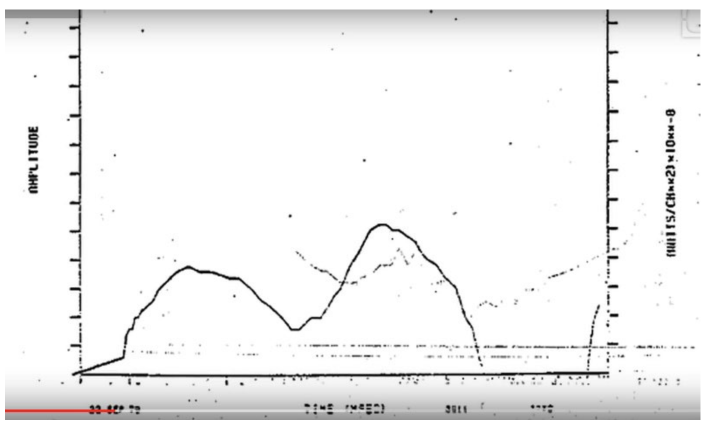
Situation

The Intelligence Community has high confidence, after intense technical scrutiny of satellite data, that a low yield atmospheric nuclear explosion occurred in the early morning hours of September 22 somewhere in an area comprising the southern portions of the Indian and Atlantic Oceans, the southern portion of Africa, and a portion of the Antarctic land mass. Efforts to acquire radioactive debris have been fruitless, but debris could have escaped our collection effort. There is no corroborating seismic or hydro-acoustic data, although those systems' existing capabilities to detect low yield nuclear events in the region of interest is poor. We are unlikely to obtain any more information on the event in the near term--if at all.



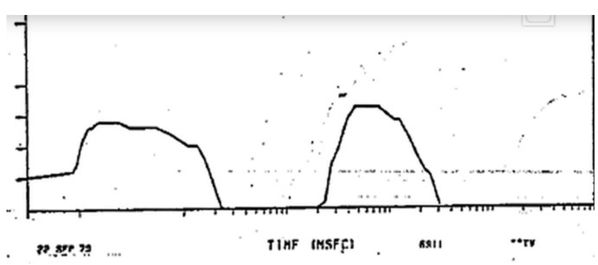
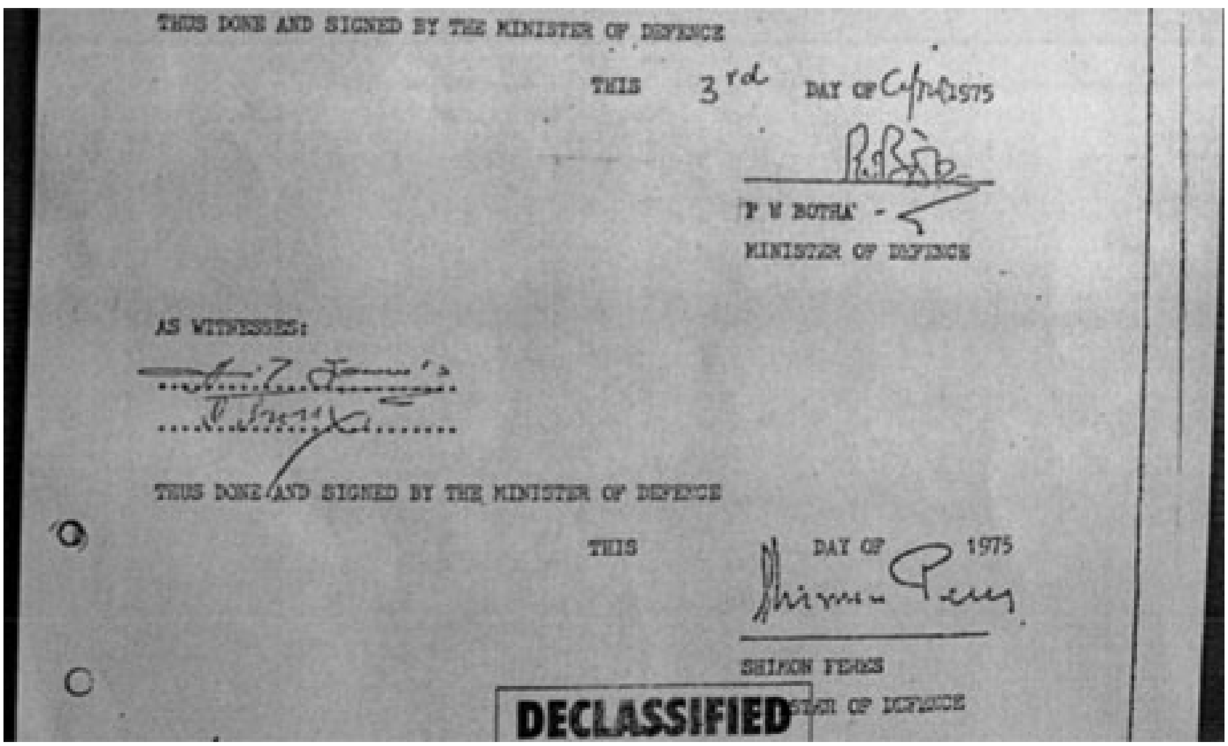


Figure 71. The Vela incident, or "zeek wolfe" operation, September 22, 1979 near the remote Bouvet Island near Prince Edward Island in the Pacific. The "double flash" is characteristic of a 2 - 4 kT of TNT equivalent nuclear device; the first one is released by the prompt gamma rays from fission, and the second from the delayed emission from the fission products and the activated device components. A lightning strike would release an

electromagnetic pulse with a single peak. A Mylar balloon surrounding the device can absorb the prompt gammas and reemit them with a time delay merging them with the delayed gammas, disguising the event as lightning strike with a single pulse.

Israel, having collaborated with France in building the heavy water plutonium production Dimona reactor in the Negev desert is renowned, according to the American Central Intelligence Agency (CIA) reports, to possess 200-400 Nagasaki-sized nuclear devices (20 kT TNT), and possibly more advanced 100 – 150 kT TNT tritium boosted thermonuclear devices. It is rumored to have tested its weapons in collaboration with South Africa, but depends primarily on sophisticated computer simulations to maintain its stockpile. Its weapons are mounted on cruise missiles carried on German Dolphin class submarines and are targeted against regional as well as international targets making it another de facto, yet intentionally-ambiguous superpower.

SECRET AGREEMENT


THUS DONE AND SIGNED BY THE MINISTER OF DEFENCE

THIS 3rd DAY OF April 1975

P W BOTHA

MINISTER OF DEFENCE

AS WITNESSES:

THUS DONE AND SIGNED BY THE MINISTER OF DEFENCE

THIS DAY OF 1975

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DECLASSIFIED

Figure 72. Secret 1975 military agreement signed by Shimon Peres and P. W. Botha during the South Africa apartheid period. Source: The Guardian.

According to the Guardian:

> “Secret South African documents reveal that Israel offered to sell nuclear warheads to the apartheid regime, providing the first official documentary evidence of the state's possession of nuclear weapons.
>
> The "top secret" minutes of meetings between senior officials from the two countries in 1975 show that South Africa's defence

minister, PW Botha, asked for the warheads and Shimon Peres, then Israel's defence minister and now its president, responded by offering them "in three sizes". The two men also signed a broad-ranging agreement governing military ties between the two countries that included a clause declaring that "the very existence of this agreement" was to remain secret.

The documents, uncovered by an American academic, Sasha Polakow-Suransky, in research for a book on the close relationship between the two countries, provide evidence that Israel has nuclear weapons despite its policy of "ambiguity" in neither confirming nor denying their existence.

The Israeli authorities tried to stop South Africa's post-apartheid government declassifying the documents at Polakow-Suransky's request and the revelations will be an embarrassment, particularly as this week's nuclear non-proliferation talks in New York focus on the Middle East.

They will also undermine Israel's attempts to suggest that, if it has nuclear weapons, it is a "responsible" power that would not misuse them, whereas countries such as Iran cannot be trusted.

A spokeswoman for Peres today said the report was baseless and there were "never any negotiations" between the two countries. She did not comment on the authenticity of the documents.

South African documents show that the apartheid-era military wanted the missiles as a deterrent and for potential strikes against neighbouring states.

The documents show both sides met on 31 March 1975. Polakow-Suransky writes in his book published in the US this week, The Unspoken Alliance: Israel's secret alliance with apartheid South Africa. At the talks Israeli officials "formally offered to sell South Africa some of the nuclear-capable Jericho missiles in its arsenal".

Among those attending the meeting was the South African military chief of staff, Lieutenant General RF Armstrong. He immediately drew up a memo in which he laid out the benefits of South Africa obtaining the Jericho missiles but only if they were fitted with nuclear weapons.

The memo, marked "top secret" and dated the same day as the meeting with the Israelis, has previously been revealed but its context was not fully understood because it was not known to be directly linked to the Israeli offer on the same day and that it was the basis for a direct request to Israel. In it, Armstrong writes: "In considering the merits of a weapon system such as the one being offered, certain assumptions have been made: a) That the missiles will be armed with nuclear warheads manufactured in RSA (Republic of South Africa) or acquired elsewhere."

But South Africa was years from being able to build atomic weapons. A little more than two months later, on 4 June, Peres and

Botha met in Zurich. By then the Jericho project had the codename Chalet.

The top secret minutes of the meeting record that: "Minister Botha expressed interest in a limited number of units of Chalet subject to the correct payload being available." The document then records: "Minister Peres said the correct payload was available in three sizes. Minister Botha expressed his appreciation and said that he would ask for advice." The "three sizes" are believed to refer to the conventional, chemical and nuclear weapons.

The use of a euphemism, the "correct payload", reflects Israeli sensitivity over the nuclear issue and would not have been used had it been referring to conventional weapons. It can also only have meant nuclear warheads as Armstrong's memorandum makes clear South Africa was interested in the Jericho missiles solely as a means of delivering nuclear weapons.

In addition, the only payload the South Africans would have needed to obtain from Israel was nuclear. The South Africans were capable of putting together other warheads.

Botha did not go ahead with the deal in part because of the cost. In addition, any deal would have to have had final approval by Israel's prime minister and it is uncertain it would have been forthcoming.

South Africa eventually built its own nuclear bombs, albeit possibly with Israeli assistance. But the collaboration on military technology only grew over the following years. South Africa also provided much of the yellowcake uranium that Israel required to develop its weapons.

The documents confirm accounts by a former South African naval commander, Dieter Gerhardt – jailed in 1983 for spying for the Soviet Union. After his release with the collapse of apartheid, Gerhardt said there was an agreement between Israel and South Africa called Chalet which involved an offer by the Jewish state to arm eight Jericho missiles with "special warheads". Gerhardt said these were atomic bombs. But until now there has been no documentary evidence of the offer.

Some weeks before Peres made his offer of nuclear warheads to Botha, the two defence ministers signed a covert agreement governing the military alliance known as Secment. It was so secret that it included a denial of its own existence: "It is hereby expressly agreed that the very existence of this agreement... shall be secret and shall not be disclosed by either party".

The agreement also said that neither party could unilaterally renounce it.

The existence of Israel's nuclear weapons programme was revealed by Mordechai Vanunu to the Sunday Times in 1986. He provided photographs taken inside the Dimona nuclear site and gave detailed descriptions of the processes involved in producing part of the nuclear material but provided no written documentation.

Documents seized by Iranian students from the US embassy in Tehran after the 1979 revolution revealed the Shah expressed an interest to Israel in developing nuclear arms. But the South African documents offer confirmation Israel was in a position to arm Jericho missiles with nuclear warheads.

Israel pressured the present South African government not to declassify documents obtained by Polakow-Suransky. "The Israeli defence ministry tried to block my access to the Secment agreement on the grounds it was sensitive material, especially the signature and the date," he said. "The South Africans didn't seem to care; they blacked out a few lines and handed it over to me. The ANC government is not so worried about protecting the dirty laundry of the apartheid regime's old allies."

THE COUNTER PROLIFERATION REGIME REPLACING THE NON PROLIFERATION REGIME

The Gulf I campaign and an earlier raid by Israel on the French supplied Osiraq reactor in Iraq may have stopped at its birth a suspected nascent Iraqi effort at acquiring nuclear weapons. The Iraqis then switched to a misinformed U^{235} enrichment effort using magnetic separation and reportedly centrifugation. They were swindled by various unscrupulous equipment suppliers of their oil money on a grand scale. They dismantled their program under the supervision of the IAEA after the first 1991 Gulf War. Their already dismantled nuclear program was nevertheless used as pretext for invading Iraq in 2001, changing its regime, dividing it along ethnic lines into three Kurdish, Shiite and Sunni entities, hanging its previous president after a show trial and shooting his children, and plunging it into an irreconcilable civil war for the foreseeable future.

South Africa in 1991, avoiding the trouble of maintaining a nuclear stockpile, voluntarily asked the IAEA to supervise the dismantlement of its program. Lybia, in 2004, under USA pressure and UK brokering, agreed to dismantle a failed insignificant program.

A uranium enrichment program in Iran for the production of fuel for pressurized power water reactors (3-5 percent enrichment) and for research reactors (20 percent enrichment) is suspected to aim towards the production of nuclear weapons (90 percent enrichment). Consequently, sabotage using computer Trojan horses and worms such as Suxnet of its manufacturing capability, special-forces spying and destruction missions, and extrajudicial assassination of the personnel involved in the program has been undertaken. A campaign has been planned for bombing and dismantling its nuclear facilities, and awaits a suitable timing for its execution.

North Korea withdrew from the Nuclear Nonproliferation Treaty (NPT) and declared that it possessed nuclear weapons, and reportedly tested a device on October 8, 2006. It appears that it was a fizzle generating a low yield; having been constructed of reactor grade rather than from weapons grade plutonium. It was followed by apparently more successful tests.

Ongoing less publicized clandestine Brazilian, Argentinean, and Algerian programs bubble to the surface every once in a while. They sink out of international attention and the eyes are turned away, so as not to embarrass friendly regimes or secure economic ties.

PERSISTENT CONTEMPORARY COLD WAR, MISSILE DEFENSE SYSTEM

On April 20, 2010, with great fanfare in Prague Castle, Czech Republic, USA President Barack Obama and Russian President Dmitri Medvedev signed a new START nuclear arms disarmament treaty. President Dmitri Medvedev called the treaty "a truly historic event" that would "open anew page" in Russian American relations.

Less than 19 months later, all that turned into ashes. In November of 2011, President Dmitri Medvedev, upset about a missile defense system being built by the USA in Europe, declared he did not rule out a possibility to retreat from the policy of disarmament and that Russia could also revise the previous agreements about arms control. A month later, "to preserve parity in the field" with the USA and "because of the unwillingness of the USA side to provide any guarantees," Russia began developing what the Pravda newspaper calls "a new intercontinental missile of enormous power, a 100-ton monster ballistic missile" named Satan. The new 100 tons missile is meant to replace the "Voevoda" ICBM. The missile separates into a cloud of real and decoy warheads, which makes it harder for interceptors to detect the real warheads. Russia's new ballistic missiles have a boost phase of the flight that is shorter than it was with older missiles. At this short part of the flight the missiles perform active maneuvers which makes it difficult for interceptors to plan a counterattack.

The Russian Federation's Strategic Missile Forces (SMF) are planned to be renovated with the help of state-of-the-art Topol-M and Yars missile systems over the next ten years. A decision about the creation of a new silo-based missile system with a liquid-fuel heavy missile has been made. The complex will be designed to overcome the prospective USA missile defense system. By 2012, Russia will begin the process to bring the Yars missile systems into service. The range of the system is up to 11,000 kilometers or 6,835 miles. It will also introduce the Topol-M missile system.

Figure 73. B-1B Lancer, B-2 Spirit stealth bomber and B-52H Stratofortress positioned at Anderson Air Force Base, Guam from Ellsworth Air Force Base South Dakota, as a display of force, February 2018. The B-1 bomber is being phased out and the B-52 Bomber Stratofortress is being renovated because for its larger payload capability.

