**Nuclear Weapon Yield**

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| **Nuclear weapons** |
| One of the first nuclear bombs. |  |
| History of nuclear weapons |
| Nuclear warfare |
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| Weapon design / testing |
| Nuclear explosion |
| Delivery systems |
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| Proliferation |
| **Countries** |  |
| Nuclear weapons statesUS · Russia · UK · FranceChina · India · PakistanIsrael · North Korea |

The explosive yield of a nuclear weapon is the amount of energy discharged when the weapon is detonated, expressed usually in the equivalent mass of trinitrotoluene (TNT), either in kilotons (thousands of tons of TNT) or megatons (millions of tons of TNT), but sometimes also in terajoules (1 kiloton of TNT = 4.184 TJ). Because the precise amount of energy released by TNT is and was subject to measurement uncertainties, especially at the dawn of the nuclear age, the accepted convention is that one kt of TNT is simply defined to be 1012 calories equivalent, this being very roughly equal to the energy yield of one thousand tons of TNT.

**Examples of nuclear weapon yields**



Comparative fireball diameters for a selection of nuclear weapons. Note that full blast effects would extend many times beyond the fireball itself.

In order of increasing yield (most yield figures are approximate):

* Davy Crockett tactical nuclear weapon: variable yield 0.01–1 kt — mass only 23 kg (51 lb), lightest ever deployed by the United States (same warhead as Special Atomic Demolition Munition and GAR-11 Nuclear Falcon missile).
* Hiroshima's "Little Boy" gravity bomb: 12–15 kt — gun type uranium-235 fission bomb (the first of the two nuclear weapons that have been used in warfare).
* Nagasaki's "Fat Man" gravity bomb: 20–22 kt — implosion type plutonium-239 fission bomb (the second of the two nuclear weapons used in warfare).
* W-76 warhead 100 kt (10 of these may be in a MIRVed Trident II missile).
* B61 nuclear bomb: Mod 7 (up to 350 kt), Mod 10 (4 yield options: 0.3 kt, 1.5 kt, 60 kt, and 170 kt), and Mod 11 (undisclosed yield).
* W-87 warhead: 300 kt (10 of these were in a MIRVed LG-118A Peacekeeper).
* W-88 warhead: 475 kt (8 of these may be in a Trident II missile).
* *Ivy King* device: 500 kt — most powerful pure fission bomb; 60 kg uranium; implosion type.
* B83 nuclear bomb: variable, up to 1.2 Mt; most powerful US weapon in active service.
* B53 nuclear bomb: 9Mt, most powerful US warhead; no longer in active service, but 50 are retained as part of the "Hedge" portion of the Enduring Stockpile; similar to the W-53 warhead that has been used in the Titan II Missile, decommissioned in 1987.
* *Castle Bravo* device: 15 Mt — most powerful US test.
* EC17/Mk-17, the EC24/Mk-24, and the B41 (Mk-41) (most powerful US weapons ever: 25 Mt; the Mk-17 was also the largest by size and mass: ca. 20 tons; the Mk-41 had a mass of 4800 kg; gravity bombs carried by B-36 bomber (retired by 1957).
* The entire Operation Castle nuclear test series: 48.2 Mt — the highest-yielding test series conducted by the U.S.
* *Tsar Bomba* device: 50 Mt — USSR, most powerful explosive device ever, mass of 27 short tons (24 metric tons), in its "full" form (i.e. with a depleted uranium tamper instead of one made of lead) it would have been 100 Mt.
* All nuclear testing: 510.4 Mt — total megatonnage expended during all nuclear testing.

As a comparison, the Oklahoma City bombing, using a truck-based fertilizer bomb, was a mere 0.002 kt. Most artificial non-nuclear explosions are considerably smaller than even what are considered to be very small nuclear weapons.

**Yield limits**



Logarithmic scatterplot comparing the yield (in kilotons) and weight (in kilograms) of all nuclear weapons developed by the United States.

