**Nuclear Weapon**

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*"A-bomb" redirects here. For other uses, see A-bomb (disambiguation).*



The mushroom cloud of the atomic bombing of the Japanese city of Nagasaki on August 9, 1945 rose some 11 miles (18 km) above the bomb's hypocenter.

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| Replica of the "Fat Man" nuclear bomb dropped on Nagasaki, Japan, on August 9, 1945 |
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A **nuclear weapon** is an explosive device that derives its destructive force from nuclear reactions, either fission (fission bomb) or a combination of fission and fusion (thermonuclear weapon). Both reactions release vast quantities of energy from relatively small amounts of matter. The first fission ("atomic") bomb test released the same amount of energy as approximately 20,000 tons of TNT (see Trinity (nuclear test)). The first thermonuclear ("hydrogen") bomb test released the same amount of energy as approximately 10,000,000 tons of TNT.

A thermonuclear weapon weighing little more than 2,400 pounds (1,100 kg) can produce an explosive force comparable to the detonation of more than 1.2 million tons (1.1 million tonnes) of TNT. A nuclear device no larger than traditional bombs can devastate an entire city by blast, fire, and radiation. Nuclear weapons are considered weapons of mass destruction, and their use and control have been a major focus of international relations policy since their debut.

Nuclear weapons have been used twice in nuclear warfare, both times by the United States against Japan near the end of World War II. On August 6, 1945, the U.S. Army Air Forces detonated a uranium gun-type fission bomb over the Japanese city of Hiroshima; three days later, on August 9, the U.S. Army Air Forces detonated a plutonium implosion-type fission bomb codenamed "Fat Man" over the Japanese city of Nagasaki. The bombings resulted in the deaths of approximately 200,000 civilians and military personnel from acute injuries sustained from the explosions. The ethics of the bombings and their role in Japan's surrender remain the subject of scholarly and popular debate.

Since the atomic bombings of Hiroshima and Nagasaki, nuclear weapons have been detonated on over two thousand occasions for the purposes of testing and demonstration. Only a few nations possess such weapons or are suspected of seeking them. The only countries known to have detonated nuclear weapons—and acknowledge possessing them—are (chronologically by date of first test) the United States, the Soviet Union (succeeded as a nuclear power by Russia), the United Kingdom, France, the People's Republic of China, India, Pakistan, and North Korea. Israel is also believed to possess nuclear weapons, though it does not acknowledge having them. One state, South Africa, fabricated nuclear weapons in the past, but as its apartheid regime was coming to an end, it disassembled its arsenal, acceded to the Nuclear Non-Proliferation Treaty, and accepted full-scope international safeguards. The Federation of American Scientists estimated there were more than 15,700 nuclear warheads worldwide as of 2015, with around 4,100 of them considered "operational" (ready for immediate use).

**Types**

Main article: Nuclear weapon design



The two basic fission weapon designs

There are two basic types of nuclear weapons: those that derive the majority of their energy from nuclear fission reactions alone, and those that use fission reactions to begin nuclear fusion reactions that produce a large amount of the total energy output.

**Fission weapons**

All existing nuclear weapons derive some of their explosive energy from nuclear fission reactions. Weapons whose explosive output is exclusively from fission reactions are commonly referred to as **atomic bombs** or **atom bombs** (abbreviated as **A-bombs**). This has long been noted as something of a misnomer, as their energy comes from the nucleus of the atom, just as it does with fusion weapons.

In fission weapons, a mass of fissile material (enriched uranium or plutonium) is assembled into a supercritical mass—the amount of material needed to start an exponentially growing nuclear chain reaction—either by shooting one piece of sub-critical material into another (the "gun" method) or by compressing using explosive lenses a sub-critical sphere of material using chemical explosives to many times its original density (the "implosion" method). The latter approach is considered more sophisticated than the former and only the latter approach can be used if the fissile material is plutonium.

A major challenge in all nuclear weapon designs is to ensure that a significant fraction of the fuel is consumed before the weapon destroys itself. The amount of energy released by fission bombs can range from the equivalent of just under a ton of TNT, to upwards of 500,000 tons (500 kilotons) of TNT.

All fission reactions necessarily generate fission products, the radioactive remains of the atomic nuclei split by the fission reactions. Many fission products are either highly radioactive (but short-lived) or moderately radioactive (but long-lived), and as such are a serious form of radioactive contamination if not fully contained. Fission products are the principal radioactive component of nuclear fallout.

The most commonly used fissile materials for nuclear weapons applications have been uranium-235 and plutonium-239. Less commonly used has been uranium-233. Neptunium-237 and some isotopes of americium may be usable for nuclear explosives as well, but it is not clear that this has ever been implemented, and even their plausible use in nuclear weapons is a matter of scientific dispute.

**Fusion weapons**

Main article: Thermonuclear weapon



The basics of the Teller–Ulam design for a hydrogen bomb: a fission bomb uses radiation to compress and heat a separate section of fusion fuel.

The other basic type of nuclear weapon produces a large proportion of its energy in nuclear fusion reactions. Such fusion weapons are generally referred to as **thermonuclear weapons** or more colloquially as **hydrogen bombs** (abbreviated as **H-bombs**), as they rely on fusion reactions between isotopes of hydrogen (deuterium and tritium). All such weapons derive a significant portion, and sometimes a majority, of their energy from fission. This is because a fission weapon is required as a "trigger" for the fusion reactions, and the fusion reactions can themselves trigger additional fission reactions.

