What Are A-Bombs vs. Thermonuclear Weapons?

by Charles B. Stevens

To understand the implications of the imminent threat of near-total extinction of civilization from a thermonuclear world war, the following comparison is highly instructive.

Dec. 3—The first two nuclear weapons were dropped on the Japanese cities of Hiroshima and Nagasaki in August 1945, killing over 200,000 people. These were fission weapons, also known as atomic, or A-bombs, which utilize the principle of the chain-reaction fission of the heavy elements uranium or plutonium.

The Hiroshima bomb used the fissile isotope uranium-235, which makes up only 7 of every 1,000 atoms of uranium found in the Earth. In order to be effective in a bomb, the percentage of the U-235 isotope must be increased (enriched) to about 800 to 900 parts per 1,000, and then converted into metallic form, a difficult and very dangerous process.

The other bomb dropped on Japan used plutonium as the fissile material. Plutonium does not occur naturally, and can only be produced as a byproduct of nuclear fission in a specially designed reactor. The first example was produced at Hanford, Wash., as part of the World War II Manhattan Project.

The two atomic bombs each produced an explosive energy (heat and blast) about equal to 20 kilotons (20,000 tons) of TNT chemical explosive. Only a small fraction of their actual nuclear fuel was "burned up" by the fission reaction.

By the early 1950s, both the United States and the Soviet Union had also developed nuclear weapons based on the thermonuclear fusion of the isotopes of hydrogen, or H-bombs. Thermonuclear fusion is the same process that energizes the stars like our Sun. In principle, it can be unlimited in scale, and generates potentially far greater energy densities than can be achieved through nuclear fission.

In 1961, the Soviet Union exploded the Tsar Bomb with an output of 50 megatons (50 million tons) of TNT equivalent. But such a large device is militarily inefficient, because most of its energy is simply blown out into space. Most strategic warheads in the U.S. and Russian arsenals have an explosive yield of about 1 megaton, and weigh about 2,400 pounds.

The United Kingdom, France, the People's Republic of China, India, Pakistan, and North Korea have tested nuclear weapons. Israel is reported to have a large nuclear arsenal, but some experts dispute this, and report that Israel utilizes biological warheads in its arsenal of weapons of mass destruction.

How Nuclear Weapons Work

To achieve a nuclear fission explosion, one needs to assemble a critical mass of fissile material. This is minimally 52 kilograms (115 lbs.) in the case of uranium-235, and 10 kilograms (22 lbs.) in the case of plutonium-239. This is usually achieved by utilizing chemical explosives formed into a "lens" system, which implodes a hollow sphere of the appropriate critical mass.

The output of A-bombs can be significantly boosted by injecting a small quantity of fusion fuel into the hollow sphere. This usually consists of the two heavy isotopes of hydrogen, deuterium (D) and tritium (T). Although the heat from the nuclear fission explosion is not sufficient to fully ignite the D-T fusion fuel, some fusion reactions are generated. The D-T reaction output primarily consists of 14 MeV (million electron volt) neutrons. Even a small number of these fusion byproduct neutrons can greatly accelerate the nuclear fission chain reaction, and thereby increase the burn-up of the nuclear fissile fuel.

For example, what would only be a 1 kiloton output fission weapon can be boosted to 100 kilotons with a full D-T loading. It is possible to "dial" the yield to any level in between by simply changing the D-T loading. This is the basis of "dial-a-yield" tactical nuclear weapons.

Achieving a fully ignited fusion plasma is far more difficult. It took France nearly seven years to replicate what the U.S. and Russia had achieved. The key proved to be a scientific concept first developed by Max Planck in the early 20th Century, the hohlraum. A hohlraum (German for a hollow space or cavity) is simply a chamber, like a hollow cylinder, in which radiation (soft X-rays in this case) can be temporarily trapped.

In the Teller-Ulam configuration, an atom bomb is placed at one end of the hohlraum cylinder, and a sphere

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In 1961, the Soviet Union exploded the "Tsar Bomb" (shown here), based on the Teller-Ulam design, with an output of 50 megatons of TNT equivalent—the largest weapon ever detonated.

of fusion fuel is placed at the other end. Layers of material are placed between the two. The primary output of the atom bomb is high-energy (hard) X-rays. The in-between material absorbs these hard X-rays and emits low-energy (soft) x-rays.

The soft X-rays are trapped in the fusion fuel end of the hohlraum, and bathe the fuel sphere in soft x-rays. This causes the sphere surface to rapidly burn off, thereby imploding the remaining fusion fuel. After the fuel is compressed by the implosion process, the implosion shock will converge on the center and heat the fusion fuel to over 100,000,000°Celsius, thereby igniting D-T fusion in the core. This burning core will then propagate outwardly, burning up much of the remaining fusion fuel.

Most H-bombs utilized lithium deuteride. In this case, neutrons from the atom bomb interact with the lithium and generate the tritium fusion fuel.

Tactical Nuclear Weapons

A wide variety of tactical and special nuclear weapons has been developed. There have been over several thousand nuclear weapons tests since 1945. These range from small fission devices the size of a grapefruit for battlefield mortars, to large Reduced Residual Radiation Devices for excavation of tunnels and mountain passes.

The most famous of these tactical weapons is the neutron bomb. By reducing the fission component to a very low level in a small thermonuclear weapon, it is possible to have an output of mostly 14 MeV neutrons with a very small residual blast wave. The primary effect of the weapon is biological—killing everything that does not have three feet of dirt between it and the detonation point, over a radius of about 1 kilometer. This can give a huge offensive capability to a small number of troops.

For example, experts have said that a tank platoon armed with neutron bombs would have the battlefield fire power equivalent to 30,000 155-millimeter howitzers. Deployment of the neutron bomb to Europe in the mid-1980s went a long way toward convincing Soviet military planners that war was not an option that could be contemplated.

Both the U.S.A. and Russia possess many more atomic than thermonuclear weapons. Arms limitation treaties do not cover tactical battlefield weapons and cruise missile-launched nuclear devices with range below 300 miles. Such weapons may have yields in the 20- to 100-kiloton range (larger than the Hiroshima or Nagasaki bombs). There are far more of these smaller nuclear weapons than the strategic or intermediate-range type. Some experts suggest that Russia possesses ten times more tactical nuclear weapons than the U.S.A. For technical reasons, atomic weapons are far easier to maintain than either the thermonuclear or boosted devices containing both fission and fusion explosives.