Figure 74. AGM-84D all-weather over-the-horizon Harpoon anti-ship missile.

Figure 75. B2A Stealth Bomber being air-refueled.

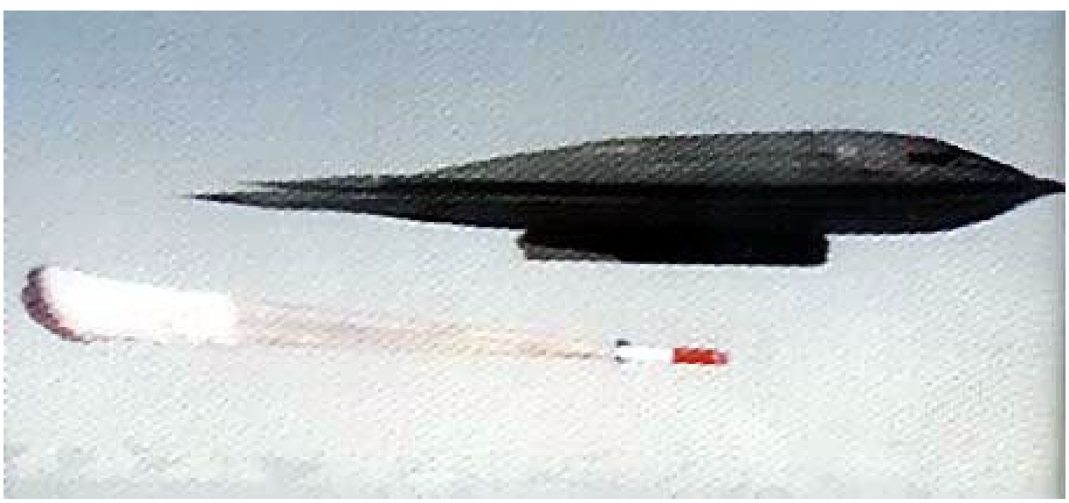


Figure 76. A B-2 stealth bomber drops a mock B83 warhead.

The Northrop-Grumman B-2 Spirit strategic radar-evading stealth bombers date back to the 1980s. Its systems have been overhauled and updated throughout the years, pushing the cost well past the initial $2.8 billion price tag to design and build the. The plane, at 69 feet long, 17 feet high with a wingspan of 172 feet, is the only aircraft that can carry large Air to Surface Missiles (ASMs) in a stealth configuration. To remain hidden from tracking systems, stealth bomber employs a variety of multispectral camouflage techniques. Its engines are buried within its wings, which minimizes the heat signature generated by the exhaust, and hides their fans at the same time. A gap below the engine's air intake sucks in cool air, which is then combined with hot air from exhaust, reducing the temperature of the resulting mixture. Together, this reduces B-2's infrared signature. The aircraft lack the afterburners, which would reveal the aircraft during the supersonic flight and increase its overall infrared signature due to the excess heat produced by the exhaust, as well as the aerodynamic heating.

The aircraft is a "flying wing;" that is a tailless aircraft with no clearly discernible fuselage configuration that provides low drag and significantly reduces its radar profile because it lacks angles that may reflect radar waves. Its design employs a series of curved areas across its surface known as "continuous curvature", designed to deflect radar beams.

To reduce its optical visibility, the aircraft is painted with an anti-reflective paint. Its underside is dark gray, because that color blends with the background sky at high altitudes around 50,000 feet. It also has a special contrail sensor that warns the pilot to change altitude to minimize the resulting exhaust vapor condensation.

Most of the body is made of graphite composite material that is stronger than steel and lighter than aluminum and acts as a Radar Absorbent Material (RAM) that absorbs or neutralizes radar beams. It is covered with a special radar-absorbent ferrite coating known as Alternate High Frequency Material (AHMF).

As a flying wing aircraft, the B-2 requires additional stabilization using a specialized computer-controlled fly-by-wire flight control system that translates pilot inputs into complex movements of flight surfaces and settings. It is also equipped with the AN/APQ-18, a low probability of intercept radar system that provides a series of subsystems capable of low-flight assistance, navigation and target tracking at very high speeds, as well as target assessment and Global Positioning System (GPS).

A B-2 bomber can carry heavy-duty ordnance with 40,000 pounds of payload including the B61 and B63 nuclear warheads and the AGM-129 Advanced Cruise Missiles. Conventional weaponry includes the GATS, or GPS-Aided-Targeting-System, which enables the bomber to launch up to 80 guided "smart" bombs on previously mapped targets. The B-2 is the only stealth bomber that can employ the "bunker buster" MOP (Massive Ordnance Penetrator) burrowing through 200 feet of earth and 60 feet of concrete before detonating. Its successor, the B-21, is planned to enter combat service by 2025.

Figure 77. The Ground-launched cruise missile used the inactivated W84 warhead.

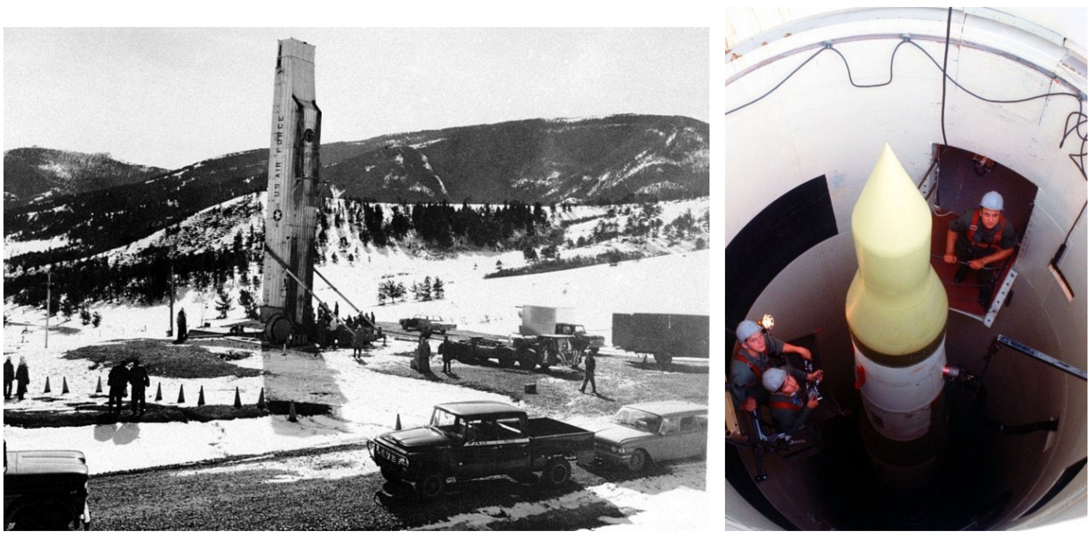


Figure 78. Minuteman III being lowered into its silo.

Figure 79. Launch of the Minuteman III Inter Continental Ballistic Missile (ICBM) carrying a W62 warhead.

Figure 80. A retired LGM-118 Peacekeeper land-based ICBM equipped with the W87 warhead.

Figure 81. Trident missile submarine launches.

Figure 82. Submarine-launched cruise missile.

Figure 83. Davy Crockett 20-ton of TNT-equivalent tactical device. The M28 or M29 Davey Crockett weapon system was a tactical battlefield smooth bore recoilless rifle for delivering the W388 nuclear projectile with the W54 nuclear warhead. It was developed during the Cold War. Depending on source its yield was 20 tons of TNT equivalent. It entered service in 1961 and was deployed with USA forces in West Germany.

SUSPENSION OF NEW START TREATY

President Vladimir Putin suspended, without withdrawal, Russian participation in the last remaining nuclear arms control treaty with the USA, warning Washington that Russia had put new ground-based strategic nuclear weapons on combat duty,

In March 2021 the New START Treaty was renewed for a period of five years, and it would expire in February 2026 if it is not continued. USA-Russia relations have deteriorated so fast over the Ukraine war they were near a complete breaking point. A President Vladimir Putin declaration on February 21, 2023 appears to be the final death knell after the treaty's fate was already extremely uncertain.

The treaty was intended to limit and reduce nuclear arms on either side, setting a limit of no more than 1,550 deployed warheads and 700 missiles. START I began in 1991, with New START signed under the Obama and Medvedev administrations in 2010 as a successor agreement.

It comes over a year after Moscow signed onto a five-year extension, and after in August 2022 the USA accused Russia of violating the treaty in disallowing USA on-site inspections under its stipulations. Washington halted Russian inspectors' ability to do the same on American soil. "No one should be under the illusion that global strategic parity can be violated," according to President Vladimir Putin.

President Vladimir Putin’s speech came just after President Joe Biden showed up in Kiev and Poland for a surprise visit. He rearticulated Russia's reasons for going to war: "Russia did its best to solve the problem in Ukraine peacefully, but the statements of Western leaders turned out to be fraudulent and untrue," calling Ukraine part of the "historical Russian land."

MUTUALLY ASSURED DESTRUCTION (MAD) STRATEGIES

Russia and China have almost abandoned permanently stationed ICBMs. Most of the Russian and Chinese nuclear forces are moving all the time, using different mobility strategies:

1. Russian and USA missile submarines are practically undetectable and constitute the only surviving military force after a first strike.
2. In hundreds of kilometers of underground tunnels in Siberia and Northern China where ICBM nuclear trains and trucks are constantly moving. Few ICBMS are buried in underground shafts.
3. On rail, camouflaged as a container cargo trains, mixed among thousands of trains and rail cars. They have some real containers with goods on them to confuse satellites surveillance.
4. Russian and other ownership ocean ships, are suspected to be loaded clandestinely with ballistic missiles moving constantly from port to port.
5. It is a rumored that China, the USA and perhaps Russia have space weapons to kill satellites or attack ground or air targets.

Russia stopped relying on the Global Positioning System (GPS) as a primary tracking and locator. Instead, it relies is on auxiliary mapping systems and weapon systems interoperability. A soldier may leave a tank and remotely control it and operate without central command. Repairs of the equipment is made interchangeable among different weapons systems so parts could be removed and cannibalized from a defective system to another.

In 1980, a USA chief of staff gave a classified briefing to members of Congress where he was asked for how long the aircraft carriers fleet would survive under an all-out global war with the USSR or China. His response was that they could survive from a few hours to a few days if they were in port on repairs.

The superpowers' arsenals still remain at a significant level. The NATO nations possess hundreds of nuclear weapons, mostly tactical but strategic ones as well, backed by Anti-Ballistic Missiles (ABMs) that can eliminate, at the launch stage, most retaliatory Russian missiles that survive a First Strike.

The USA's stockpile of 9 MT of TNT equivalent B53 bunker-buster devices has been retired, and the 1.2 megaton B83 will be retired after the upgraded B61 bomb is deployed.

Russia's arsenal of megaton warheads includes an estimated five SS-18s armed with 20 Mt of TNT equivalent warheads and previously deployed 5 Mt of TNT equivalent warheads on SS-19s missiles. Russia once built the largest nuclear weapon, the 50-100 Mt bomb called the Tsar Bomba, or "Tsar of bombs."

China uses megaton warheads on its DF-5A missiles. Two-dozen DF-5As are armed with 5 Mt of TNT equivalent warheads.

Table 4 shows the characteristics of some of the USA's Air Force warheads. The delivery methods range from submarines, bombers aircraft, cruise missiles, ships including submarines, and Inter Continental Ballistic Missiles (ICBMs).

Table 3. Yields of USA nuclear devices. Some devices have adjustable yield that is controlled by elimination of the secondary fusion physical package, controlling the amount of Tritium seed, some are fixed yield, and some are essentially neutron bombs with primarily fusion yield. Source: Union of Concerned Scientists.

Warhead	Yield kT of TNT equivalent
B61-3,4,12	0.3
B61-3,4,12	1.5
W80-1	5 (Air Launched Cruise Missile, ALCM)
W76-2	6.5 (Submarine based, New production)
B61-4,7,12	10
Hiroshima Little Boy	15
B61-4,12	45
B61-3	60
W76-0,1	100

W80-1	150 (ALCM)
B61-3	170
W87	300
B61-7	300
W78	335
B61-11	400
W88	455
B83	1,200

Table 4. Characteristics of five of the nine USA Air Force nuclear warheads.

Warhead	Usage	Characteristics	Missile Carrier
W80	Refurbished	Cruise Missiles	Cruise Missiles
W84	Not presently in use	Cruise Missile	Ground Launched Cruise Missile
W87	Surface to Surface, retired	ICBM warhead	Peacekeeper ICBM
W62	Surface to Surface	ICBM warhead	Minuteman III ICBM
B83-0/1	Air to Surface Under retirement	Strategic warhead	B-52, B-2 aircraft
B61	Air to surface Under deployment	Strategic warhead	Aircraft delivery

The members of the current nuclear club, either with public or with unpublicized weapons programs, are clearly determined individually or collectively on foiling the efforts and denying access of any new members to their exclusive club, with diplomatic and economic pressure, and with sabotage and military means if necessary. This leads to a simple mathematical law governing nonproliferation where the probability of a nuclear weapons program becoming successful (p) is inversely proportional to the most current number of the nuclear club membership:

$$p \;\; \alpha_{\ell} \; \frac{1}{N} \tag{20}$$

The New START arms treaty limited the USA and Russia to 700 strategic missiles and bombers and a total of 1,550 deployed strategic warheads. Table 5 shows the number of strategic non-tactical warheads thought to be stockpiled by different countries. These are designed to target missile locations, and military installations, and unfortunately, civilian population centers and large cities, as part of strategic planning.

Figure 84. The membership in the prestigious "Nuclear Club" providing deterrence against conventional and nuclear attack, inspired the cartoon: "We reserve the right to refuse service to anyone." The phrase is a remnant of racial segregation in the southern USA.

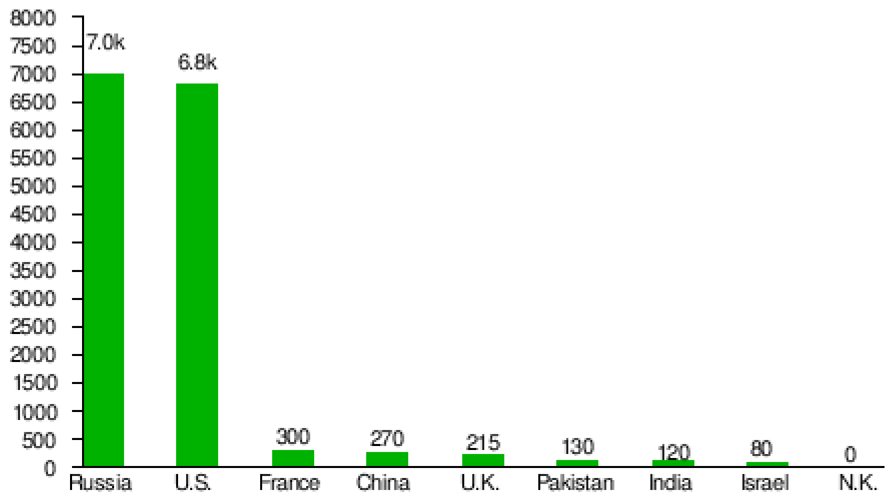
Table 5. Estimated number of strategic warheads in nuclear weapons states. Source: Federation of American Scientists.

State	Estimated number of strategic warheads
NPT signatories	
Russia	2,800
USA	2,200
France	300
China	180
UK	160
Non-NPT signatories	
Israel	200-400
Pakistan	60
India	60
North Korea	10

Table 6. Estimated number of strategic warheads in nuclear weapons states. Source: Stockholm International Peace Research Institute, SIPRI, 2017.