Only six countries—United States, Russia, United Kingdom, People's Republic of China, France and India—have conducted thermonuclear weapon tests. (Whether India has detonated a "true", multi-staged thermonuclear weapon is controversial.) Thermonuclear weapons are considered much more difficult to successfully design and execute than primitive fission weapons. Almost all of the nuclear weapons deployed today use the thermonuclear design because it is more efficient.

Thermonuclear bombs work by using the energy of a fission bomb to compress and heat fusion fuel. In the Teller-Ulam design, which accounts for all multi-megaton yield hydrogen bombs, this is accomplished by placing a fission bomb and fusion fuel (tritium, deuterium, or lithium deuteride) in proximity within a special, radiation-reflecting container. When the fission bomb is detonated, gamma rays and X-rays emitted first compress the fusion fuel, then heat it to thermonuclear temperatures. The ensuing fusion reaction creates enormous numbers of high-speed neutrons, which can then induce fission in materials not normally prone to it, such as depleted uranium. Each of these components is known as a "stage", with the fission bomb as the "primary" and the fusion capsule as the "secondary". In large, megaton-range hydrogen bombs, about half of the yield comes from the final fissioning of depleted uranium.

Virtually all thermonuclear weapons deployed today use the "two-stage" design described above, but it is possible to add additional fusion stages—each stage igniting a larger amount of fusion fuel in the next stage. This technique can be used to construct thermonuclear weapons of arbitrarily large yield, in contrast to fission bombs, which are limited in their explosive force. The largest nuclear weapon ever detonated—the Tsar Bomba of the USSR, which released an energy equivalent of over 50 million tons (50 megatons) of TNT—was a three-stage weapon. Most thermonuclear weapons are considerably smaller than this, due to practical constraints from missile warhead space and weight requirements.



Edward Teller, often referred to as the "father of the hydrogen bomb"

Fusion reactions do not create fission products, and thus contribute far less to the creation of nuclear fallout than fission reactions, but because all thermonuclear weapons contain at least one fission stage, and many high-yield thermonuclear devices have a final fission stage, thermonuclear weapons can generate at least as much nuclear fallout as fission-only weapons.

**Other types**

Main articles: boosted fission weapon, neutron bomb and radiological bomb

There are other types of nuclear weapons as well. For example, a boosted fission weapon is a fission bomb that increases its explosive yield through a small amount of fusion reactions, but it is not a fusion bomb. In the boosted bomb, the neutrons produced by the fusion reactions serve primarily to increase the efficiency of the fission bomb.

Some weapons are designed for special purposes; a neutron bomb is a thermonuclear weapon that yields a relatively small explosion but a relatively large amount of neutron radiation; such a device could theoretically be used to cause massive casualties while leaving infrastructure mostly intact and creating a minimal amount of fallout. The detonation of any nuclear weapon is accompanied by a blast of neutron radiation. Surrounding a nuclear weapon with suitable materials (such as cobalt or gold) creates a weapon known as a salted bomb. This device can produce exceptionally large quantities of radioactive contamination.

Research has been done into the possibility of pure fusion bombs: nuclear weapons that consist of fusion reactions without requiring a fission bomb to initiate them. Such a device might provide a simpler path to thermonuclear weapons than one that required development of fission weapons first, and pure fusion weapons would create significantly less nuclear fallout than other thermonuclear weapons, because they would not disperse fission products. In 1998, the United States Department of Energy divulged that the United States had, "...made a substantial investment" in the past to develop pure fusion weapons, but that, "The U.S. does not have and is not developing a pure fusion weapon", and that, "No credible design for a pure fusion weapon resulted from the DOE investment".

Most variation in nuclear weapon design is for the purpose of achieving different yields for different situations, and in manipulating design elements to attempt to minimize weapon size.

Antimatter, which consists of particles resembling ordinary matter particles in most of their properties but having opposite electric charge, has been considered as a trigger mechanism for nuclear weapons. A major obstacle is the difficulty of producing antimatter in large enough quantities, and there is no evidence that it is feasible beyond the military domain. However, the U.S. Air Force funded studies of the physics of antimatter in the Cold War, and began considering its possible use in weapons, not just as a trigger, but as the explosive itself. A fourth generation nuclear weapon design is related to, and relies upon, the same principle as Antimatter-catalyzed nuclear pulse propulsion.

**Weapons delivery**

*See also: Nuclear weapons delivery, nuclear triad, Strategic bomber, Intercontinental ballistic missile and Submarine-launched ballistic missile*



The first nuclear weapons were gravity bombs, such as this "Fat Man" weapon dropped on Nagasaki, Japan. They were very large and could only be delivered by heavy bomber aircraft



A demilitarized and commercial launch of the Russian Strategic Rocket Forces R-36 ICBM; also known by the NATO reporting name: SS-18 Satan. Upon its first fielding in the late 1960s, the SS-18 remains the single highest throw weight missile delivery system ever built.

Nuclear weapons delivery—the technology and systems used to bring a nuclear weapon to its target—is an important aspect of nuclear weapons relating both to nuclear weapon design and nuclear strategy. Additionally, development and maintenance of delivery options is among the most resource-intensive aspects of a nuclear weapons program: according to one estimate, deployment costs accounted for 57% of the total financial resources spent by the United States in relation to nuclear weapons since 1940.

Historically the first method of delivery, and the method used in the two nuclear weapons used in warfare, was as a gravity bomb, dropped from bomber aircraft. This is usually the first method that countries developed, as it does not place many restrictions on the size of the weapon and *weapon miniaturization* requires considerable weapons design knowledge. It does, however, limit attack range, response time to an impending attack, and the number of weapons that a country can field at the same time.

