Jewish Statesmanship College

המכללה למדינאות יהודית ולחשיבה אסטרטגית

Practical Aspects of Nuclear Threat

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This brochure is dedicated to the memory of two Jews:

Yaakov Socol *(1909-1990), my grandfather who taught me a lot, devoted his long life to the technological Progress that should make the Mankind happier. In 1941-1945 he was the director of Chelyabinsk Metallurgical Plant, USSR, being a part of global combat against the evil, endangering the Civilization at that time.*

Ido Zoldan *(1978-2007), my fellow Jew and neighbor whom I never met, devoted his short life to the Land of Israel. At the days this work was completed, he was killed by Arab terrorists in Samaria. He fell in combat against the evil, now endangering the Civilization.*

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"Civil defense – will not eliminate the danger of nuclear war. It will considerably diminish its probability."

Edward Teller, "Father" of the H-bomb

"When Hitler first bombed London the panic the bombs caused did far more damage than the bombs themselves. After the citizens of London lost their exaggerated fears of the bombings, life went on much as normal. And so it would be with a nuclear terrorist attack..."

Cresson H. Kearny, Civil Defense Consultant to the US Govement

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Despite the fact that nuclear weapons release unparalleled and horrifying destructive power in an instant of time, their effects are nevertheless limited. Much of the speculation in the public domain regarding the consequences of nuclear attack or war is exaggerated. A clear understanding of the effects of nuclear weapons is crucial for proper emergency resource-management, and indeed for national survival.

Basics and History

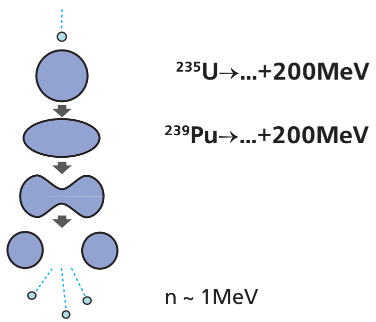
Nuclear weapons are divided into 2 classes, usually referred to as "atomic" and "hydrogen" (or "thermo-nuclear"). Nuclear weapon strength (or "yield") is measured in kilotons (thousands of tons of TNT explosive) or megatons (1Mt = 1000kt).

Nuclear Warheads

"Atomic"	**1–20 Kton**
Hiroshima	~15 Kton
destruction range	~1 km
"Hydrogen"	**100–1000 Kton**
H-bomb, fusion, thermo-nuclear	
destruction range	~3-5 km

The yield of atomic bombs is generally 1-20kt (Hiroshima – 15 kt). The destruction radius of a 20kt-bomb is approximately 1 km. Hydrogen bomb yield is generally 100-1000kt. The destruction radius of a 1Mt-bomb is ~3-5 km. High-yield multi-Mt devices (up to 50 Mt) were built and tested, but proved to be inefficient and are obsolete. The devastation caused by nuclear weapons is generally considered to be scalable as $(\text{yield})^{2/3}$ – i.e. a 1Mt device devastates an area 100 times greater than a 1kt device (the destruction range is 10-fold).

Nuclear Fission

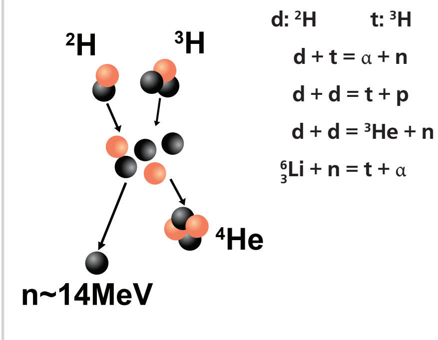


1 kg ~ 10^{14} J ~ $2\cdot10^{6}$ kg oil ~20 kt TNT

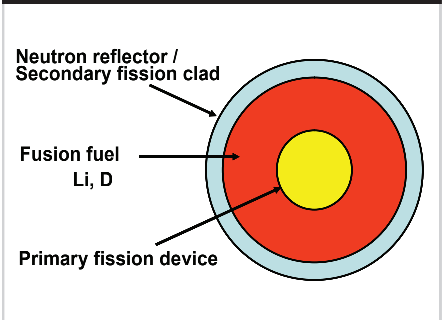
In an atomic bomb, energy is released due to the nuclear fission ("cracking") of Plutonium ^{239}Pu or Uranium ^{235}U[6]. 1kg of fissionable material produces energy equivalent to 20kt of TNT, assuming all the material reacts fully. However, unlike conventional explosives, the yield is not fully scalable: the chain reaction will only take place if the amount of fissionable material is above a certain minimal value referred to as "critical mass" (5-50kg design-dependent).

In a hydrogen bomb, the essential energy (~50%) is released due to the nuclear fusion ("melting together") of light isotopes (^{2}H, ^{3}H, ^{6}Li). Fusion – which is not a chain reaction and therefore does not require a critical mass – can only be initiated at very high temperatures and can be started ("ignited") by a fission ("atomic") device.