State	Estimated number of

	strategic warheads
NPT signatories	
Russia	7,000
USA	6,800
France	300
China	270
UK	215
Non-NPT signatories	
Pakistan	130-140
India	120-130
Israel	80
North Korea	10-20



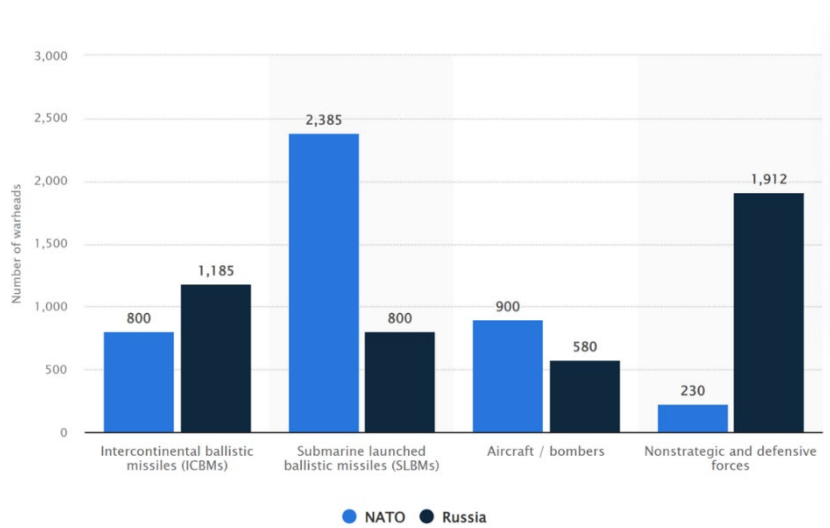


Figure 85. Number and types of strategic warheads. Source: SIPRI, BBC.

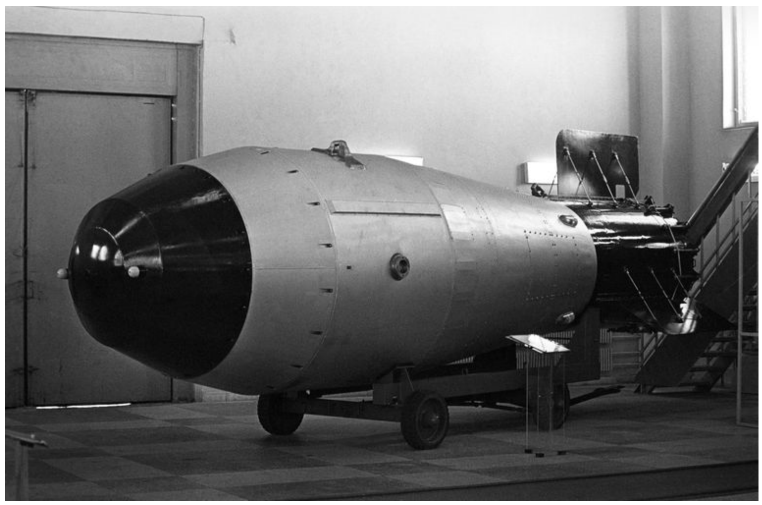


Figure 86. Museum replica of "Tsar Bomba" with a design yield of 100 Mt of TNT. It had its fusion yield reduced from 100 Mt to 58 Mt to become the largest ever tested in the atmosphere on October 30, 1961. The "superbomba" was 8 m in length and 2 m in diameter and 27 metric tonnes in weight.

Figure 87. Tupolev 95, T-95, or Bear bomber used to deliver the 58 Mt TNT Tsar Bomba. The aircraft is thought to be non-survivable in a real combat sortie, hence it is replaced by a drone submarine: the Poseidon; as a delivery system.

As the number of current members N increases, the probability p of being able to join the club decreases. Currently N comprises the USA, Russia, France, the UK and China, as well as Israel, India, Pakistan, and North Korea for a total of 9. Some countries can be considered as *latent* nuclear weapons states such as Germany, South Africa, Brazil, Argentina, Iran and Japan, in that they possess the science, technology, manpower, knowledge and facilities to initiate nuclear weapons programs on a short notice, should their national and international security compel them to do so.

However, if humanity is to save itself from the threat of nuclear war, the nuclear club membership needs to be collectively reduced to N = 0.

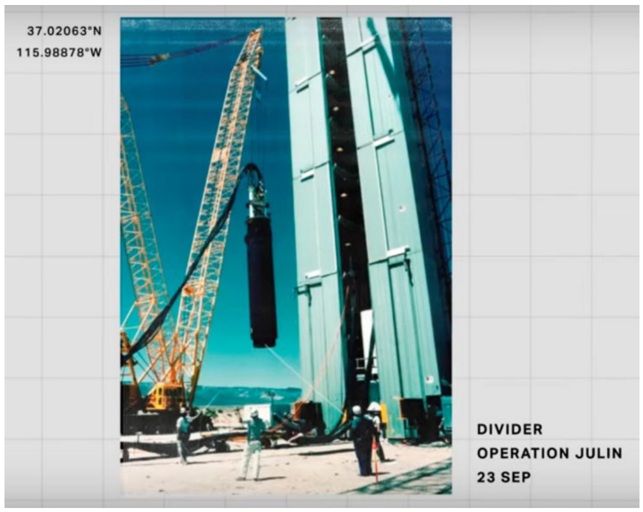


Figure 88. Last USA Nuclear device test, Divider, 1992.

Figure 89. Sierra IBM supercomputer at the Lawrence Livermore National Laboratory, LLNL, is "air-gapped" or kept off-line from other computing networks and dedicated to the weapons "stockpile stewardship" program. It is also used for is Decrypting encrypted data. It uses Red Hat Enterprise Linux and NVidia GPUs. "Sierra" is the second-most powerful supercomputer on the planet in support of the USA's nuclear arsenal. A more powerful "El Capitan" machine is planned. The most powerful USA computer is named "Summit" at Oak Ridge National Laboratory, ORNL used in biological and medical simulations. The USA spends ~600-700 billion dollars annually on its military sector and ~100-150 billion dollars on its science one.

Figure 90. W-80 warhead enclosure. Nuclear weapons are a Pandora's Box that has been opened and cannot be closed on the world. The knowledge about then is a genie that has exited the Aladdin Lamp and cannot be returned in. Just like humans discovering fire or the firearm, once discovered they cannot be "un-discovered".

4.12 FALSE ALARM, SYSTEM MALFUNCTION, NEAR-MISS "BROKEN ARROW"

Lieutenant Colonel Stanislav Petrov sober reasoning

On a September night in 1983, Soviet Lieutenant Colonel Stanislav Petrov stood guard at a satellite-based missile launch detection system. When the alarm went off, announcing that the USA had launched a missile against the USSR, Stanislav Petrov had thirty minutes to decide whether the launch was real or false. He took the decision that they were a system's false alarm and did not report them to his superiors. His action possibly prevented nuclear war.

Stanislav Petrov had received computer readouts in the early hours of the morning of September 26, 1983 suggesting a single missile followed by several USA missiles had been launched. Although his training dictated that he should contact the Soviet military immediately, Stanislav Petrov instead called the duty officer at army headquarters and reported a system malfunction. If he had been wrong, the first nuclear blasts would have happened minutes later. A later investigation concluded that the USSR satellites had mistakenly identified sunlight reflecting off clouds as the engines of ICBMs. His sober reasoning was that a genuine attack would involve an initial whole volley of missiles, not a single one.

Naval Officer Vasili Alexandrovich Arkhipov level headedness, Cuba Missile Crisis

From October 16 to October 28, 1962, during the Cuban Missile Crisis, the world came closer to a nuclear war than at any time since, including the 1983 war games. The decisive action of a levelheaded senior Russian submarine officer averted a full-blown nuclear war and changed the fate of the entire world.

Vasili Alexandrovich Arkhipov defied orders to fire a nuclear torpedo at a U.S. aircraft carrier and likely prevented a third world war and nuclear destruction. It was an era when the two greatest world powers, the U.S. and Soviet Union, were at the brink of war over the presence of Soviet nuclear-armed missiles in Cuba, just 90 miles off the coast of Florida.

The premier of the Soviet Union at the time, Nikita Khrushchev, while promising to defend Cuba with the USSR’s military, may have miscalculated how severe the USA reaction would be. In July 1962, after learning about the Soviet Union’s missile shipments to Cuba and the construction of new military facilities there with the help of Soviet technicians, USA President John F. Kennedy declared a naval blockade of Cuba.

By October 27, 1962, a day described as the “most dangerous” in human history, a Soviet submarine designated B-59 was churning through the Sargasso Sea when it was rocked by a series of explosions from USA warships. Unknown to the U.S. warships, B-59 was one of the submarines that was loaded with nuclear missiles on board. The captain of the submarine ordered a quick launch of its torpedoes toward the USA ship.

Knowing the repercussions of such a launch, Arkhipov, who was the second in command, swallowed one of the launch keys and prevented what could have been the start of a nuclear war with devastating effects on the rest of the world. Despite his unsovietic act, Arkhipov was actually upon reaching the Soviet Union, promoted for his decision. He managed to save the crew on the submarine and indirectly stopped a nuclear war that even the Soviets did not want on their heads.

Figure 91. Mark 39, 4 MT of TNT equivalent thermonuclear device with parachute embedded in ground after a B-52G bomber aircraft crash near Goldsboro, North Carolina, 1961.

Lost nuclear devices

In real life tactical aircraft are not flown loaded with nuclear devices over the continental USA. The USAF has lost a couple of large nuclear devices. A 2007 incident in which six nuclear weapons were unknowingly flown on a B-52 out of Minot Air Force Base, North Dakota, to Barksdale Air Force Base, Louisiana, was taken very seriously by the USA Air Force and led to the unprecedented, simultaneous firing of the then-secretary and chief of staff.

A 3 - 4 Mt TNT thermonuclear device was one switch away in the arming and detonation sequence from exploding over the USA in 1961. Two Mark 39 thermonuclear devices were on board a B-52G plane that went into an uncontrolled spin over North Carolina. Both devices fell and one began the detonation process. The plane was on a routine flight when it began to break up over North Carolina on January 24, 1961, a few days after President John F. Kennedy's inauguration. As it was breaking apart, a control in the cockpit released the two devices. One fell to the ground unarmed. But the second: "assumed it was being deliberately released over an enemy target, and went through all its arming mechanisms save one, and very nearly detonated over North Carolina. Only one safety mechanism, a single low-voltage switch, prevented an explosion." The accident event occurred during the height of the Cold War between the USA and the USSR, just over a year before the Cuban missile crisis. A 1961 book by a former government scientist, Ralph Lapp, describes the event.

A declassified document was written eight years after the incident by USA Sandia National Laboratories' scientist Parker F. Jones, who was responsible for the mechanical safety of nuclear devices. He comments and corrects Ralph Lapp's narrative of the accident, including listing that three out of the four fail-safe mechanisms failed, not five out of six as originally described by Ralph Lapp: "One set off by the fall. Two rendered ineffective by aircraft breakup. It would have been bad news in spades. One simple dynamo-technology low voltage switch stood between the United States and a major catastrophe."

One of the devices fell to the ground by a deployed parachute and was recovered. The second embedded itself so deep in the ground that it was not reachable in ground water at 55 ft depth. Its pit was reportedly recovered.

On Jan. 17, 1966, a USA B52 bomber and a refueling tanker plane collided over the Spanish coast near Almeria. The bomber, on a routine patrol flight, was carrying four thermonuclear devices. Three of them fell to the ground near the Andalusian village of Palomares and their contents of Pu and tritium were dispersed. The fourth device was retrieved from the bottom of the ocean on April 7, 1966.

Another device was reportedly "pickled off" in its safe mode by mistake off the coast of Georgia, USA in the southern USA. After a long arduous search, it could not be located as it was deeply embedded in coastal marshy soil sediment. Another one is rumored to have been lost in Canada when a B-36 went down..

4.13 FOOTBALL AND BISCUIT NUCLEAR BUTTONS

A 

Figure 92. USA Marine carrying a nuclear football into a presidential helicopter, November 2017. Source: BBC.

Figure 93. Nuclear football leather suitcase.

A military aide carrying a leather briefcase follows the USA president. The briefcase is known as the "nuclear football". The football is needed to fire USA nuclear weapons and in theory never leaves the president's side. In the football there are communication tools and books with prepared war plans. The plans are designed for quick decision-making. The retaliatory options boil down to "rare, medium, or well done."

Inside is a piece of digital hardware measuring 3in or 7.3cm by 5in, known as "the biscuit." This contains the launch codes for a strategic nuclear strike.

Other senior figures are also involved in the chain of command, such as the USA Secretary of Defense. The secretary of defense could, in theory, refuse to obey the order if he had reason to doubt the president's sanity, but this would constitute mutiny and the president can then fire him and assign the task to the deputy secretary of defense.

Under the 25th Amendment of the US Constitution a vice-president could, in theory, declare the president mentally incapable of taking a proper decision, but he would need to be backed by a majority of the Cabinet.

Inside the leather briefcase, the "nuclear football" that never leaves the president's side, is a "black book" of strike options for him to choose from once he has authenticated his identity as commander-in-chief, using a plastic card.

Once the president has selected his strike options from a long-prepared "menu" or "biscuit", the order is passed via the chairman of the Joint Chiefs of Staff to the Pentagon's war room and then, using sealed authentication codes, on to USA Strategic Command HQ in Offutt Airbase in Nebraska. The order to fire is transmitted to the actual launch crews using encrypted codes that have to match the codes locked inside their safes.

The USA and Russia both possess enough nuclear missiles to destroy each other's cities several times over. There are reported to be 100 USA nuclear warheads aimed at Moscow alone. The two countries' arsenals account for more than 90% of the world's total number of nuclear warheads.

As of September 2016 Russia had the most, with an estimated 1796 strategic nuclear warheads, deployed on a mixed platform of intercontinental ballistic missiles (ICBMs), submarine-launched ballistic missiles (SLBMs) and strategic bombers.

Under a program ordered by President Vladimir Putin, Moscow invested billions of rubles in upgrading its strategic nuclear missile force, keeping an arsenal of constantly mobile ballistic missiles travelling through tunnels deep beneath the forests of Siberia.

The USA had, as of September 2016, 1,367 strategic nuclear warheads, similarly deployed in land-based underground missile silos, which by their static nature are vulnerable to a first strike, at sea onboard submarines, where they are harder to detect, and at airbases, where they can be loaded on to bombers.

The UK has about 120 strategic warheads, of which only a third are deployed at sea. The Royal Navy always keeps a portion of the nation's Trident nuclear force somewhere in the world's oceans, maintaining what is known as the continuous at sea deterrent.

ICBMs travel at a speed of over 17,000 mph (Mach 23), flying high above the Earth's atmosphere before descending towards their pre-programmed targets at four miles a second. The flight-time for land-based missiles flying between Russia and the USA is between 25 and 30 minutes. For submarine-based missiles, where the boats may be able to approach a coast covertly, the flight time could be considerably shorter, even as little as 12 minutes.

This does not leave a president much time to decide whether it is a false alarm or imminent Armageddon. Once ICBMs have been launched they cannot be recalled, but if they remain in their silos they will probably be destroyed by the inbound attack.

The "biscuit" is a card containing codes, which is supposed to be carried by the president at all times. It is separate to the football. If the president were to order a strike, he would use the codes to identify himself to the military. Once he has identified himself, he passes his order to the Chairman of the Joint Chiefs of Staff. The chairman is the highest-ranking USA military officer. The order then goes to the USA Strategic Command HQ in Offutt Airbase, Nebraska. They then pass it to "on the ground" teams although these may be at sea, or under water. The order to fire is transmitted via codes - which must match codes locked in the launch team's safes.

The president is commander-in-chief of the USA military and he can order a nuclear attack. However, one of the experts was C. Robert Kehler, commander of the USA Strategic Command from 2011-2013. He told a congressional committee that, as trained, he would follow the president's nuclear order; but only if it were legal. Under certain circumstances, he explained: "I would have said 'I am not ready to proceed." One senator asked: "Then what happens?" Kehler admitted: "I do not know." The committee laughed in response.