With the advent of miniaturization, nuclear bombs can be delivered by both strategic bombers and tactical fighter-bombers, allowing an air force to use its current fleet with little or no modification. This method may still be considered the primary means of nuclear weapons delivery; the majority of U.S. nuclear warheads, for example, are free-fall gravity bombs, namely the B61.



Montage of an inert test of a United States Trident SLBM (submarine launched ballistic missile), from submerged to the terminal, or re-entry phase, of the multiple independently targetable reentry vehicles

More preferable from a strategic point of view is a nuclear weapon mounted onto a missile, which can use a ballistic trajectory to deliver the warhead over the horizon. Although even short-range missiles allow for a faster and less vulnerable attack, the development of long-range intercontinental ballistic missiles (ICBMs) and submarine-launched ballistic missiles (SLBMs) has given some nations the ability to plausibly deliver missiles anywhere on the globe with a high likelihood of success.

More advanced systems, such as multiple independently targetable reentry vehicles (MIRVs), can launch multiple warheads at different targets from one missile, reducing the chance of a successful missile defense. Today, missiles are most common among systems designed for delivery of nuclear weapons. Making a warhead small enough to fit onto a missile, though, can be difficult.

Tactical weapons have involved the most variety of delivery types, including not only gravity bombs and missiles but also artillery shells, land mines, and nuclear depth charges and torpedoes for anti-submarine warfare. An atomic mortar was also tested at one time by the United States. Small, two-man portable tactical weapons (somewhat misleadingly referred to as suitcase bombs), such as the Special Atomic Demolition Munition, have been developed, although the difficulty of combining sufficient yield with portability limits their military utility.

**Nuclear strategy**

Main articles: Nuclear strategy and Deterrence theory

Nuclear warfare strategy is a set of policies that deal with preventing or fighting a nuclear war. The policy of trying to prevent an attack by a nuclear weapon from another country by threatening nuclear retaliation is known as the strategy of nuclear deterrence. The goal in deterrence is to always maintain a second strike capability (the ability of a country to respond to a nuclear attack with one of its own) and potentially to strive for first strike status (the ability to completely destroy an enemy's nuclear forces before they could retaliate). During the Cold War, policy and military theorists in nuclear-enabled countries worked out models of what sorts of policies could prevent one from ever being attacked by a nuclear weapon, and developed weapon game theory models that create the greatest and most stable deterrence conditions.



The now decommissioned United States' Peacekeeper missile was an ICBM developed to entirely replace the minuteman missile in the late 1980s. Each missile, like the heavier lift Russian SS-18 Satan, could contain up to ten nuclear warheads (shown in red), each of which could be aimed at a different target. A factor in the development of MIRVs was to make complete missile defense very difficult for an enemy country.

Different forms of nuclear weapons delivery (see above) allow for different types of nuclear strategies. The goals of any strategy are generally to make it difficult for an enemy to launch a pre-emptive strike against the weapon system and difficult to defend against the delivery of the weapon during a potential conflict. Sometimes this has meant keeping the weapon locations hidden, such as deploying them on submarines or land mobile transporter erector launchers whose locations are very hard for an enemy to track, and other times, this means protecting them by burying them in hardened missile silo bunkers.

Other components of nuclear strategies have included using missile defense (to destroy the missiles before they land) or implementation of civil defense measures (using early-warning systems to evacuate citizens to safe areas before an attack).

Note that weapons designed to threaten large populations, or to generally deter attacks are known as *strategic weapons.* Weapons designed for use on a battlefield in military situations are called *tactical weapons.*

There are critics of the very idea of nuclear strategy for waging nuclear war who have suggested that a nuclear war between two nuclear powers would result in mutual annihilation. From this point of view, the significance of nuclear weapons is purely to deter war because any nuclear war would immediately escalate out of mutual distrust and fear, resulting in mutually assured destruction. This threat of national, if not global, destruction has been a strong motivation for anti-nuclear weapons activism.

Critics from the peace movement and within the military establishment have questioned the usefulness of such weapons in the current military climate. According to an advisory opinion issued by the International Court of Justice in 1996, the use of (or threat of use of) such weapons would generally be contrary to the rules of international law applicable in armed conflict, but the court did not reach an opinion as to whether or not the threat or use would be lawful in specific extreme circumstances such as if the survival of the state were at stake.

Another deterrence position in nuclear strategy is that nuclear proliferation can be desirable. This view argues that, unlike conventional weapons, nuclear weapons successfully deter all-out war between states, and they succeeded in doing this during the Cold War between the U.S. and the Soviet Union. In the late 1950s and early 1960s, Gen. Pierre Marie Gallois of France, an adviser to Charles DeGaulle, argued in books like *The Balance of Terror: Strategy for the Nuclear Age* (1961) that mere possession of a nuclear arsenal, what the French called the *force de frappe*, was enough to ensure deterrence, and thus concluded that the spread of nuclear weapons could increase international stability. Some very prominent neo-realist scholars, such as the late Kenneth Waltz, formerly a Political Science at UC Berkeley and Adjunct Senior Research Scholar at Columbia University, and John Mearsheimer of University of Chicago, have also argued along the lines of Gallois. Specifically, these scholars have advocated some forms of nuclear proliferation, arguing that it would decrease the likelihood of total war, especially in troubled regions of the world where there exists a unipolar nuclear weapon state. Aside from the public opinion that opposes proliferation in any form, there are two schools of thought on the matter: those, like Mearsheimer, who favor selective proliferation, and those of Kenneth Waltz, who was somewhat more non-interventionist.