The yield-to-weight ratio is the amount of weapon yield compared to the mass of the weapon. The theoretical maximum yield-to-weight ratio for fusion weapons is 6 Megatons per metric ton (6 Mt/t). The practical achievable limit is somewhat lower. For current US weapons 600 kt/t (2.5 TJ/kg) to 2.2 Mt/t (9.2 TJ/kg). By comparison, for the Davy Crockett it was 0.4 - 40 kt/t (0.002 - 0.167 TJ/kg), for Little Boy 4 kt/t, and for the Tsar Bomba 2 Mt/t (8 TJ/kg) (deliberately reduced from the possible maximum which was twice as much), and for the Mk-41 5.2 Mt/t.

The largest pure-fission bomb ever constructed had a 500 kt yield, which is probably in the range of the upper limit on such designs. Fusion boosting could likely raise the efficiency of such a weapon significantly, but eventually all fission-based weapons have an upper yield due to the difficulties of dealing with large critical masses. However there is no known upper yield limit for a fusion (e.g., hydrogen) bomb. In principle a fusion bomb could be many thousand megatons. Because of the maximum theoretical yield-to-weight ratio is about 6Mt/t, and the maximum achievable ratio about 5.2 MT/t, there is a practical limit on air delivery of the weapon.

For example, if the full payload of 250 t of the Antonov An-225 could be used, the limit would be 250 t \* 5.2 Mt/t, or 1300 Mt. Likewise the maximum limit of a missile-delivered weapon is determined by the missile payload capacity. The large Russian SS-18 ICBM has a payload capacity of 7,200 kg, so the calculated maximum delivered yield would be 37.4 Mt. In fact the SS-18 mod 1 yield for a single warhead is about 24 Mt. In more recent practice, large single warheads are seldom used, since smaller MIRV warheads are more destructive for a given total yield or payload capacity.

**Milestone nuclear explosions**

The following list is of milestone nuclear explosions. In addition to the atomic bombings of Hiroshima and Nagasaki, the first nuclear test of a given weapon type for a country is included, and tests which were otherwise notable (such as the largest test ever). All yields (explosive power) are given in their estimated energy equivalents in kilotons of TNT (see megaton).

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| **Date** | **Name** | **Yield (kt)** | **Country** | **Significance** |
| Jul 16 1945 | ***Trinity*** | 19 | United StatesUSA | First fission weapon test |
| Aug 6 1945 | ***Little Boy*** | 15 | United StatesUSA | Bombing of Hiroshima, Japan |
| Aug 9 1945 | ***Fat Man*** | 21 | United StatesUSA | Bombing of Nagasaki, Japan |
| Aug 29 1949 | ***Joe 1*** | 22 | Union of Soviet Socialist RepublicsUSSR | First fission weapon test by the USSR |
| Oct 3 1952 | ***Hurricane*** | 25 | United KingdomUK | First fission weapon test by the UK |
| Nov 1 1952 | ***Ivy Mike*** | 10,200 | United StatesUSA | First "staged" thermonuclear weapon test (not deployable) |
| Aug 12 1953 | ***Joe 4*** | 400 | Union of Soviet Socialist RepublicsUSSR | First fusion weapon test by the USSR (not "staged", but deployable) |
| Mar 1 1954 | ***Castle Bravo*** | 15,000 | United StatesUSA | First deployable "staged" thermonuclear weapon; fallout accident |
| Nov 22 1955 | ***RDS-37*** | 1,600 | Union of Soviet Socialist RepublicsUSSR | First "staged" thermonuclear weapon test by the USSR (deployable) |
| Nov 8 1957 | ***Grapple X*** | 1,800 | United KingdomUK | First (successful) "staged" thermonuclear weapon test by the UK |
| Feb 13 1960 | ***Gerboise Bleue*** | 60 | FranceFrance | First fission weapon test by France |
| Oct 31 1961 | ***Tsar Bomba*** | 50,000 | Union of Soviet Socialist RepublicsUSSR | Largest thermonuclear weapon ever tested |
| Oct 16 1964 | ***596*** | 22 | People's Republic of ChinaChina | First fission weapon test by China |
| Jun 17 1967 | ***Test No. 6*** | 3,300 | People's Republic of ChinaChina | First "staged" thermonuclear weapon test by China |
| Aug 24 1968 | ***Canopus*** | 2,600 | FranceFrance | First "staged" thermonuclear test by France |
| May 18 1974 | ***Smiling Buddha*** | 12 | IndiaIndia | First fission nuclear explosive test by India |
| May 11 1998 | ***Shakti I*** | 43 | IndiaIndia | First potential fusion/boosted weapon test by India(exact yields disputed, between 25kt and 45kt) |
| May 13 1998 | ***Shakti II*** | 12 | IndiaIndia | First fission "weapon" test by India |
| May 28 1998 | ***Chagai-I*** | 9 | Islamic Republic Of PakistanPakistan | First fission weapon test by Pakistan |