H-bomb
nuclear fusion



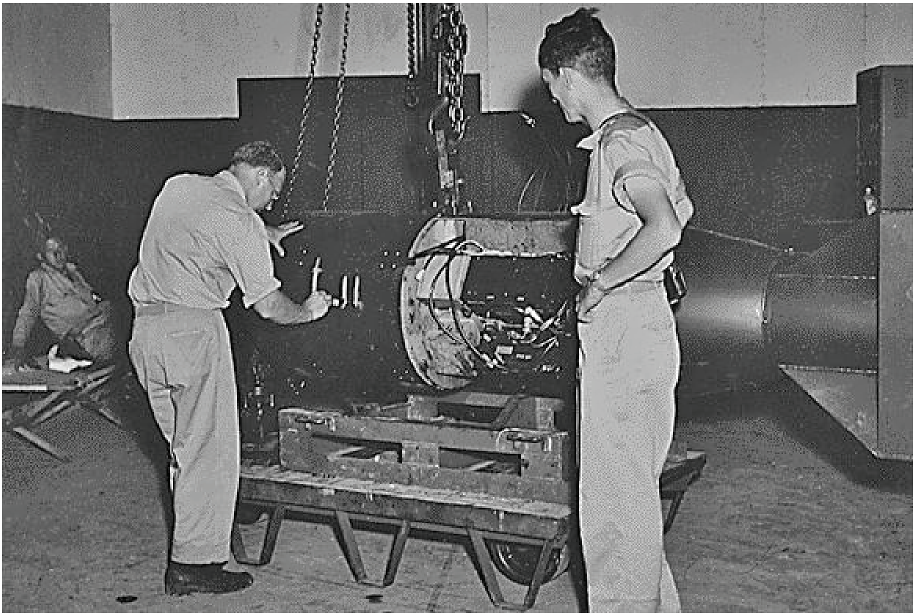
H-bomb
design: fission-fusion-fission



The first atomic bombs, detonated at Hiroshima (15kt) and Nagasaki (21kt), were several meters in length and weighed several tons. The first hydrogen bombs with multi-Mt yields were over 10m long and weighed over 15 tons. Modern nuclear warheads are much smaller and generally of lower yield.

As early as 1953, nuclear artillery shells (US "Atomic Annie") were tested: the 280-mm 365-kg shell had a 15kt yield. Later designs produced 155-mm field artillery shells (e.g. US 58-kg W48) which delivered a relatively low yield of ~0.1kt (i.e. 100 ton of TNT). Today superpower stockpiles of nuclear artillery shells have allegedly been disposed of, but the technological capability undoubtedly exists.

Modern thermonuclear warheads with a yield of ~500kt (e.g. US W87) weigh probably less than 500kg.



1945: "Little Boy" (Hiroshima)

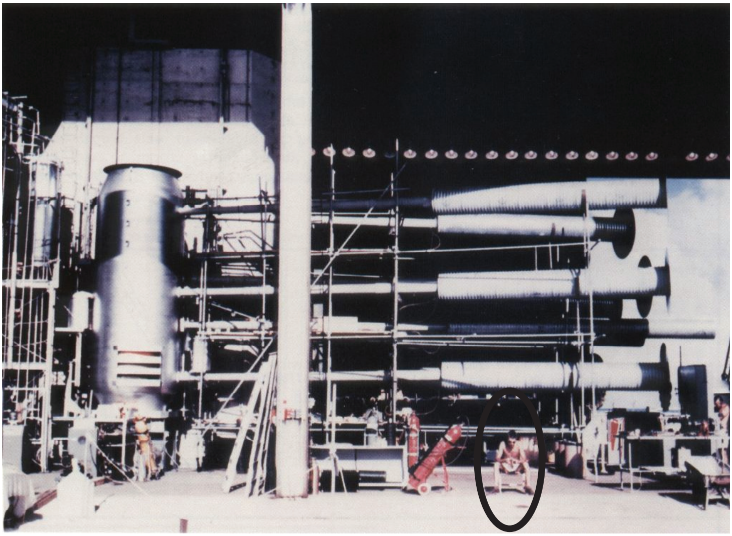
Diameter	710mm
Length	3m
Weight	4000kg
Yield	15kt

1953: "Atomic Annie"