The threat of potentially suicidal terrorists possessing nuclear weapons (a form of nuclear terrorism) complicates the decision process. The prospect of mutually assured destruction may not deter an enemy who expects to die in the confrontation. Further, if the initial act is from a stateless terrorist instead of a sovereign nation, there is no fixed nation or fixed military targets to retaliate against. It has been argued by the New York Times, especially after the September 11, 2001 attacks, that this complication is the sign of the next age of nuclear strategy, distinct from the relative stability of the Cold War. In 1996, the United States adopted a policy of allowing the targeting of its nuclear weapons at terrorists armed with weapons of mass destruction.

Robert Gallucci, president of the John D. and Catherine T. MacArthur Foundation, argues that although traditional deterrence is not an effective approach toward terrorist groups bent on causing a nuclear catastrophe, Gallucci believes that “the United States should instead consider a policy of expanded deterrence, which focuses not solely on the would-be nuclear terrorists but on those states that may deliberately transfer or inadvertently lead nuclear weapons and materials to them. By threatening retaliation against those states, the United States may be able to deter that which it cannot physically prevent.”

Graham Allison makes a similar case, arguing that the key to expanded deterrence is coming up with ways of tracing nuclear material to the country that forged the fissile material. “After a nuclear bomb detonates, nuclear forensics cops would collect debris samples and send them to a laboratory for radiological analysis. By identifying unique attributes of the fissile material, including its impurities and contaminants, one could trace the path back to its origin.” The process is analogous to identifying a criminal by fingerprints. “The goal would be twofold: first, to deter leaders of nuclear states from selling weapons to terrorists by holding them accountable for any use of their own weapons; second, to give leader every incentive to tightly secure their nuclear weapons and materials.”

**Governance, control, and law**

Main articles: Nuclear Non-Proliferation Treaty, Strategic Arms Limitation Talks, Intermediate-Range Nuclear Forces Treaty, START I, Strategic Offensive Reductions Treaty, Comprehensive Nuclear-Test-Ban Treaty and New START



The International Atomic Energy Agency was created in 1957 to encourage peaceful development of nuclear technology while providing international safeguards against nuclear proliferation.

Because of the immense military power they can confer, the political control of nuclear weapons has been a key issue for as long as they have existed; in most countries the use of nuclear force can only be authorized by the head of government or head of state. Controls and regulations governing nuclear weapons are man-made, and so are imperfect. Therefore there is an inherent danger of "accidents, mistakes, false alarms, blackmail, theft, and sabotage".

In the late 1940s, lack of mutual trust was preventing the United States and the Soviet Union from making ground towards international arms control agreements. The Russell–Einstein Manifesto was issued in London on July 9, 1955 by Bertrand Russell in the midst of the Cold War. It highlighted the dangers posed by nuclear weapons and called for world leaders to seek peaceful resolutions to international conflict. The signatories included eleven pre-eminent intellectuals and scientists, including Albert Einstein, who signed it just days before his death on April 18, 1955. A few days after the release, philanthropist Cyrus S. Eaton offered to sponsor a conference—called for in the manifesto—in Pugwash, Nova Scotia, Eaton's birthplace. This conference was to be the first of the Pugwash Conferences on Science and World Affairs, held in July 1957.

By the 1960s steps were being taken to limit both the proliferation of nuclear weapons to other countries and the environmental effects of nuclear testing. The Partial Test Ban Treaty (1963) restricted all nuclear testing to underground nuclear testing, to prevent contamination from nuclear fallout, whereas the Nuclear Non-Proliferation Treaty (1968) attempted to place restrictions on the types of activities signatories could participate in, with the goal of allowing the transference of non-military nuclear technology to member countries without fear of proliferation.

In 1957, the International Atomic Energy Agency (IAEA) was established under the mandate of the United Nations to encourage development of peaceful applications for nuclear technology, provide international safeguards against its misuse, and facilitate the application of safety measures in its use. In 1996, many nations signed the Comprehensive Test Ban Treaty, which prohibits all testing of nuclear weapons. A testing ban imposes a significant hindrance to nuclear arms development by any complying country. The Treaty requires the ratification by 44 specific states before it can go into force; as of 2012, the ratification of eight of these states is still required.

Additional treaties and agreements have governed nuclear weapons stockpiles between the countries with the two largest stockpiles, the United States and the Soviet Union, and later between the United States and Russia. These include treaties such as SALT II (never ratified), START I (expired), INF, START II (never ratified), SORT, and New START, as well as non-binding agreements such as SALT I and the Presidential Nuclear Initiatives of 1991. Even when they did not enter into force, these agreements helped limit and later reduce the numbers and types of nuclear weapons between the United States and the Soviet Union/Russia.

Nuclear weapons have also been opposed by agreements between countries. Many nations have been declared Nuclear-Weapon-Free Zones, areas where nuclear weapons production and deployment are prohibited, through the use of treaties. The Treaty of Tlatelolco (1967) prohibited any production or deployment of nuclear weapons in Latin America and the Caribbean, and the Treaty of Pelindaba (1964) prohibits nuclear weapons in many African countries. As recently as 2006 a Central Asian Nuclear Weapon Free Zone was established amongst the former Soviet republics of Central Asia prohibiting nuclear weapons.