4.14 "FIRST USE" USA POLICY, "MUTUALLY ASSURED DESTRUCTION, MAD", "NUCLEAR PRIMACY" DOCTRINES, BLOODY-NOSE OPERATIONS, NUCLEAR POSTURE REVIEW, 2018

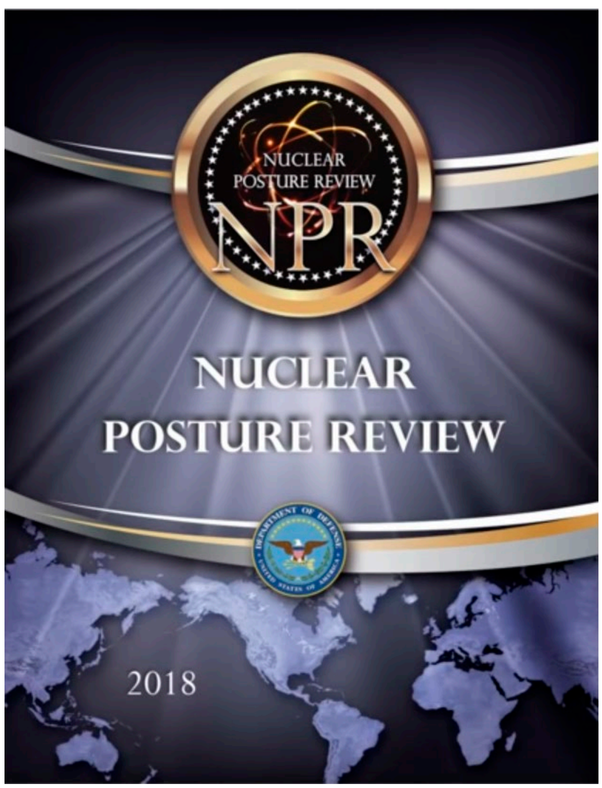


Figure 94. Nuclear Posture Review, 2018.

In 2022, President Joe Biden announced a new policy that the USA is no longer limited to the use of nuclear weapons as a response to the use of nuclear attack but also as "first use" in response to conventional attack.

The Congressional Budget Office (CBO) estimated in May 2021 that the USA will spend a total of $634 billion over the next 10 years to sustain and modernize its nuclear arsenal, which is 28 percent higher than the previous 10-year projection released in 2019.

In 2002 the prospect of continued nuclear deterrence suffered a major change when the USA pulled out of the Anti-Ballistic Missiles (ABM) treaty and developed an antiballistic defense system. Ballistic missiles are propelled by rockets that boost the missile to close to escape velocity. After that the missile follows a ballistic trajectory like an artillery shell or a bullet. With fast computers its path is easily calculated, and the missile easy to intercept.

Since 2006, the Mutually Assured Destruction (MAD) doctrine that had long dominated nuclear thinking on both sides of Russia and its allies, and the USA and its NATO military alliance, has escalated to the paradigm of "Nuclear Primacy," in which each side's nuclear weapons are to be used not to stave off a potential WW III, but instead so as to achieve victory in an actual decapitating first-strike or a hopeful local-conflict "nose-bleeding" nuclear confrontation between the global players. On February 2, 2018 the USA's administration issued a Nuclear Posture Review in which it explicitly reserved the right to first-use of nuclear weapons to prevent Russia from using its nuclear deterrent.

The "more usable" tactical earth-penetrating nuclear weapons B61-11 and B61-12 with an explosive capacity between one third and twelve times a Hiroshima bomb (20 kT of TNT equivalent) are lauded as "peace-making" bombs, "harmless to the surrounding civilian population because the explosion is underground" or "safe for civilians." These are devices contemplated for use against North Korea (DPRK) and Iran in what is described as "a bloody nose operation", with limited civilian casualties.

The new weapon, W76-2 is a modification of an existing Trident submarine-based nuclear warhead has been deployed in 2019 with an "initial operational capability." The yield on the W76 was likely reduced to create the W76-2 by removing the secondary stage from the original two-stage device and replacing it with a dummy version. The yield has been reduced by 95 percent from 100 kT of TNT equivalent to around 6.55 KT; which is around 1/3 of the yield of the Hiroshima Little Boy device.

The reasoning is that a low-yield device will make nuclear war less likely, as the USA will have a more flexible deterrent. The W76-2 would be able to counter the perception that the USA would balk at using its massive nuclear arsenal against a potential adversary in response to a similarly small nuclear attack since existing USA nukes are in the hundreds of kilotons range, and "too big to use" without massive civilian casualties. The assertion is that low-yield devices "help ensure that potential adversaries perceive no possible advantage in limited nuclear escalation, making nuclear employment less likely," according to the 2018 nuclear posture review.

Critics suggest that this assumes that there are no miscalculations and many other uncontrollable possible scenarios. For instance, opponents would have no way of knowing if the USA has fired a full-force Trident or the low-yield version. Former Defense Secretary William Perry told reporters that he was less worried about the amount of nuclear warheads remaining in the world than by the dialogue shifting back to said weapons being "usable." Further: "The belief that there might be tactical advantage using nuclear weapons – which

I have not heard that being openly discussed in the USA or in Russia for a good many years – is happening now in those countries which I think is extremely distressing. That is a very dangerous belief."

An unsubstantiated rumor is that Russia uses a so-called “dead-man switch.” Every country with nuclear weapons is targeted by default, and a launch countdown is happening all the time. A person manually aborts the launch at 10 seconds out. If everyone in Russia instantly died, their entire land-based nuclear arsenal would launch. When there are dozens of actual plans by Western nations to launch a preemptive strike, they have to take it to this level. Ensured mutual destruction could occur by human error.

4.15 REVIVED ARMS RACE

In a revived arms race, on March 1st, 2018, Russia responded asymmetrically by revealing an alleged new set of weapons under different stages of development and deployment that challenge the anti-ballistic system built by the USA and NATO in Poland, Romania and Alaska; and planned for South Korea and Japan, providing a possible first-strike capability with a quick replacement of the delivery vehicles. Russian voters have decided to name Russia’s new combat nuclear-powered underwater drone the Poseidon, the laser weapon system, the Peresvet, and the nuclear-powered cruise missile, the Burevestnik.

None of the new alleged Russian weapons in the development and deployment stages follow ballistic trajectories that can be intercepted by an ABM defense system:

1. A new RS-28 “Sarmat” missile variant with a range of 6,200 miles.

This comes without the B for “Ballistic” designation, as a non-ICBM that can maneuver out of range around radar installations throughout a tortuous flight path and can fly through the atmosphere rather than popping up above it: “with a range and number of warheads exceeding its predecessor.” It has a short boost phase, making it difficult to intercept after launch. It can fly in arbitrary paths around the planet such as the South Pole to reach any point on Earth. It carries up to 15 multiple maneuverable hypersonic nuclear-armed reentry vehicles and decoys which no existing or planned missile defense system can intercept.

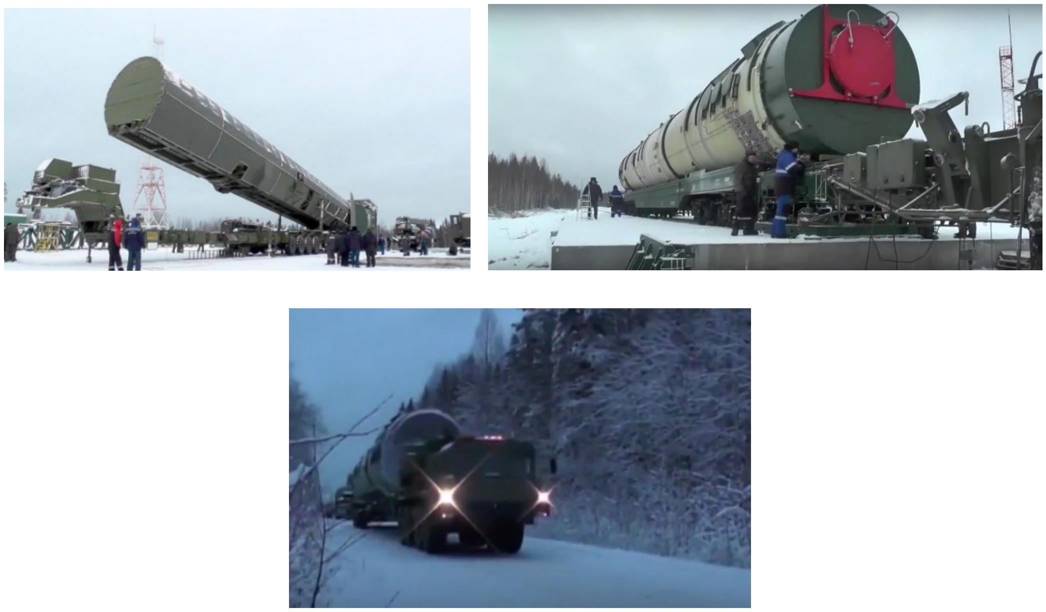


Figure 95. The mobile SARMAT non-ballistic radar evading missile equipped with up to 15 MIRVed reentry vehicles, including decoys.

Its main characteristics are:
i) Heavy ICBM,
ii) Wide range of nuclear devices,
iii) A short booster stage,
iv) Capable of penetrating missile and air defenses,
v) Has unlimited global flight range,
vi) Liquid-fueled.

2. The “Burevestnik” nuclear-powered cruise missile:

This is claimed to have a virtually unlimited range probably using a ramjet engine powered by a nuclear reactor. A possible 9M730 project, the device, once launched, heats up the inlet shocked-air, which is mostly nitrogen gas, and does not require any more fuel, hence claims an unlimited range. “Russia has completed the trials of miniaturized nuclear power units for cruise missiles of unlimited range and for autonomous submersibles of an oceanic multi-purpose system. "Russia has created a small-size super-powerful power plant that can be placed inside the hull of a cruise missile and guarantee a range of flight ten times greater than that of other missiles." "A low-flying low-visibility cruise missile armed with a nuclear warhead and possessing a practically unlimited range, unpredictable flight path and the capability to impregnate practically all interception lines is invulnerable to all existing and future missile and air defenses". To date, those technologies have been designed and put into practice only by Russia.

Its main characteristics are:
i) Low-flying and steady,
ii) Nuclear powered,
iii) Unlimited flight range,

iv) Penetrates missile and air defense shields,
v) Unpredictable flight path.

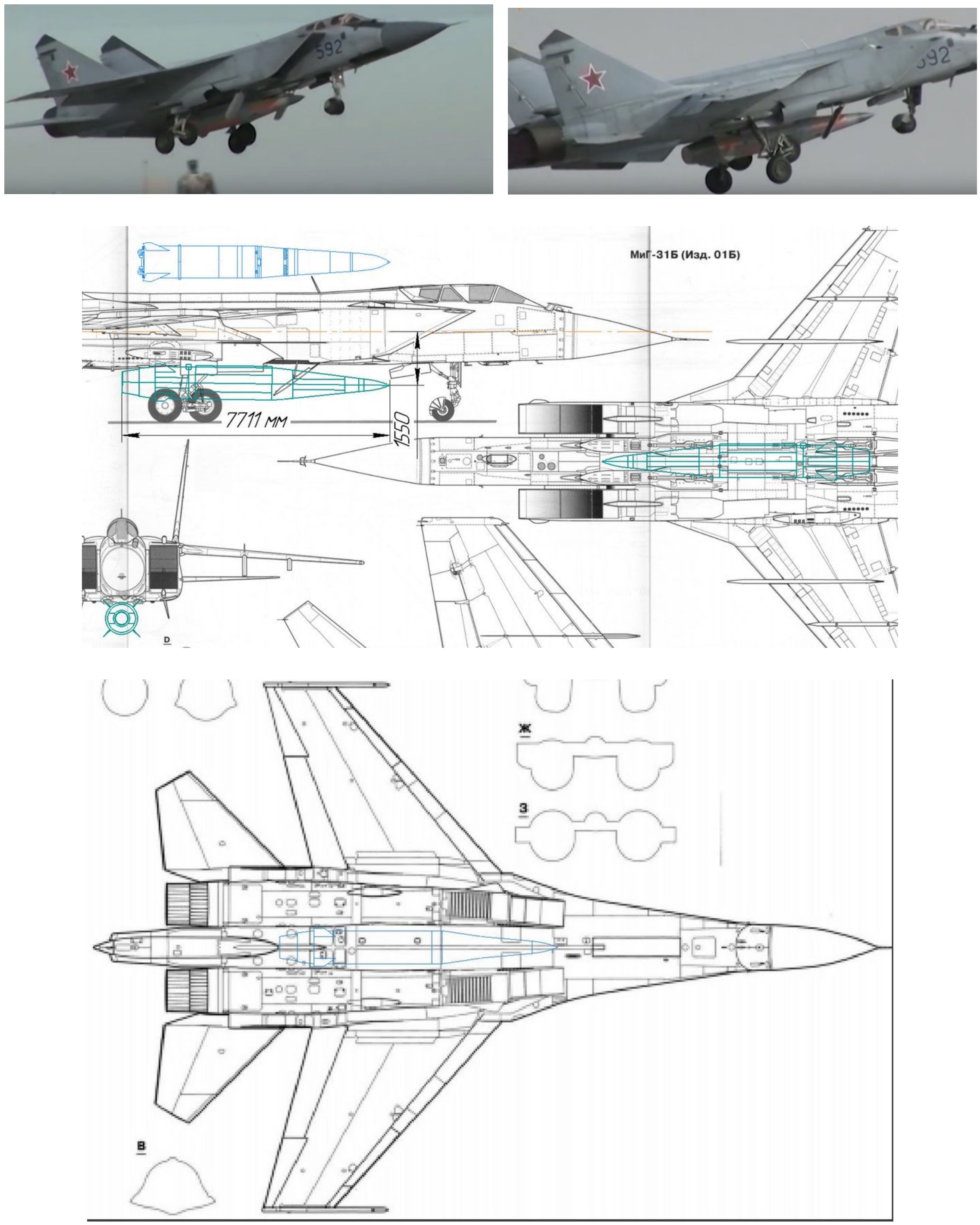


Figure 96. Russian Mig 31 supersonic interceptor-launched possibly the hypersonic M10, 2,000 km air-launched cruise missile Kinzhal (Dagger) or “Air Iskander” compared with Iskander 9K720 missile.

Figure 97. Nuclear-powered earth-hugging, radar-evading cruise missile which is claimed to have a virtually unlimited range probably using a ramjet engine powered by a miniature nuclear reactor. This missile can take an arbitrary path to its target and circumvent any enemy defenses. And the advantage to being nuclear-powered is that it can loiter around for months, due to its almost practically limitless energy supply. The missile has special compartments where air is heated by a nuclear reactor to several thousand degrees, then thrust is created by ejecting the superheated air. The picture shows four rear nozzles creating thrust for the missile.