"Deployable" refers to whether the device tested could be hypothetically used in actual combat (in contrast with a proof-of-concept device). "Staging" refers to whether it was a "true" hydrogen bomb of the so-called Teller-Ulam configuration or simply a form of a boosted fission weapon. For a more complete list of nuclear test series, see List of nuclear tests. Some exact yield estimates, such as that of the Tsar Bomba and the tests by India and Pakistan in 1998, are somewhat contested among specialists.

**Calculating yields and controversy**

Yields of nuclear explosions can be very hard to calculate, even using numbers as rough as in the kiloton or megaton range (much less down to the resolution of individual terajoules). Even under very controlled conditions, precise yields can be very hard to determine, and for less controlled conditions the margins of error can be quite large. Yields can be calculated in a number of ways, including calculations based on blast size, blast brightness, seismographic data, and the strength of the shock wave. Enrico Fermi famously made a (very) rough calculation of the yield of the Trinity test by dropping small pieces of paper in the air and measuring at how far they were moved by the shock wave of the explosion. Excellent approximations of yields can be approximated by the dimensionless number developed by G. I. Taylor. *G. I. Taylor, Proc. Roy. Soc. London A201, 175 (1950)* and *G. I. Taylor, Proc. Roy. Soc. London A201, 159 (1950)*:



Here, *E* is the energy (in joules for SI), *t* is the time (in seconds for SI), ρ is the density of air (kg/m³ for SI) and *R* is the blast radius (in m for SI). With *c* as a constant (for air ~1.033), all that is needed is a picture that shows the radius of the blast, a reference length scale, and the time since the blast to determine the energy. Using the picture of the Trinity test as an example, take the density of air to be 1 kg/m³, the radius as approximately 140 m, solving for *E*:



and substituting in, *E*=8.889e13 J. With 1 kiloton of TNT= 4.184e12 J the result is 21.24 kilotons of TNT, which agrees nicely with commonly stated value of 20 KT.

Where this data is not available, as in a number of cases, precise yields have been in dispute, especially when they are tied to questions of politics. The weapons used in the atomic bombings of Hiroshima and Nagasaki, for example, were highly individual and very idiosyncratic designs, and gauging their yield retrospectively has been quite difficult. The Hiroshima bomb, "Little Boy", is estimated to have been between 12 and 18 kt (a 20% margin of error), while the Nagasaki bomb, "Fat Man", is estimated to be between 18 and 23 kt (a 10% margin of error). Such apparently small changes in values can be important when trying to use the data from these bombings as reflective of how other bombs would behave in combat, and also result in differing assessments of how many "Hiroshima bombs" other weapons are equivalent to (for example, the Ivy Mike hydrogen bomb was equivalent to either 867 or 578 Hiroshima weapons — a rhetorically quite substantial difference — depending on whether one uses the high or low figure for the calculation). Other disputed yields have included the massive Tsar Bomba, whose yield was claimed between being "only" 50 Mt or at a maximum of 57 Mt by differing political figures, either as a way for hyping the power of the bomb or as an attempt to undercut it.

Nuclear testing yields, as in the Tsar Bomba example, can also be used as a way of reflecting upon technical expertise, and claiming higher yields or accusations of lower yields can be used as a way of promoting or disparaging the technical abilities of a nuclear program. When India claimed to have successfully detonated a hydrogen bomb in their 1998 Operation Shakti tests, many Western observers relied on analysis of seismographic data to determine whether the Indian tests reflected a successful hydrogen bomb detonation. Some have alleged that India's reported yields have been higher than their actual test yields, a move which would apparently be for political purposes (to claim more nuclear ability than their rival Pakistan, for example, or to demonstrate their military might to other potential rivals such as nearby China) if true.