In the middle of 1996, the International Court of Justice, the highest court of the United Nations, issued an Advisory Opinion concerned with the "Legality of the Threat or Use of Nuclear Weapons". The court ruled that the use or threat of use of nuclear weapons would violate various articles of international law, including the Geneva Conventions, the Hague Conventions, the UN Charter, and the Universal Declaration of Human Rights. In view of the unique, destructive characteristics of nuclear weapons, the International Committee of the Red Cross calls on States to ensure that these weapons are never used, irrespective of whether they consider them lawful or not.

Additionally, there have been other, specific actions meant to discourage countries from developing nuclear arms. In the wake of the tests by India and Pakistan in 1998, economic sanctions were (temporarily) levied against both countries, though neither were signatories with the Nuclear Non-Proliferation Treaty. One of the stated *casus belli* for the initiation of the 2003 Iraq War was an accusation by the United States that Iraq was actively pursuing nuclear arms (though this was soon discovered not to be the case as the program had been discontinued). In 1981, Israel had bombed a nuclear reactor being constructed in Osirak, Iraq, in what it called an attempt to halt Iraq's previous nuclear arms ambitions; in 2007, Israel bombed another reactor being constructed in Syria.

In 2013, Mark Diesendorf says that governments of France, India, North Korea, Pakistan, UK, and South Africa have used nuclear power and/or research reactors to assist nuclear weapons development or to contribute to their supplies of nuclear explosives from military reactors.

**Disarmament**

Main article: Nuclear disarmament

*See also: Nuclear Tipping Point*



The USSR and USA nuclear weapon stockpiles throughout the Cold War until 2005, with a precipitous drop in total numbers following the end of the Cold War in 1991.

Nuclear disarmament refers to both the act of reducing or eliminating nuclear weapons and to the end state of a nuclear-free world, in which nuclear weapons are completely eliminated.

Beginning with the 1963 Partial Test Ban Treaty and continuing through the 1996 Comprehensive Test Ban Treaty, there have been many treaties to limit or reduce nuclear weapons testing and stockpiles. The 1968 Nuclear Non-Proliferation Treaty has as one of its explicit conditions that all signatories must "pursue negotiations in good faith" towards the long-term goal of "complete disarmament". The nuclear weapon states have largely treated that aspect of the agreement as "decorative" and without force.

Only one country—South Africa—has ever fully renounced nuclear weapons they had independently developed. The former Soviet republics of Belarus, Kazakhstan, and Ukraine returned Soviet nuclear arms stationed in their countries to Russia after the collapse of the USSR.

Proponents of nuclear disarmament say that it would lessen the probability of nuclear war occurring, especially accidentally. Critics of nuclear disarmament say that it would undermine the present nuclear peace and deterrence and would lead to increased global instability. Various American elder statesmen, who were in office during the Cold War period, have been advocating the elimination of nuclear weapons. These officials include Henry Kissinger, George Shultz, Sam Nunn, and William Perry. In January 2010, Lawrence M. Krauss stated that "no issue carries more importance to the long-term health and security of humanity than the effort to reduce, and perhaps one day, rid the world of nuclear weapons".



Ukrainian workers use equipment provided by the U.S. Defense Threat Reduction Agency to dismantle a Soviet-era missile silo. After the end of the Cold War, Ukraine and the other non-Russian, post-Soviet republics relinquished Soviet nuclear stockpiles to Russia.

In the years after the end of the Cold War, there have been numerous campaigns to urge the abolition of nuclear weapons, such as that organized by the Global Zero movement, and the goal of a "world without nuclear weapons" was advocated by United States President Barack Obama in an April 2009 speech in Prague. A CNN poll from April 2010 indicated that the American public was nearly evenly split on the issue.

Some analysts have argued that nuclear weapons have made the world relatively safer, with peace through deterrence and through the stability–instability paradox, including in south Asia. Kenneth Waltz has argued that nuclear weapons have helped keep an uneasy peace, and further nuclear weapon proliferation might even help avoid the large scale conventional wars that were so common prior to their invention at the end of World War II. But former Secretary Henry Kissinger says there is a new danger, which cannot be addressed by deterrence: "The classical notion of deterrence was that there was some consequences before which aggressors and evildoers would recoil. In a world of suicide bombers, that calculation doesn’t operate in any comparable way". George Shultz has said, "If you think of the people who are doing suicide attacks, and people like that get a nuclear weapon, they are almost by definition not deterrable".

**United Nations**

Main article: United Nations Office for Disarmament Affairs

The UN Office for Disarmament Affairs (UNODA) is a department of the United Nations Secretariat established in January 1998 as part of the United Nations Secretary-General Kofi Annan's plan to reform the UN as presented in his report to the General Assembly in July 1997.

Its goal is to promote nuclear disarmament and non-proliferation and the strengthening of the disarmament regimes in respect to other weapons of mass destruction, chemical and biological weapons. It also promotes disarmament efforts in the area of conventional weapons, especially land mines and small arms, which are often the weapons of choice in contemporary conflicts.

**Controversy**

**Ethics**

Even before the first nuclear weapons had been developed, scientists involved with the Manhattan Project were divided over the use of the weapon. The role of the two atomic bombings of the country in Japan's surrender and the U.S.'s ethical justification for them has been the subject of scholarly and popular debate for decades. The question of whether nations should have nuclear weapons, or test them, has been continually and nearly universally controversial.