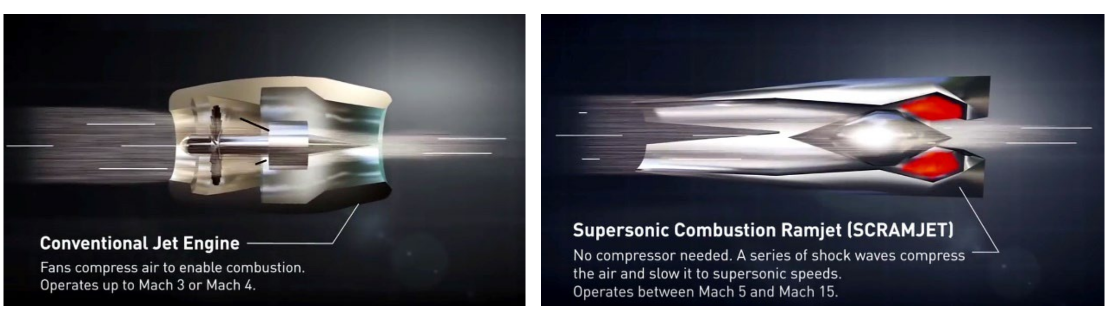
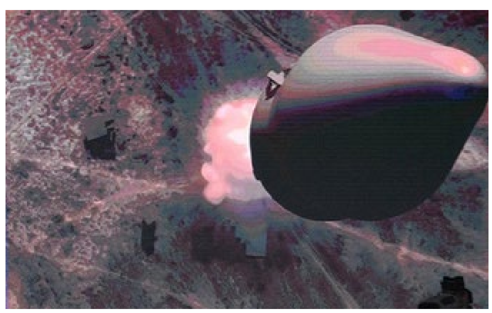
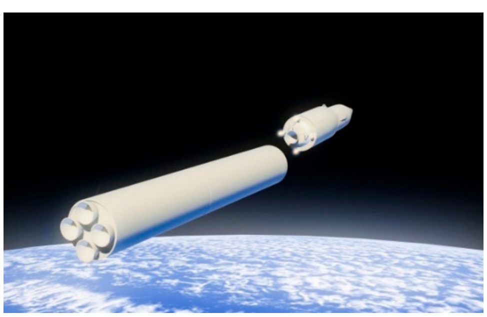
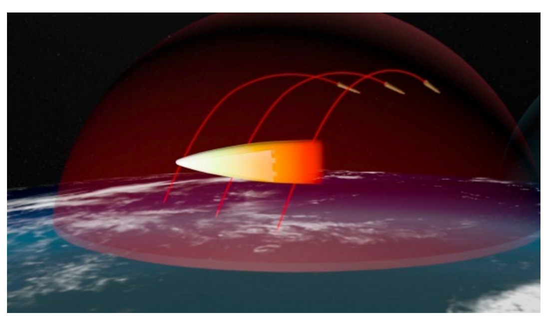


Figure 98. Operation of a ramjet/scramjet engine.

Figure 99. Kinzhal or air Iskander “Dagger” air-launched cruise missile.







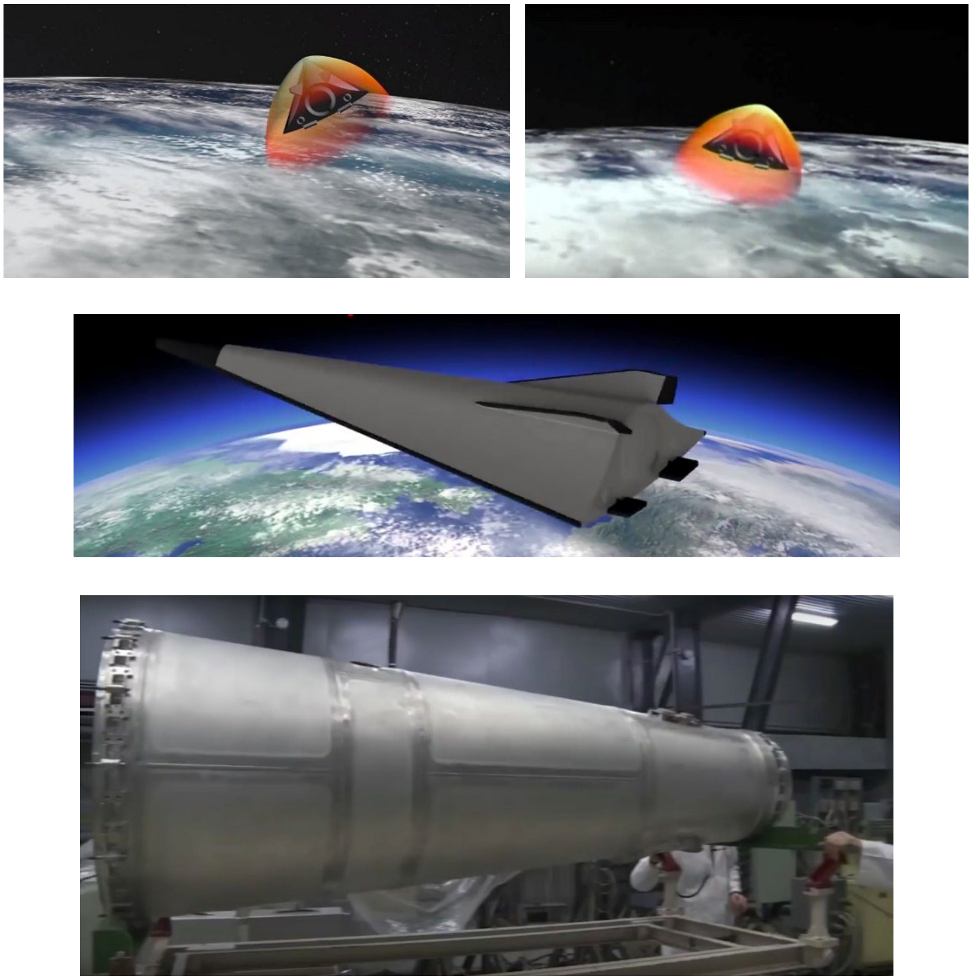


Figure 100. “Avangard” booster-glide supersonic cruise missile with the 15Yu71 warhead. The diagram displays a claimed stealth “ion cloud” sheath plasma technology possibly inspired by super-cavitation torpedoes technology surrounding the craft.

3. The Aeroballistic Kinzhal “Dagger”, Sir Iskander air-launched cruise missile:

Its main characteristics are:
i) Boasts speed of over Mach 10,
ii) High maneuverability,
iii) Carries conventional and nuclear warheads,
iv) Penetrates missile and air defense shields.

4. Hypersonic dodging boost-glide cruise missile system “Avangard”:

As the massive RS 28 Sarmat that can fly a South Pole trajectory towards American targets becomes operational, it will be used to deliver the Avangard supersonic glide vehicle. The Avangard will be equipped with a single massive thermonuclear warhead with a yield exceeding two megatons. It will have considerably greater destructive power in an individual warhead than a typical modern ICBM, which have smaller yields usually no more than 500 kT of TNT equivalent.

The Avangard is a strategic intercontinental ballistic missile system equipped with a gliding hypersonic maneuvering warhead. The guided hypersonic warhead of the Avangard intercontinental ballistic missile system is codenamed 15Yu71. Compared to traditional warheads of intercontinental ballistic missiles, which follow the ballistic trajectory towards their targets, the maneuvering glider warhead travels a part of its flight path at an altitude of several dozen kilometers in the dense layers of the atmosphere. While maneuvering along its flight path and by its altitude, the glider warhead is capable of bypassing the area of the missile defense’s detection and destruction capabilities.

The glider vehicle is about 5.4 meters long and develops a speed exceeding Mach 20. The warhead is either nuclear with a yield from 150 kT to 1 mT of TNT equivalent or conventional.

The vehicle’s body is made of composite materials, which makes it resistant to aerodynamic heating of several thousand degrees and protects it from laser irradiation. The vehicle is equipped with the thermoregulation system developed by the Nauka Research and Production Association.

The tests of the "object 4202" had been held since 2004 at the Baikonur and Yasny space ports where the RS-18B rocket based on the 15A35 intercontinental ballistic missile of the UR-100NUTTKh strategic missile complex was used as a carrier.

In his State of the Nation Address to the Federal Assembly on March 1, 2018, Russian President Vladimir Putin highlighted the Avangard missile complex with the maneuvering warhead: "the vehicle approaches the target like a fireball" while "being reliably guided."

ICBMs, except de-MIRVed Minuteman III, have multiple independent reentry vehicles (MIRVs). That suggests that the Avangard is primarily a counter-value weapon intended for an assured retaliatory second strike capability designed to bypass missile defenses.

The Avangard claims that it can travel at 20 Mach, or 7.5 kilometers per second. The weapon is capable of performing sharp manoeuvers, making it "absolutely invulnerable for any missile defense system."

Temperatures on the surface of a combat unit reach up to 2,000 degrees Celsius. It goes through the air surrounded by a plasma. Its characteristics are:
i) Hypersonic speed,
ii) Flies in lower atmosphere with intercontinental range capability,
iii) Highly maneuverable,
iv) Penetration of missile and air defenses.

5. The “Poseidon” nuclear-powered drone submarine or drones

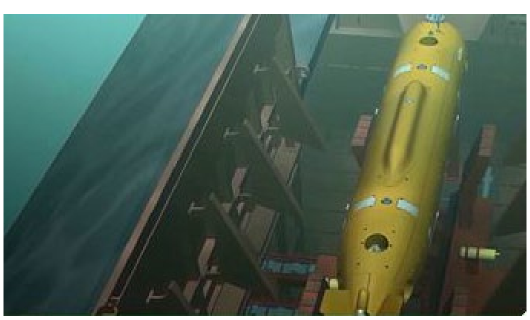
Also called Uninhabited Underwater Vehicles (UUV), which can descend to much larger depths than any existing submarine and moves faster than any existing vessel. The Status-6 could carry a multi-megaton nuclear bomb with a range of about 10,000 kilometers moving at 56 knots, or 104 km/h and travel to a depth of more than 1,000 meters. It is also capable of carrying a 100-megaton nuclear warhead, which could target coastal targets and warships. To put it in perspective, the most powerful nuclear bomb ever tested was the Tsar Bomba that had a yield of 56 mT of TNT equivalent. It is meant to attack coastal installations and naval bases as well as large naval vessels. There is a consideration of the use of the gamma radiation from Co^{60} for the interdiction of a large swath of an opponent’s territory such as naval bases and shipyards.

Russia is developing new underwater drones that can carry nuclear warheads. These were described as un-manned, noiseless submarines that move at ultra-deep levels and at high speed: "There is no defense system that can cope with such subsurface vehicles that can be equipped with conventional or nuclear weapons, attacking coastal defenses and infrastructure facilities." “These underwater drones were 100 times smaller than a conventional submarine.”

Russian Academician Sakharov's wrote in his Memoirs:

> "After testing the" big "product, I was worried that for him there is no good carrier (bombers do not count, they are easily knocked down) - that is, in a military sense, our work was wasted. I decided that such a carrier could be a large torpedo launched from a submarine. I imagined that it would be possible to develop a straight-flow water-steam atomic jet engine for such a torpedo. The purpose of the attack from a distance of several hundred kilometers should be the enemy's ports. War on the sea is lost, if the ports are destroyed - in this we are assured by the sailors. The body of such a torpedo can be made very durable, it will not be afraid of mines and fence networks."

The Status-6 would be carried in a submarine and parked in the Arctic Sea, where it would be difficult for USA submarines to find it. As it is launched, it would difficult to stop it. Its characteristics are:
i) Carries nuclear and conventional warheads,
ii) Small size,
iii) Unlimited range,
iv) High power to weight ratio implies high acceleration,
v) Low noise level,
vi) Highly maneuverable.



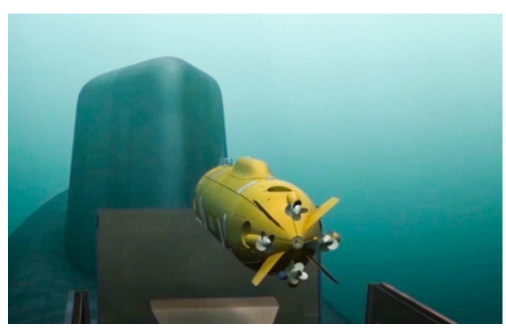
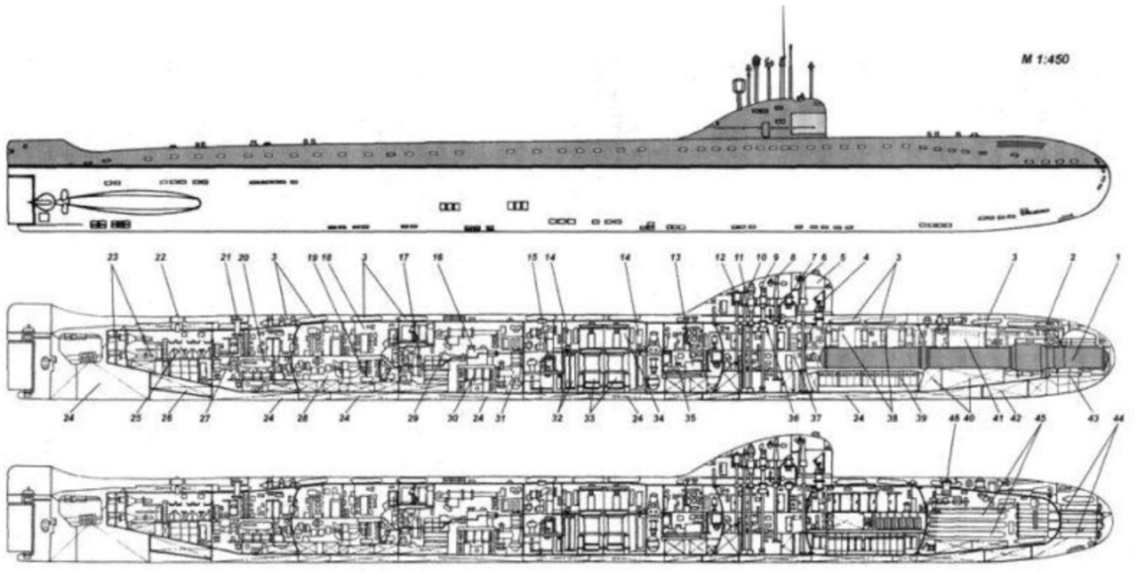


Figure 101. Autonomous Klavesin 2R PM nuclear-powered drone under construction. Submarines are usually designed to be as quiet as possible. The Status-6 would not need to be silent, due to its speed that cannot be matched by existing torpedoes, and since it is unmanned, the Unmanned Underwater Vehicle (UUV) is capable of diving to depths no other submarines can.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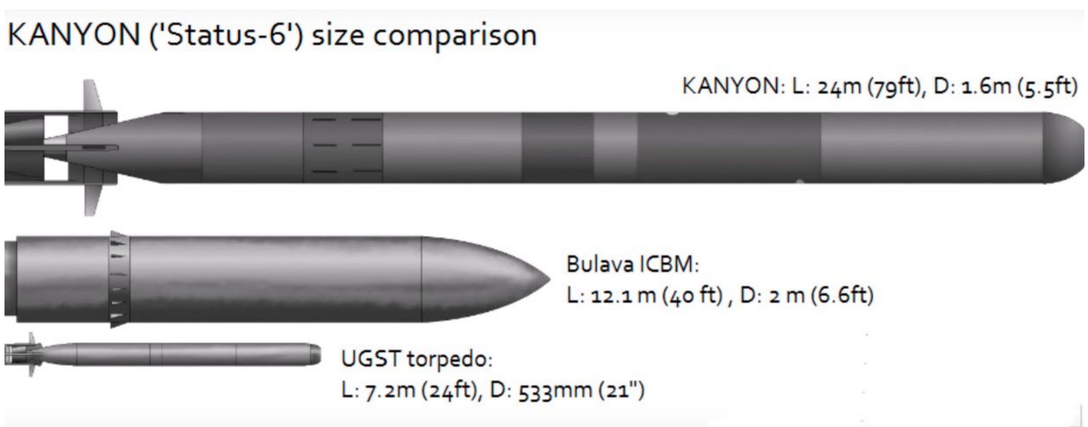
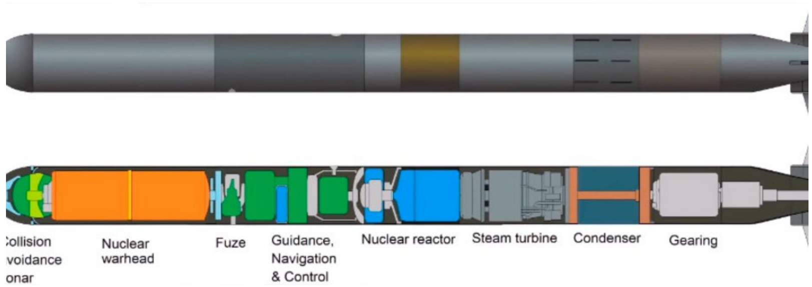

KANYON ('Status-6') size comparison
KANYON: L: 24m (79ft), D: 1.6m (5.5ft)
Bulava ICBM:
L: 12.1 m (40 ft) , D: 2 m (6.6ft)
UGST torpedo:
L: 7.2m (24ft), D: 533mm (21")


ollision
voidance
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Nuclear
warhead
Fuze
Guidance,
Navigation
& Control
Nuclear reactor
Steam turbine
Condenser
Gearing

Figure 102. Poseidon Nuclear-powered torpedo design with a modified Oscar II submarine as a delivery vehicle. Russia designates the program as the Ocean Multipurpose System Status-6.