**Notable nuclear weapons accidents**

*See also: United States military nuclear incident terminology*

* February 13, 1950: a Convair B-36B crashed in northern British Columbia after jettisoning a Mark IV atomic bomb. This was the first such nuclear weapon loss in history.
* June 7, 1960: the 1960 Fort Dix IM-99 accident destroyed a Boeing CIM-10 Bomarc nuclear missile and shelter and contaminated the BOMARC Missile Accident Site in New Jersey.
* January 24, 1961: the 1961 Goldsboro B-52 crash occurred near Goldsboro, North Carolina. A B-52 Stratofortress carrying two Mark 39 nuclear bombs broke up in mid-air, dropping its nuclear payload in the process.
* 1965 Philippine Sea A-4 crash, where a Skyhawk attack aircraft with a nuclear weapon fell into the sea. The pilot, the aircraft, and the B43 nuclear bomb were never recovered. It was not until 1989 that the Pentagon revealed the loss of the one-megaton bomb.
* January 17, 1966: the 1966 Palomares B-52 crash occurred when a B-52G bomber of the USAF collided with a KC-135 tanker during mid-air refueling off the coast of Spain. The KC-135 was completely destroyed when its fuel load ignited, killing all four crew members. The B-52G broke apart, killing three of the seven crew members aboard. Of the four Mk28 type hydrogen bombs the B-52G carried, three were found on land near Almería, Spain. The non-nuclear explosives in two of the weapons detonated upon impact with the ground, resulting in the contamination of a 2-square-kilometer (490-acre) (0.78 square mile) area by radioactive plutonium. The fourth, which fell into the Mediterranean Sea, was recovered intact after a 2½-month-long search.
* January 21, 1968: the 1968 Thule Air Base B-52 crash involved a United States Air Force (USAF) B-52 bomber. The aircraft was carrying four hydrogen bombs when a cabin fire forced the crew to abandon the aircraft. Six crew members ejected safely, but one who did not have an ejection seat was killed while trying to bail out. The bomber crashed onto sea ice in Greenland, causing the nuclear payload to rupture and disperse, which resulted in widespread radioactive contamination.

**Nuclear testing and fallout**

Main article: Nuclear fallout



Over 2,000 nuclear tests have been conducted, in over a dozen different sites around the world. Red Russia/Soviet Union, blue France, light blue United States, violet Britain, black Israel, orange China, yellow India, brown Pakistan, green North Korea and light green (territories exposed to nuclear bombs)



This view of downtown Las Vegas shows a mushroom cloud in the background. Scenes such as this were typical during the 1950s. From 1951 to 1962 the government conducted 100 atmospheric tests at the nearby Nevada Test Site.

Over 500 atmospheric nuclear weapons tests were conducted at various sites around the world from 1945 to 1980. Radioactive fallout from nuclear weapons testing was first drawn to public attention in 1954 when the Castle Bravo hydrogen bomb test at the Pacific Proving Grounds contaminated the crew and catch of the Japanese fishing boat *Lucky Dragon*. One of the fishermen died in Japan seven months later, and the fear of contaminated tuna led to a temporary boycotting of the popular staple in Japan. The incident caused widespread concern around the world, especially regarding the effects of nuclear fallout and atmospheric nuclear testing, and "provided a decisive impetus for the emergence of the anti-nuclear weapons movement in many countries".

As public awareness and concern mounted over the possible health hazards associated with exposure to the nuclear fallout, various studies were done to assess the extent of the hazard. A Centers for Disease Control and Prevention/ National Cancer Institute study claims that fallout from atmospheric nuclear tests would lead to perhaps 11,000 excess deaths amongst people alive during atmospheric testing in the United States from all forms of cancer, including leukemia, from 1951 to well into the 21st century. As of March 2009, the U.S. is the only nation that compensates nuclear test victims. Since the Radiation Exposure Compensation Act of 1990, more than $1.38 billion in compensation has been approved. The money is going to people who took part in the tests, notably at the Nevada Test Site, and to others exposed to the radiation.

**Public opposition**



Women Strike for Peace during the Cuban Missile Crisis



Demonstration against nuclear testing in Lyon, France, in the 1980s.

Peace movements emerged in Japan and in 1954 they converged to form a unified "Japanese Council Against Atomic and Hydrogen Bombs". Japanese opposition to nuclear weapons tests in the Pacific Ocean was widespread, and "an estimated 35 million signatures were collected on petitions calling for bans on nuclear weapons".

In the United Kingdom, the first Aldermaston March organized by the Campaign for Nuclear Disarmament(CND) took place at Easter 1958, when, according to the CND, several thousand people marched for four days from Trafalgar Square, London, to the Atomic Weapons Research Establishment close to Aldermaston in Berkshire, England, to demonstrate their opposition to nuclear weapons. The Aldermaston marches continued into the late 1960s when tens of thousands of people took part in the four-day marches.

In 1959, a letter in the *Bulletin of Atomic Scientists* was the start of a successful campaign to stop the Atomic Energy Commission dumping radioactive wastein the sea 19 kilometers from Boston. In 1962, Linus Pauling won the Nobel Peace Prize for his work to stop the atmospheric testing of nuclear weapons, and the "Ban the Bomb" movement spread.

In 1963, many countries ratified the Partial Test Ban Treaty prohibiting atmospheric nuclear testing. Radioactive fallout became less of an issue and the anti-nuclear weapons movement went into decline for some years. A resurgence of interest occurred amid European and American fears of nuclear war in the 1980s.

**Costs and technology spin-offs**

According to an audit by the Brookings Institution, between 1940 and 1996, the U.S. spent $8.78 trillion in present-day terms on nuclear weapons programs. 57 percent of which was spent on building nuclear weapons delivery systems. 6.3 percent of the total, $551 billion in present-day terms, was spent on environmental remediation and nuclear waste management, for example cleaning up the Hanford site, and 7 percent of the total, $617 billion was spent on making nuclear weapons themselves.