6. The "Peresvet" mobile battle laser cannon that could possibly blind military satellites and target airborne drones.

Figure 103. Mobile land-based laser system.

The development of new materials, such as ceramics, make it possible to build vehicles that fly at Mach 10, with their skin heating up to 2,000 ºC, improvements in microelectronics, communications and artificial intelligence, allow the development of such weapon systems.

A sobering thought is that the largest argument regarding why humanity is unlikely to ever make contact with an interstellar species is that given Darwinian evolution and competition for resources; or survival of the fittest, if a species acquires the capability to travel through interstellar space, it probably is more likely to have self-destructed well before reaching another species. De-escalation needs to be the humanity's survival order of the day.

NUCLEAR NON PROLIFERATION TREATY, NPT

The Non-Proliferation Treaty, backed by 190 countries in 1970, commits countries which signed up, including the USA, Russia, France the UK and China, to reducing their stockpiles and bars others from acquiring nuclear weapons. India, Pakistan and Israel did not sign up and North Korea left in 2003.

The USA, Russia and the UK have been reducing their inventories. Russia and the USA are trying to extend their last remaining nuclear arms agreement. New Start, signed in 2010, limits the number of long-range nuclear warheads each can possess to 1,550.

The USA pulled out of another treaty, the Intermediate-Range Nuclear Forces treaty signed during the Cold War, after accusing Russia of violating it.

THE INTERNATIONAL CAMPAIGN TO ABOLISH NUCLEAR WEAPONS (ICAN)

Honduras became the critical 50th country to ratify the Treaty on the Prohibition of Nuclear Weapons so it will now come into force. The five recognized nuclear powers have not signed the accord.The accord was approved by 122 countries at the UN General Assembly in 2017 but needed to be ratified by at least 50 before being enacted.

It declares that those countries that ratify it must "never under any circumstances develop, test, produce, manufacture, otherwise acquire, possess or stockpile nuclear weapons or other nuclear explosive devices".

The treaty outlaws the use or threat to use nuclear arms, and bars signatories from allowing "any stationing, installation or deployment of any nuclear weapons or other nuclear explosive devices" on their territory.

The International Campaign to Abolish Nuclear Weapons (Ican) described the 50th ratification as heralding "a new chapter for nuclear disarmament". Beatrice Fihn, the head of Ican, which was awarded the Nobel Peace Prize in 2017, said: "Decades of activism have achieved what many said was impossible: nuclear weapons are banned."

The president of the International Committee of the Red Cross, Peter Maurer, said: "Today is a victory for humanity, and a promise of a safer future."

A statement from the UN Secretary-General, Antonio Guterres, described the move as "a meaningful commitment towards the total elimination of nuclear weapons, which is the highest disarmament priority of the United Nations".

There has been no immediate reaction from the five main nuclear powers - the US, Russia, China, the UK and France. But the USA and the UK made clear their opposition in 2017. The UK said at the time that, while committed to a nuclear-free world, the government does not believe the treaty will bring about an end to nuclear weapons and could undermine existing efforts to do so, such as the Nuclear Non-Proliferation Treaty. The USA wrote to the treaty signatories saying the accord "turns back the clock on verification and disarmament".

4.16 DISCUSSION

Efforts at controlling the proliferation of Nuclear Weapons are nowadays centered on the Non Proliferation Treaty (NPT) joined by 133 nations in 1968. Some states including India, Pakistan, China and Israel advanced diverse reasons and excuses and have not yet signed nor ratified the treaty. North Korea withdrew from the treaty, then is negotiating rejoining it for economic and security incentives. It is supervised by the International Atomic Energy Agency (IAEA) as an arm of the United Nations (UN).

Figure 104. SS-25 Topol Road Mobile and SS-27 Topol M silo-land-based Russian ICBM paraded on Red Square, Moscow, 2009. The latest Russian ICBM is supposedly able to take a South Polar route. This means that any ABM shields should be pointed in all directions to knock out incoming MIRV vehicles. Russia has too much land mass for its ICBMs to be intercepted in the boost phase; when they are easiest to shoot down. The Topol-M missile has auxiliary engines that fire randomly, to keep the missile on a non-ballistic trajectory to evade traditional ballistic missile defenses.

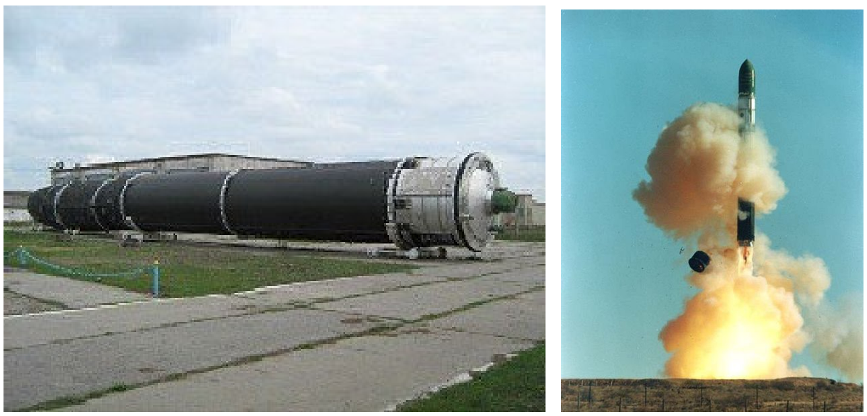

Figure 105. R-36 or NATO-reporting SS-18 Satan Russian ICBM. It is rumored to be capable of altering its course, foiling attempts at downing it during flight. They can be armed with single fission-fusion-fission warheads with 18-20 Mt of TNT equivalent or 10 MIRV-ed warheads with 550-750 kT TNT each. Russian efforts to outfit the old rocket with solid fuel are reported to have failed. Thus they have returned to fueling these old rockets with liquid fuel within an hour of their liftoff, which would be too late.

Figure 106. Chinese DF-31A TELs on parade, 2009.

Figure 107. China's Dong Feng -5 (DF-5) ICBM in its silo.

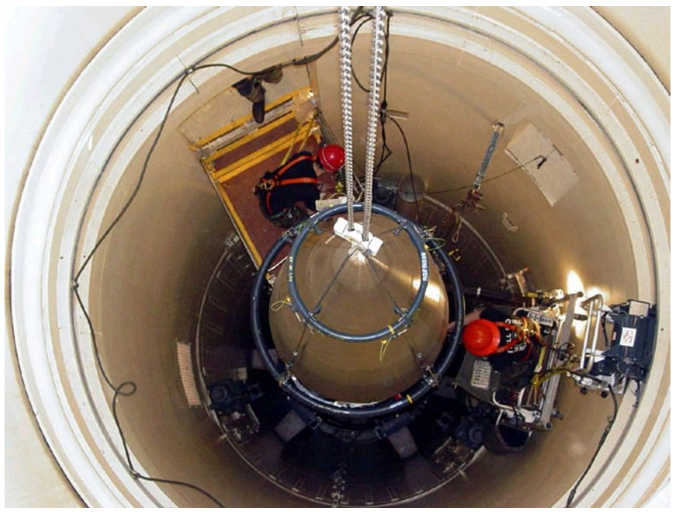

Figure 108. Nuclear missile silo at Malmstrom Air Force Base, Germany.

Figure 109. Radiation Fallout pattern and potential nuclear targets on USA's West coast: Seattle, Los Angeles, San Francisco and San Diego. Farcically odd non-military "Counter-value" targets include: Greenbay, Wisconsin, Lansing, Michigan, Albany, New York, Manchester, New Hampshire, and Augusta, Maine. Source: Global Times newspaper, China.

Figure 110. China's contemporary Underground Great Wall stretches over 5,000 kms in the Hebel region, and is reported to harbor its counterforce of 500 ICBMs in around 100 silos.

Figure 111. Russian Rs-18 missile silo at Baikonur, Kazakhstan, 2007.

Figure 112. Russian Tu-160 Blackjack bomber shadowed by F3 Tornado jet, UK.

Figure 113. Buchel missile base in Germany includes 20 B61 missile silos. Source: DDP.

Figure 114. Missile silo shield on rails, Germany.

Figure 115. The B61 thermonuclear free-fall precision guided munitions with tail flaps. It is a variable "dial-a-yield" design with a yield of 0.3 to 340 kT of TNT equivalent in its various mods. The B61 is a low to intermediate-yield strategic and tactical thermonuclear gravity bomb which features a two-stage radiation implosion design. It is capable of being deployed on a range of aircraft such as the F-15E, F-16 and Tornado. It can be released at speeds up to Mach 2 and dropped from as low as 50 feet where it features a 31 second delay to allow the delivery aircraft to escape the ensuing blast wave.

Figure 116. Joint strike fighter F35 carries B61 munitions in its belly for radar stealth considerations.

Figure 117. Mock B61-12 device launch.

The new nuclear bomb B61-12 large-scale production began in the United States in May 2022. This announcement was made by the National Nuclear Security Administration of the United States Department of Energy (NNSA is part of the USA Department of Energy). As they leave the factory, the new nuclear bombs will be delivered to the USA Air Force, which will install them in USA bases in Italy and other European countries replacing the B61s.

The B61-12 is a new nuclear weapon replacing three of the current B61 variants (3, 4, and 7). It has a nuclear warhead with four selectable power options according to the target to destroy. It does not drop vertically like the B61, but at distance from the target to which it is directed and guided by a satellite system. It can penetrate underground, exploding deep to destroy command center bunkers to "behead" the enemy nation in a nuclear first strike.

The current arms control efforts include a set of global and regional treaties: The Antarctic Treaty, The Sea-Bed Treaty, The Treaty of Tlatelolco in South America, The Outer Space Treaty, The Non-Proliferation Treaty (NPT), The Strategic Arms Limitations Treaty (SALT), The Vladivostok and SALT II treaties.

Figure 118. F15 Eagle fighter launching a GBU 28 earth-penetrating 2,300 kg munition.

Between the USA and Russia, the following treaties are at different stages of signature and ratification: The Intermediate-range Nuclear Forces Treaty (INF), and the Strategic Arms Reduction Treaty (START).

In 2002, USA President George W. Bush and Russian President Vladimir Putin signed the "Moscow Treaty on Strategic Offensive Reductions." According to that treaty, the USA reduced the number of operationally deployed strategic warheads and nuclear devices to 1,700-2,200 by 2012.

In 2004, USA President George W. Bush issued a directive to cut the entire USA nuclear stockpile of both deployed and reserve warheads in half by 2012 relative to 2001. The goal was achieved by 2007; five years ahead of schedule.

The USA is pursuing the construction of a missile defense system and is involved in an unpublicized new cold war with both Russia and China. The three competing powers are adopting a "counter-value strategy," where nuclear targeting makes no distinction between targeting purely civilian activities versus a "counter-force strategy" targeting military and military-industrial assets.

As the USA is still enjoying its status as the sole hyper-power in the continuously evolving and dangerous Nuclear World, it pursues an active Counter Proliferation Policy which is perceived as competitive to the Non Proliferation Treaty (NPT), substituting cooperation and economical and security incentives with a pre-emptive disarmament campaigns against unfriendly regimes using economic sanctions, as well as coercion and threats of resorting to military means whenever feasible. Fake hyped charges of "weapons of mass destruction", disavowed by the UN weapons inspectors were used, despite the evidence to the contrary, to invade Iraq and to destroy a country. This lie was later repudiated by USA Secretary of State Colin Powell, who regretted the stain on his reputation caused by the misuse of his credibility before the UN. False news reports of "Iranian nukes" are disseminated. Brinkmanship and chilling mind-numbing rhetorical threats from politicians are invoked by both sides and then tempered after second thoughts and cool heads prevail with softer Orwellian language under the codified "first-strike doctrine." An over-speeding out-of-control train that is not slowing down until it derails and collapses on itself in an epic fashion.

Former USA Secretary of Defense William J. Perry assesses the situation as follows:

> "When the Cold War ended, I believed that we no longer had to take that risk [nuclear annihilation] so I put all my energy into efforts to dismantle the deadly nuclear legacy of the Cold War. During my period as the Secretary of Defense in the 90s, I oversaw the dismantlement of 8,000 nuclear weapons evenly divided between the United States and the former Soviet Union. And I thought then that we were well on our way to putting behind us this deadly existential threat, But that was not to be. Today, inexplicably to me, we are recreating the geopolitical hostility of the Cold War, and we are rebuilding the nuclear dangers.

We are doing this without any serious public discussion or any real understanding of the consequences of these actions. We are sleepwalking into a new Cold War, and there is very real danger that we will blunder into a nuclear war. If we are to prevent this catastrophe, the public must understand what is happening."

About 50 years after signing the Non-Proliferation Treaty (NPT), which mandates the nuclear weapons states to nuclear disarm; of the 193 member states of the United Nations (UN), only nine possess nuclear weapons. Some countries like Norway refuse to have nuclear devices stationed on their soil, even though a member of NATO. This is the good news and gives hope of peace to humanity.

Conspiracy theorists suggest that Russia has developed a so-called "fail safe" system which would fire nuclear weapons toward any target through preprogrammed software requiring only one push of a lever. The doomsday system can deduce who fired and from what geographical region and fire its missiles in retaliation. Russia has repeatedly said that it will not be pulled to fight a conventional war that it would consider as disadvantageous to its force balance.

The USA is developing two new nuclear weapons. One of them may be a "low yield" submarine-launched nuclear device. The 2018 Pentagon review argues the USA will have more credible options to respond to Russian threats without using more powerful strategic nuclear weapons, which the Kremlin may calculate Washington would be reluctant to use for fear of unleashing an all-out nuclear war. Because the new weapons it is proposing would be based at sea, the USA would not need the permission of other nations to deploy them and their deployment would not violate existing arms-control agreements. The "low yield" nuclear weapon might be a Trident system with a warhead of just one or two kilotons, compared with the current system which has explosive yields that range from 100 kilotons to 455 kilotons. Reviewers suggest that it provides a first-strike destabilizing capability rather than an advocated stabilizing deterrence capability.

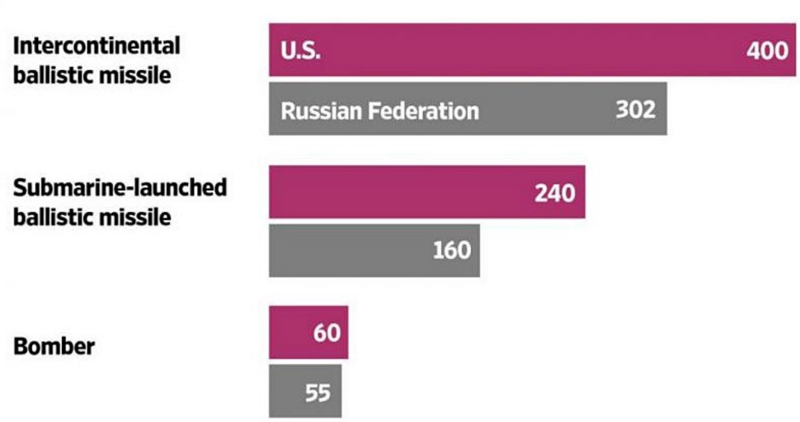

Figure 119. USA and Russian Nuclear missiles and bomber arsenals. Source: Federation of American Scientists, WSJ.