**Non-weapons uses**

Main article: Peaceful nuclear explosions

**Civil engineering and energy production**

*See also: Athabasca oil sands § Project oilsand and Project Gnome*



The 1962 Sedan nuclear test formed a crater 100 m (330 ft) deep with a diameter of about 390 m (1,300 ft), as a means of investigating the possibilities of using peaceful nuclear explosions for large-scale earth moving. If this test was conducted in 1965+, when improvements in device design were realized, a "100-fold" reduction in radiation release was considered feasible. The 140 kiloton Soviet Chagan (nuclear test), comparable in yield to the Sedan test of 104 kt, formed Lake Chagan, reportedly used as a watering hole for cattle and human swimming.

Apart from their use as weapons, nuclear explosives have been tested and used, in a similar manner to chemical high explosives, for various non-military uses. These have included large-scale earth moving, isotope production and the stimulation and the closing-off of the flow of natural gas.

At the peak of the Atomic Age, the United States initiated Operation Plowshare, involving "peaceful nuclear explosions". The United States Atomic Energy Commission chairman announced that the Plowshares project was intended to "highlight the peaceful applications of nuclear explosive devices and thereby create a climate of world opinion that is more favorable to weapons development and tests". The Operation Plowshare program included 27 nuclear tests designed towards investigating these non-weapons uses from 1961 through 1973. Due to the inability of the U.S. physicists to reduce the fission fraction of small, approximately 1 kiloton, yield nuclear devices that would have been required for many civil engineering projects, when long term health and clean-up costs from fission products were included in the cost, there was virtually no economic advantage over conventional explosives, except for potentially the very largest of projects.



Map of all proposed routes for a tunnel and/or canal route from the Mediterranean Sea to the Qattara Depression.
No route was shorter than 55 kilometers in length. Canal-cutting investigations began with the buggy salvo shot of Operation Crosstie in 1967.

The Qattara Depression Project, as developed by Professor Friedrich Bassler, who during his appointment to the West German ministry of economics in 1968, put forth a plan to create a Saharan lake and hydroelectric power station by blasting a tunnel between the Mediterranean sea and the Qattara Depression in Egypt, an area that lies below sea level. The core problem of the entire project was the water supply to the depression. Calculations by Bassler showed that digging a canal or tunnel would be too expensive, therefore Bassler determined that the use of nuclear explosive devices, to excavate the canal or tunnel, would be the most economical. The Egyptian government declined to pursue the idea.

The Soviet Union conducted a much more exhaustive program than Plowshare, with 239 nuclear tests, between 1965 and 1988. Furthermore, many of the "tests" were considered economic applications, not tests, in the Nuclear Explosions for the National Economy program.

These included one 30 kiloton explosion being used to close the Uzbekistani *Urtabulak* gas well in 1966 that had been blowing since 1963, and a few months later a 47 kiloton explosive was used to seal a higher pressure blowout at the nearby *Pamuk* gas field

The public records for devices that produced the highest proportion of their yield via fusion-only reactions are possibly the Taiga Soviet peaceful nuclear explosions of the 1970s, with 98% of their 15 kiloton explosive yield being derived from fusion reactions, a total fission fraction of 0.3 kilotons in a 15 kt device.

The repeated detonation of nuclear devices underground in salt domes, in a somewhat analogous manner to the explosions that power a car internal combustion engine(in that it would be a heat engine) has also been proposed as a means of fusion power, in what is termed PACER. Other investigated uses for peaceful nuclear explosions were underground detonations to stimulate, by a process analogous to fracking, the flow of petroleum and natural gas in tight formations, this was most developed in the Soviet Union, with an increase in the production of many well heads being reported.

**Physics**



The element einsteinium was first discovered, in minute quantities, following the analysis of the fallout from the first thermonuclear atmospheric test.

The discovery and synthesis of new chemical elements by nuclear transmutation, and their production in the necessary quantities to allow the studying of their properties, was carried out in nuclear explosive device testing. For example, the discovery of the short lived einsteinium and fermium, both created under the intense neutron flux environment within thermonuclear explosions, followed the first Teller-Ulam thermonuclear device test – Ivy Mike. The rapid capture of so many neutrons required in the synthesis of einsteinium would provide the needed direct experimental confirmation of the so-called r-process, the multiple neutron absorptions needed to explain the cosmic nucleosynthesis (production) of all heavy chemical elements heavier than nickel on the periodic table, in supernova explosions, before beta decay, with the r-process explaining the existence of many stable elements in the universe.

The worldwide presence of new isotopes from atmospheric testing beginning in the 1950s led to the 2008 development of a reliable way to detect art forgeries. Paintings created after that period may contain traces of caesium-137 and strontium-90, isotopes that did not exist in nature before 1945. (Fission products were produced in the natural nuclear fission reactor at Oklo about 1.7 billion years ago, but these decayed away before the earliest known human painting.)

Both climatology and particularly aerosol science, a subfield of atmospheric science, were largely created to answer the question of how far and wide fallout would travel. Similar to radioactive tracers used in hydrology and materials testing, fallout and the neutron activation of nitrogen gas served as a radioactive tracer that was used to measure and then help model global circulations in the atmosphere by following the movements of fallout aerosols.

After the Van Allen Belts surrounding Earth were published about in 1958, James Van Allen suggested that a nuclear detonation would be one way of probing the magnetic phenomenon, data obtained from the August 1958 Project Argus test shots, a high altitude nuclear explosion investigation, were vital to the early understanding of Earth's magnetosphere.