Figure 120. New type of trench warfare at a one mile distance from Simon 43 kT TNT equivalent nuclear test in the Nevada Desert, 1953.

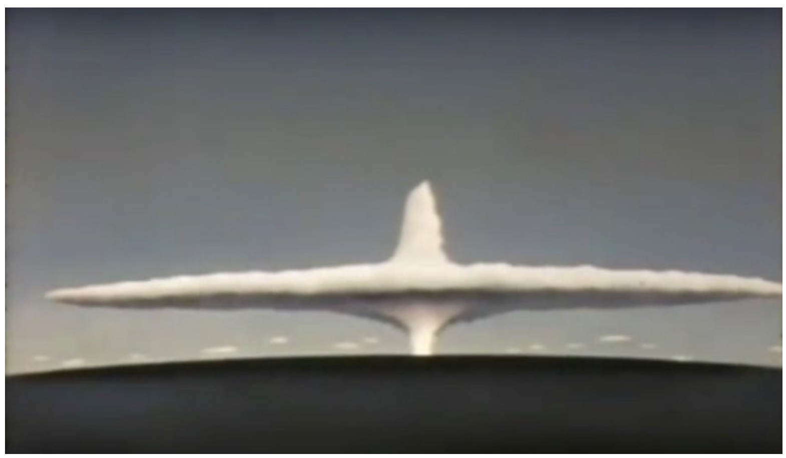

Figure 121. The mushroom cloud of the 10 Mt of TNT equivalent Ivy Mike test spreading to a width of 100 miles at the edge of the stratosphere to a height of 25 miles.

Figure 122. The fireball of the 10 Mt TNT Ivy Mike test superimposed on the New York City skyline. It would engulf one quarter of Manhattan Island.

Figure 123. The "Starfish" 1.4 Mt of TNT equivalent explosion in space did not generate a fireball but injected electrons and charged particles into the Van Allen Belts causing an Electro Magnetic Pulse (EMP) destroying several weather satellites and electronic devices damage such as street lights in Hawaii. An Aurora Borealis was observed over the Hawaiian Islands.

At the other end of the spectrum, the nine nuclear weapons states; USA, Russia, China, Britain, France, India, Pakistan, North Korea and Israel have not forsaken nuclear weaponry as hoped and are in the process of upgrading their nuclear stockpiles, not disarming them as expected. For instance, the USA is in the process of upgrading its nuclear arsenal and developing tactical small yield nuclear devices at a cost of $400 billion over 10 years, and $1 trillion over 30 years, according to the Stockholm International Peace Institute, SIPRI.

False alarms could have inadvertently started a nuclear war:

1. Saturday, January 13, 2018: False nuclear missile attack error on Hawaii created panic with people seeking shelter into manholes and basements. A police officer told commuters in cars: "The guy in North Korea launched three missiles at us. Go back and stay with your family."
2. November 1979: NORAD computers detected what appeared to be hundreds of Soviet missiles headed toward the USA. It turned out that someone had accidentally stuck a training tape into the computer system.
3. June 1980: The computers appeared to show 2,200 incoming Soviet missiles — "a full-scale general nuclear attack." This time, the alarm was blamed on the failure of a 46-cent computer chip.
4. September 1983: Soviet warning systems showed five USA missiles that appeared to be heading toward the Soviet Union. In reality, its satellites saw the sun's reflection from clouds and thought it was a missile launch.

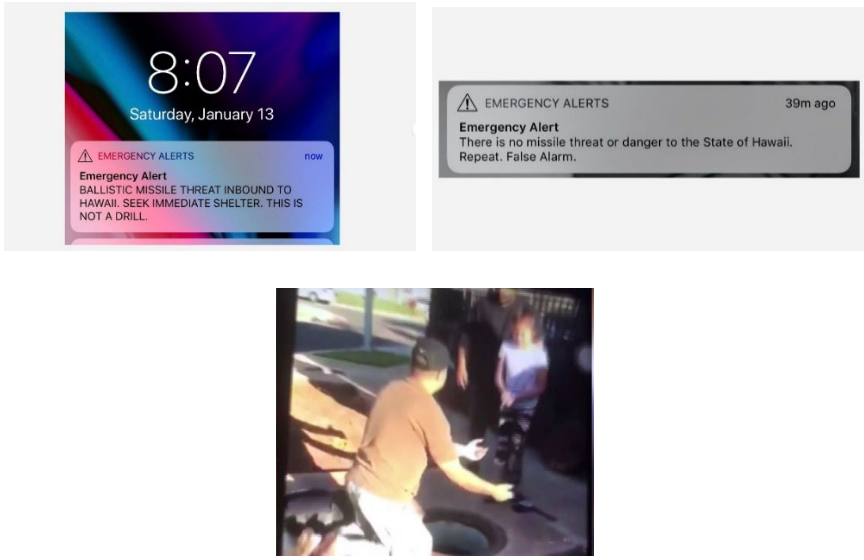

Figure 124. False nuclear missile attack error on Hawaii created panic with people seeking shelter into manholes and basements. Saturday, January 13, 2018.

SINGLE INTEGRATED OPERATIONAL PLAN, SIOP

General Curtis Le May intended to use strategic bombers to drop around 400 nuclear devices on most Warsaw Pact cities over 40,000 in population around 1947. That would have included Kiev, Warsaw, Prague, and would have wiped out surrounding countries like Finland from the fallout and most of the USA's allies in Western Europe. Production lines were ramped up and it seemed likely they would have enough warheads to complete the plan. At the time, the USA government did not realize the possibility of a nuclear winter causing global crop failure and starvation as a possible extinction event. The Russians developed their own nuclear arsenal too quickly, before a sufficient quantity of nuclear devices were produced by the USA, and the plan was foiled. In 1947 the WW II was over and President Harry Truman "liked that man", Joseph Stalin of Russia.

In 1960 the USA’s formulated nuclear war plans were formalized in the Single Integrated Operational Plan (SIOP). At first, the SIOP envisaged a massive simultaneous nuclear strike against the USSR’s nuclear forces, military targets, cities, as well as against China and Eastern Europe. It was planned that the USA’s strategic forces would use almost 3,500 atomic warheads on their targets. According to USA generals’ estimates, the attack could have resulted in the death of about 285 to 425 million people. Some of the USSR’s European allies were meant to be completely “wiped out.” “We are just going to have to wipe it [Albania] out,” USA General Thomas Power remarked at the 1960 SIOP planning conference.

WITHRAWAL FROM THE INF TREATY

In 1960 the US nuclear war plans were formalized in the Single Integrated Operational Plan (SIOP).

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"We're just going to have to wipe it [Albania] out," US General Thomas Power remarked at the 1960 SIOP planning conference, as quoted by MacKenzie.

In October 2018, President Donald Trump suggested pulling the USA out of the Intermediate-Range Nuclear Forces Treaty (INF) with Russia that was created by the Reagan administration in 1986 and signed in 1987. When first signed by President Ronald Reagan and Soviet leader Mikhail Gorbachev following their historic 1986 meeting, the INF was touted as an important de-escalation of tensions between the two superpowers. But it has become a flashpoint in the increasingly strained relationship between the USA and Russia, as both sides have accused the other of violating its terms.

Russia has been violating it since 2014 and in 2018 deployed its newest nuclear-capable Novator 9M729 missile system, said to exceed the missile range stipulated by the treaty. The decision to leave it is reportedly motivated by the USA's ability to counter a Chinese arms buildup in the Pacific region. In Romania and Poland, the USA has installed THAAD systems, which are not defensive, and can easily be switched to nuclear warheads. The Terminal High Altitude Area Defense (THAAD) is an American anti-ballistic missile defense system designed to shoot down short-, medium-, and intermediate-range ballistic missiles in their terminal phase by intercepting with a hit-to-kill approach. The treaty does not cover missile defense interceptors.

Faster hypersonic missiles have effectively changed the terms of the agreement to Russia's advantage. It is only rational that the Agreement be amended to reflect this technological development. If not, shorter range missiles becomes the answer. The move may endanger other treaties like the Strategic Arms Reduction Treaty (START) leading to chaos in nuclear arms limitations.

Figure 125. The SSC-8 Novator 9M729 Russian cruise missile.

The treaty kept the USA from developing its own line of conventional intermediate range missiles. The USA sees a threat coming from China and now plans to develop a counter-conventional force of Intermediate Range Ballistic Missiles (IRBMs).

The INF Treaty defines an intermediate-range missile as a ground-launched ballistic missile (GLBM) or GLCM having a range capability in excess of 1,000 km [about 540 nm] but not in excess of 5,500 km [2969.762 nm, but this is too precise, 3,000 nm is better]. The Treaty defines a shorter-range missile as a GLBM or GLCM having a range capability equal to or in excess of 500 km [270 nm] but not in excess of 1,000 km. A GLCM is defined as a ground-launched cruise missile that is a weapon delivery vehicle.

The USA contends that Russia also violated the treaty in developing, testing, and deploying significant numbers of a new ground-launched cruise missile called the SSC-8 (Novator 9M729). China disclosed on January 9, 2019 the test firing of one of its newest intermediate-range missiles, the DF-26. China dubbed the missile as the "Guam killer" because it can target the key USA's military base in the South Pacific. A newer anti-ship version of the 2,400-mile range DF-26 capable of maneuvering and precisely hitting an ocean-going ship also was disclosed by Chinese media. China has refused for decades to engage the USA in arms control discussions over concerns the talks will undermine the deterrent value of its weapons.

China's arsenal of ground-launched missiles is the largest and most diverse in the world and included more than 2,000 ballistic and cruise missiles. About 95 percent of all the missiles would violate the INF treaty if China were a signatory to the 1987 treaty. China's INF Treaty-noncompliant missiles include some of its short-range (between 500 and 1,000 km or 310 and 620 miles), all of its medium-range (between 1,000 and 3,000 km or 620 and 1,860 miles), and all of its intermediate- range (between 3,000 and 5,500 km or 1,860 and 3,410 miles) ballistic missile variants. China's missiles are dual-capable, nuclear or conventionally-armed weapons, and large numbers of increasingly accurate conventionally-armed missiles would be banned under the INF. In the 1995–1996 Taiwan Strait Crisis, China fired missiles into the waters off of Taiwan. The missiles were DF-15 short-range ballistic missiles that would be banned by the INF Treaty.

On February 2nd, 2019, the USA announced that it formally is pulling out of the Intermediate-Range Nuclear Forces (INF) treaty, signed in 1987 by Ronald Reagan and Mikhail Gorbachev. Russia followed by withdrawing from the treaty. Both President Barack Obama and President Donald Trump administrations have accused Russia of violating the treaty, which bans nuclear and conventional ground-launched missiles with ranges of 500 to 5,500 kilometers. The historic treaty called for a ban on all land-based missiles with a range of between 310 and 3,400 miles. Secretary of State Mike Pompeo said in December 2018 that Russia had 60 days to return to compliance, or the USA would pull out. China, meanwhile, is unconstrained by the treaty and has an arsenal of such missiles.

The USA plans to build small nuclear weapons including missiles designed to counter both Chinese intermediate-range missiles in Asia and Russian systems in Europe. The new USA missiles targeting China would be deployed in Japan, Australia, Philippines, or Guam.

TREATY VIOLATIONS, LOW-YIELD TESTING

The USA intelligence agencies suspect that Russia has been secretly conducting low-yield nuclear weapons tests in violation of the 1996 Comprehensive Nuclear Test Ban Treaty. The international treaty prohibits this type of testing: "The United States believes that Russia probably is not adhering to its nuclear testing moratorium in a manner consistent with the 'zero-yield' standard," Director of the USA Defense Intelligence Agency Lt. Gen. Robert Ashley wrote in prepared remarks for a talk at the Hudson Institute.

Russia is suspected to have conducted a number of very low-yield nuclear tests at its Novaya Zemlya testing facility in the Arctic. The US halted nuclear testing in 1992 after 1,030 nuclear detonations. Russia followed suit after 715 explosions, ratifying the treaty in 2000. The Russians were hesitant to agree to USA "zero-yield" demands, but they did agree eventually. There have long been concerns in the USA that the understanding of the treaty's requirements in Russia may be different from Washington's perceptions: "Our understanding of nuclear weapon development leads us to believe Russia's testing activities would help it improve its nuclear weapon capabilities."

China, another signatory to the test ban treaty, may also be engaging in actions "inconsistent" with this international agreement. China, like Russia, insists it is adhering to the treaty's requirements.

In the aftermath of the collapse of the 1987 INF Treaty, tensions between the USA and Russia skyrocketed. The latest accusations risk escalating an already tense situation. Both the USA and Russia have begun developing new weapons systems to challenge the other.

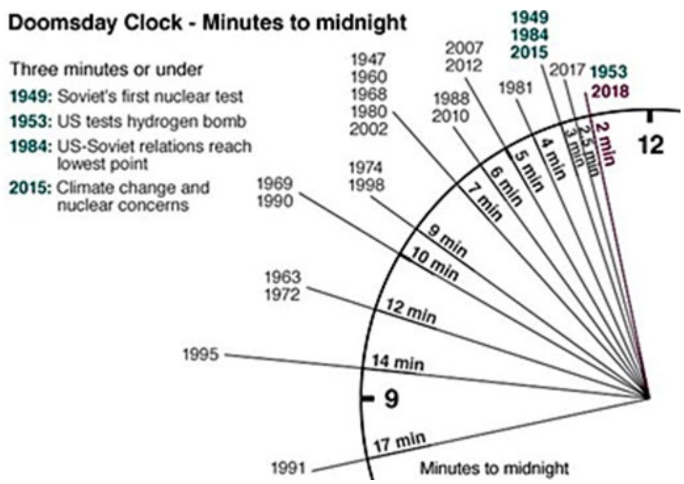
According to the USA Federal Office for Radiation Protection, elevated levels of the isotope Ruthenium^{106} have been reported in Germany, Italy, Austria, Switzerland and France since September 29, 2017. Ruthenium^{106} is a radionuclide of artificial origin. It is a fission product from the nuclear industry used in the medical field for brachytherapy treatments and sometimes in radioisotope thermoelectric generators (RTGs) as a source of energy for space satellites. The radionuclide has been detected by several European networks involved in the monitoring of atmospheric radioactive contamination, at levels of a few milliBecquerels per cubic meter of air. The filters of the stations of Seyne-sur-Mer (Var) and Nice (Alpes-Maritimes) in France showed the presence of Ruthenium^{106} at trace levels of 7.4 and 6.8 micro-Bq/m^3 respectively.

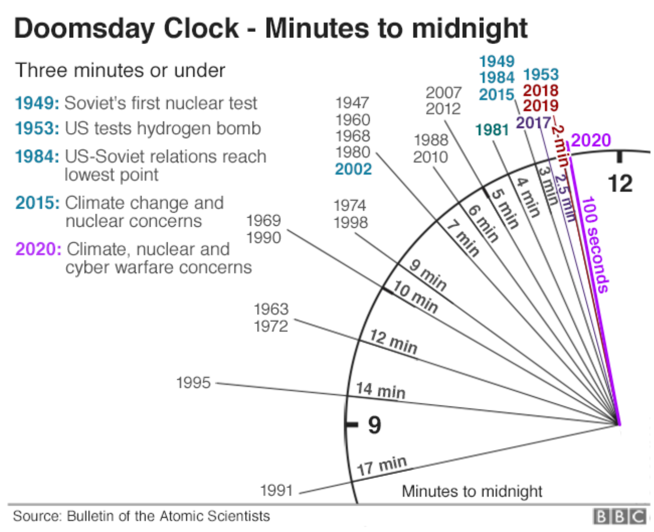
It appears that the contaminated air masses measured in Europe originate from the southern regions of the Urals. Given the amount of Ruthenium^{106} that may be at the origin of the air pollution observed in Europe, it appears that measures of protection of the populations could have been necessary in the vicinity of the site of the releases. It should be noted that the detection of ruthenium alone excludes the possibility of an accident at a nuclear power plant, which would result in the presence of other radionuclides. Ruthenium can occur in nuclear fuel cycle installations, in facilities manufacturing radioactive sources.

In January 2017, a radionuclide of anthropogenic origin, Iodine^{131}, has been detected in the ground-level atmosphere across Europe. Since Iodine^{131} is a radionuclide with a short half-life (8 days) its detection suggested a rather recent release, possibly from low-yield clandestine nuclear testing or from nuclear medicine applications. Hospitals are increasingly using radioactive isotopes for diagnostic and therapeutic applications. The main radioisotopes used in hospitals are technetium^{99m}, Iodine^{131}, Iodine^{125}, Iodine^{123}, Flourine^{18}, Tritium^3 and Carbon^{14}.

DOOMSDAY CLOCK, BULLETIN OF ATOMIC SCIENTISTS

The doomsday clock symbolic device was created by the Bulletin of the Atomic Scientists in 1947. It was founded at the University of Chicago in 1945 by a group of scientists who helped develop the first atomic weapons. The group consists of physicists and environmental scientists from around the world, who decide whether to adjust the clock in consultation with the group's Board of Sponsors. The clock is a metaphor for how close mankind is to destroying the Earth. In 2018 it reached a point that it reached in 1953 when both the USA and the Soviet tested thermonuclear devices in the atmosphere.





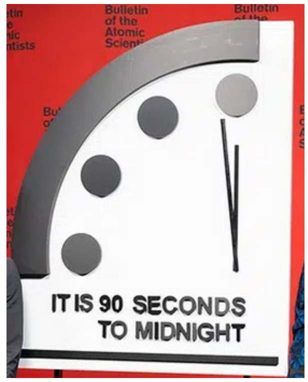


Figure 126. Doomsday clock, Bulletin of Atomic Scientists, BBC, January 25, 2018, January 23, 2020, January 24, 2023. The Doomsday clock was set at 90 seconds to midnight, due largely but not exclusively to Russia's invasion of Ukraine and the increased risk of nuclear escalation. The new Clock time was also influenced by continuing threats posed by the climate crisis and the breakdown of global norms and institutions needed to mitigate risks associated with advancing technologies and biological threats such as Covid19.

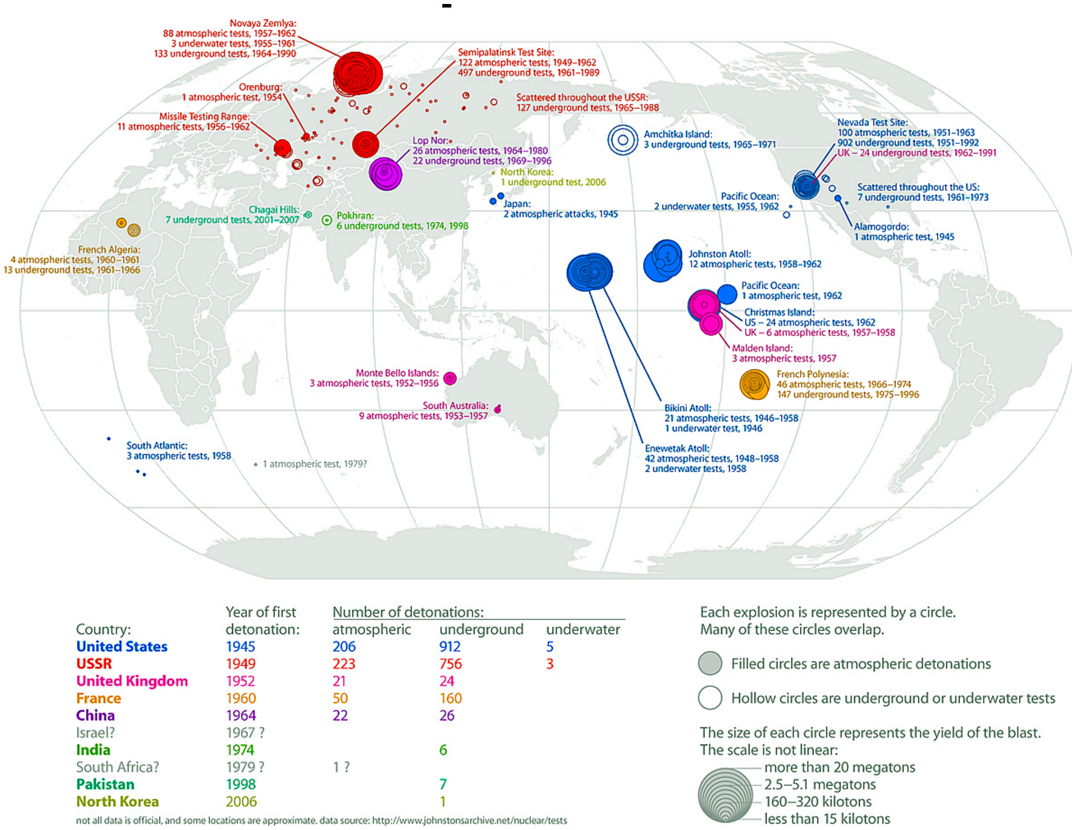


Figure 127. Nuclear testing since 1945.

CONCLUSIONS

In July 2017 more than 100 countries endorsed a UN treaty to ban nuclear weapons altogether. The International Campaign to Abolish Nuclear Weapons (ICAN), the organization behind the treaty, was awarded the 2017 Nobel Peace Prize. Honduras became the 50th country to ratify the Treaty on the Prohibition of Nuclear Weapons on October 25, 2020.

Dozens of countries have signed the legally binding instrument, the first agreement of its kind to explicitly ban nuclear weapons. However the nuclear-armed states boycotted the negotiations. The UK and USA say they never intend to join the treaty because it undermines the NPT. Allied NATO countries also failed to acknowledge the new agreement.

The 2018 new Nuclear Posture Review calls for more weapons, speaks of nuclear weapons as "usable," and justifies their use in First Strikes even against countries that do not have nuclear weapons. The USA government believes in the first use of nuclear weapons against any and every country. Nuclear powers such as Russia and China must see this to be a massive increase in the threat level from the USA. The Russian doctrine is to allow field generals to use tactical nuclear devices as necessary. In past posture reviews, nuclear weapons were regarded as unusable except in retaliation for a nuclear attack. An assumption was that no one would use them.

The 1967 Outer Space Treaty contains no language that specifically prohibits militarizing space, except when it comes to weapons of mass destruction, like nuclear weapons. It is required that all states' use of the Moon and other celestial bodies is for "peaceful purposes." Exploring and using outer space must be done for the benefit of all countries and all exploration and use must follow international law, like the UN Charter, per the treaty.

The possibility existed that false warnings of incoming ICBMs would result in the nuclear button being pushed, thus setting off a nuclear exchange. There were many false warnings during the Cold War. President Ronald Reagan was very concerned about a false warning resulting in mass death and destruction. His principal goal was to end the Cold War, which he succeeded in doing. Successor governments resurrected the Cold War. General Curtis Lemay quote comes to mind: "bomb them into the stone age". What should be realized is that nuclear weapons states capable of retaliation become immune to both nuclear and conventional attacks.

It is naïve to think that nuclear weapons are like other weapons; designed and built to be used on the battle fields. The historical evidence suggests that nuclear weapons are in reality "anti-weapons" designed to prevent nuclear as well as conventional weapons from being indiscriminately used in warfare. The historical facts imply that the nuclear, as well as the latent, nuclear weapons states are automatically elevated to the status of becoming immune to both conventional and nuclear attacks. From that perspective, nuclear weapons become conflict suppression tools. However, from the opposite perspective, it is indisputable that their incorrect use poses a mortal risk to all human civilization on Earth.

The working dynamic globally appears to be a "Precipice Rule," which suggests that sides will argue, shout and threaten but back away at the last minute before falling into a precipice. However, in a "Nuclear World," where the doctrines of "Mutually Assured Destruction" (MAD) and of "Nuclear Primacy" predominate and where there is always a possibility for accidents, miscalculations, blunders and brinkmanships; and the survival of the human species and its technical civilization are at stake, military confrontation is excluded, and diplomacy and peaceful dialogue stand up as the rational survival alternatives.

APPENDIX I

The ending of the 1983 film, Wargames. "The Only Winning Move Is Not to Play."
Global Thermonuclear War.
https://www.youtube.com/watch?v=s93KC4AGKnY&feature=emb_logo

APPENDIX II

List of nuclear explosions
Mark Belan and Govind Bhutada, Visual Capitalist

The USA's Trinity test in 1945, the first-ever nuclear detonation, released around 19 kilotons of explosive energy. The explosion instantly vaporized the tower it stood on and turned the surrounding sand into green glass, before sending a powerful heatwave across the desert.

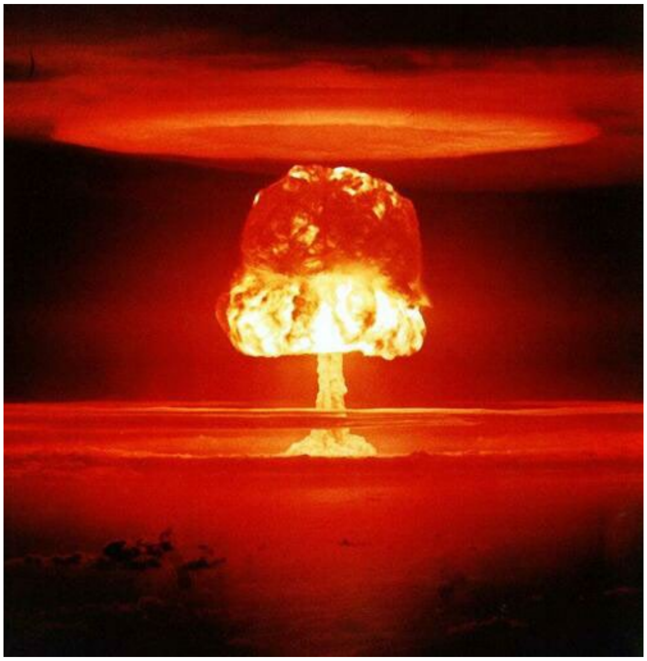
In the Cold War after WWII, the USA and the USSR tested bombs that were at least 500 times greater in explosive power.

#10: Ivy Mike (1952)

In 1952, the U.S. detonated the Mike device—the first-ever hydrogen bomb—as part of Operation Ivy. Hydrogen bombs rely on nuclear fusion to amplify their explosions, producing much more explosive energy than atomic bombs that use nuclear fission.
Weighing 140,000 pounds (63,500kg), the Ivy Mike test generated a yield of 10,400 kilotons, equivalent to the explosive power of 10.4 million tons of TNT. The explosion was 700 times more powerful than Little Boy, the bomb dropped on Hiroshima in 1945.

#9: Castle Romeo (1954)

Castle Romeo was part of the Operation Castle series of U.S. nuclear tests taking place on the Marshall Islands. Shockingly, the U.S. was running out of islands to conduct tests, making Romeo the first-ever test conducted on a barge in the ocean.
At 11,000 kilotons, the test produced more than double its predicted explosive energy of 4,000 kilotons. Its fireball, as seen below, is one of the most iconic images ever captured of a nuclear explosion.



#8: Soviet Test #123 (1961)

Test #123 was one of the 57 tests conducted by the Soviet Union in 1961. Most of these tests were conducted on the Novaya Zemlya archipelago in Northwestern Russia. The bomb yielded 12,500 kilotons of explosive energy, enough to vaporize everything within a 2.1 mile (3.5km) radius.

#7: Castle Yankee (1954)

Castle Yankee was the fifth test in Operation Castle. The explosion marked the second-most powerful nuclear test by the U.S.
It yielded 13,500 kilotons, much higher than the predicted yield of up to 10,000 kilotons. Within four days of the blast, its fallout reached Mexico City, roughly 7,100 miles (11,400km) away.

#6: Castle Bravo (1954)

Castle Bravo, the first of the Castle Operation series, accidentally became the most powerful nuclear bomb tested by the U.S.
Due to a design error, the explosive energy from the bomb reached 15,000 kilotons, two and a half times what was expected. The mushroom cloud climbed up to roughly 25 miles (40km).
As a result of the test, an area of 7,000 square miles was contaminated, and inhabitants of nearby atolls were exposed to high levels of radioactive fallout. Traces of the blast were found in Australia, India, Japan, and Europe.

#5, #4, #3: Soviet Tests #173, #174, #147 (1962)

In 1962, the Soviet Union conducted 78 nuclear tests, three of which produced the fifth, fourth, and third-most powerful explosions in history. Tests #173, #174, and #147 each yielded around 20,000 kilotons. Due to the absolute secrecy of these tests, no photos or videos have been released.

#2: Soviet Test #219 (1962)

Test #219 was an atmospheric nuclear test carried out using an intercontinental ballistic missile (ICBM), with the bomb exploding at a height of 2.3 miles (3.8km) above sea level. It was the second-most powerful nuclear explosion, with a yield of 24,200 kilotons and a destructive radius of ~25 miles (41km).

#1: Tsar Bomba (1961)

Tsar Bomba, also called Big Ivan, needed a specially designed plane because it was too heavy to carry on conventional aircraft. The bomb was attached to a giant parachute to give the plane time to fly away.
The explosion, yielding 50,000 kilotons, obliterated an abandoned village 34 miles (55km) away and generated a 5.0-5.25 magnitude earthquake in the surrounding region. Initially, it was designed as a 100,000 kiloton bomb, but its yield was cut to half its potential by the Soviet Union. Tsar Bomba's mushroom cloud breached through the stratosphere to reach a height of over 37 miles (60km), roughly six times the flying height of commercial aircraft.

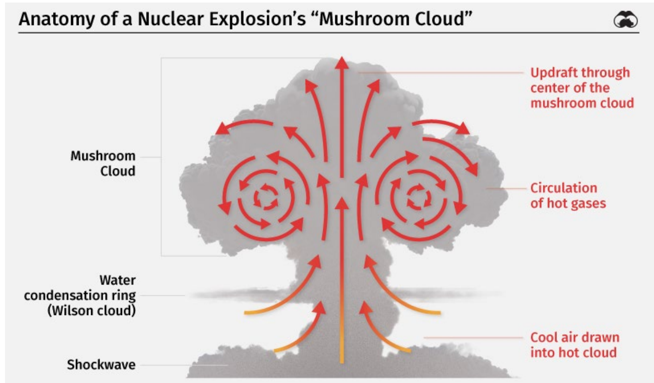
The two bombs dropped on Hiroshima and Nagasaki had devastating consequences, and their explosive yields were only a fraction of the 10 largest explosions. The power of modern nuclear weapons makes their scale of destruction truly unfathomable, and as history suggests, the outcomes can be unpredictable.

APPENDIX III

Anatomy of a nuclear explosions
Mark Belan and Govind Bhutada, Visual Capitalist

After exploding, nuclear bombs create giant fireballs that generate a blinding flash and a searing heatwave. The fireball engulfs the surrounding air, getting larger as it rises like a hot air balloon.

As the fireball and heated air rise, they are flattened by cooler, denser air high up in the atmosphere, creating the mushroom "cap" structure. At the base of the cloud, the fireball causes physical destruction by sending a shockwave moving outwards at thousands of miles an hour.



A strong updraft of air and dirt particles through the center of the cloud forms the "stem" of the mushroom cloud. In most atomic explosions, changing atmospheric pressure and water condensation create rings that surround the cloud, also known as Wilson clouds. Over time, the mushroom cloud dissipates. However, it leaves behind radioactive fallout in the form of nuclear particles, debris, dust, and ash, causing lasting damage to the local environment. Because the particles are lightweight, global wind patterns often distribute them far beyond the place of detonation.

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