An artist's conception of the NASA reference design for the Project Orion spacecraft powered by nuclear pulse propulsion.

Soviet nuclear physicist and Nobel peace prize recipient Andrei Sakharov also proposed the idea that earthquakes could be mitigated and particle accelerators could be made by utilizing nuclear explosions, with the latter created by connecting a nuclear explosive device with another of his inventions, the explosively pumped flux compression generator, to accelerate protons to collide with each other to probe their inner workings, an endeavor that is now done at much lower energy levels with non-explosive superconducting magnets in CERN. Sakharov suggested to replace the copper coil in his MK generators by a big superconductor solenoid to magnetically compress and focus underground nuclear explosions into a shaped charge effect. He theorized this could focus 1023 positively charged protons per second on a 1 mm2 surface, then envisaged making two such beams collide in the form of a supercollider.

Underground nuclear explosive data from peaceful nuclear explosion test shots have been used to investigate the composition of Earth's mantle, analogous to the exploration geophysics practice of mineral prospecting with chemical explosives in "deep seismic sounding" reflection seismology.

Project A119, proposed in the 1960s, which as Apollo scientist Gary Latham explained, would have been the detonating of a "smallish" nuclear device on the Moon in order to facilitate research into its geologic make-up. Analogous in concept to the comparatively low yield explosion created by the water prospecting (LCROSS)Lunar Crater Observation and Sensing Satellite mission, which launched in 2009 and released the "Centaur" kinetic energy impactor, an impactor with a mass of 2,305 kg (5,081 lb), and an impact velocity of about 9,000 km/h (5,600 mph), releasing the kinetic energy equivalent of detonating approximately 2 tons of TNT (8.86 GJ).



A nuclear shaped charge design that was to provide nuclear pulse propulsion to the Project Orion vehicle.

**Propulsion use**

Main article: Nuclear pulse propulsion

Although likely never achieving orbit due to aerodynamic drag, the first macroscopic object to obtain Earth orbital velocity was a "manhole cover" propelled by the detonation of test shot Pascal-B, before sputnik obtained orbital velocity, and also successfully became the first satellite, in October 1957. The use of a subterranean shaft and nuclear device to propel an object to escape velocity has since been termed a "thunder well".

The direct use of nuclear explosives, by using the impact of propellant plasma from a nuclear shaped charge acting on a pusher plate, has also been seriously studied as a potential propulsion mechanism for space travel (see Project Orion).

Edward Teller, in the United States, proposed the use of a nuclear detonation to power an explosively pumped *soft* X-ray laser as a component of a ballistic missile defense shield, this would destroy missile components by transferring momentum to the vehicles surface by laser ablation. This ablation process is one of the damage mechanisms of a laser weapon, but it is also the basis of pulsed laser propulsion for spacecraft.

Ground flight testing by Professor Leik Myrabo, using a non-nuclear, conventionally powered pulsed laser test-bed, successfully lifted a light craft 72 meters in altitude by a method similar to ablative laser propulsion in 2000.

A powerful solar system based *soft* X-ray, to ultraviolet, laser system has been calculated to be capable of propelling an interstellar spacecraft, by the light sail principle, to 11% of the speed of light. In 1972 it was also calculated that a 1 Terawatt, 1-km diameter x-ray laser with 1 angstrom wavelength impinging on a 1-km diameter sail, could propel a spacecraft to Alpha Centauri in 10 years.



Artist's impression of the impact event that resulted in the Cretaceous–Paleogene extinction event, which killed the Dinosaurs some 65 million years ago. A natural impact with an explosive yield of 100 tera tons of TNT (4.2×1023 J). The most powerful man-made explosion, the Tsar Bomba, by comparison had a yield almost 2 million times smaller – 57 megatons of TNT (2.4×1017 J). The 1994 Comet Shoemaker–Levy 9 impacts on planet Jupiter, the Tunguska and Chelyabinsk asteroid–Earth collisions of 1908 and 2013 respectively, have served as an impetus for the analysis of technologies that could prevent the destruction of human life by impact events.

**Asteroid impact avoidance**

Main article: Asteroid impact avoidance

A proposed means of averting an asteroid impacting with Earth, assuming low lead times between detection and Earth impact, is to detonate one, or a series, of nuclear explosive devices, on, in, or in a stand-off proximity orientation with the asteroid, with the latter method occurring far enough away from the incoming threat to prevent the potential fracturing of the near-Earth object, but still close enough to generate a high thrust laser ablation effect.

A 2007 NASA analysis of impact avoidance strategies using various technologies stated:

Nuclear stand-off explosions are assessed to be 10–100 times more effective than the non-nuclear alternatives analyzed in this study. Other techniques involving the surface or subsurface use of nuclear explosives may be more efficient, but they run an increased risk of fracturing the target near-Earth object. They also carry higher development and operations risks.

Analysis of the uncertainty involved in nuclear device asteroid deflection shows that the ability to protect the planet does not imply the ability to also target the planet, which is the case with all non-nuclear alternatives, such as the controversial gravity tractor technology. A nuclear explosion that changed an asteroid's velocity by 10 m/s (±20%) would be adequate to push it out of an Earth-impacting orbit. However, if the uncertainty of the velocity change is more than a few plus or minus percent, there would be no chance of directing the asteroid to a particular target.

However, if the need arises to use nuclear explosive devices to prevent an asteroid impact event, it may face the legal issue that the United Nations Committee on the Peaceful Uses of Outer Space and the 1996 Comprehensive Nuclear-Test-Ban Treaty ban nuclear weapons in space.