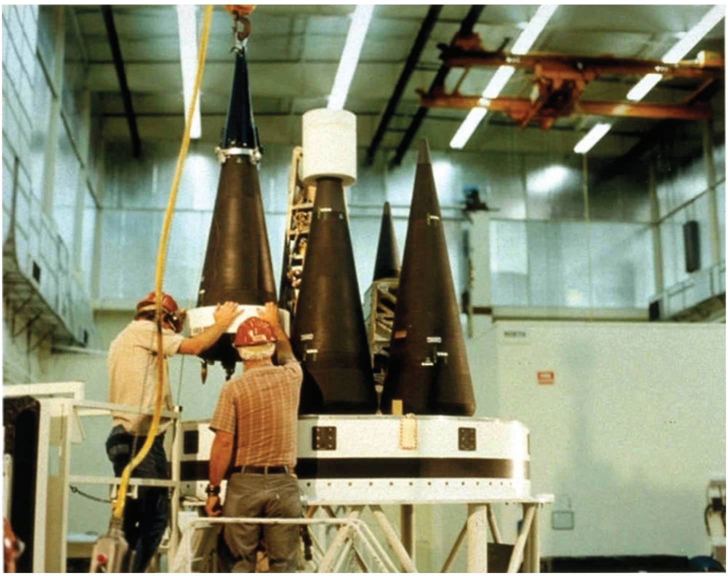
Diameter	280mm
Length	1.38m
Weight	365kg
Yield	15kt

1963: W48

Diameter	155mm
Length	0.85m
Weight	58kg
Yield	0.1kt



1–st Hydrogen bomb: "Sausage" device from the "Ivy Mike" nuclear test, 1952
The man's figure (for scale) is encircled



Hydrogen warheads: W87 on "Peacekeeper" strategic missile, 1983
Weight <500kg, Yield ~500kt

Nuclear weapons have been employed in battle only twice: 1) The bombing of Hiroshima (6th Aug.,1945, 15kt "Little Boy" device) claimed about 66,000 dead and 69,000 injured. 2) The Nagasaki bombing (9th Aug.,1945, 21kt "Fat Man") claimed about 39,000 dead and 25,000 injured. The number of people who died due to radiation following these attacks stands at about 1,200 (most of them within 15-20 years after the attack).

Nuclear Bombing

	Yield, kt	Dead	Injured
Hiroshima	15	66,000	69,000
Nagasaki	21	39,000	25,000

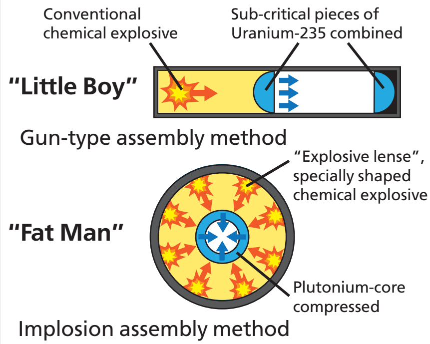
Hiroshima, aftermath

Nuclear proliferation and strategic considerations

In order to produce a nuclear device, a certain minimal quantity of nuclear material is required (critical mass). The two alternatives for such material are ^{235}U or ^{239}Pu. The respective technologies involved are very different.

^{235}U was used in the gun-type "Little Boy". Gun-type geometry is relatively very simple. Although considered today to be obsolete due to inherent safety problems, this technology is clearly feasible and is allegedly the focus of Iranian efforts. To obtain weapon-grade material ^{235}U must be enriched to nearly 100%. The percentage of ^{235}U in naturally occurring Uranium is only 0.7%, the total Uranium content of ore being 0.2%. I.e. in order to obtain 50kg of weapon-grade ^{235}U (critical mass under normal conditions), one must process 3.5kt of Uranium ore.

A-bomb designs



^{239}Pu, used in the implosion-type design ("Fat Man"), is not found in nature and is produced only in nuclear reactors. A 50MW (thermal power) nuclear reactor, optimized for Plutonium production, yields ~ 10kg ^{239}Pu per year – sufficient for one Nagasaki-sized device. For purposes of comparison, the Yongbyon reactor (N.Korea) is rated at 20-30MW, while the Bushehr reactor (Iran) at up to 1000MW. It is worth mentioning that ^{239}Pu is produced (in relatively smaller quantities)

Nuclear explosives

^{235}U	0.7% in natural U
$^{235}U + ^{238}U$	0.2% in Uranium ore
Critical mass	~50 kg ^{235}U
	=> 3.5 Kton of Uranium ore
^{239}Pu	$^{238}U \rightarrow ... \rightarrow ^{239}Pu$
	=> production in nuclear reactor
50MW reactor	=> ~10 kg/year
Critical mass	~10 kg

in any (even the most "peaceful") nuclear reactor. E.g., a 3000MW Chernobyl-type RBMK-1000 reactor, optimized for electricity production, produces over 150kg ^{239}Pu per year. However, experts use to say that removing nuclear fuel of working nuclear power plant to recover its plutonium is cumbersome, and recovering weapon-grade plutonium from used fuel (usually re-loaded once in 1-3 years) is impossible.

Let us now turn to the issue of the relative efficiency of nuclear and conventional weapons. Comparing these two categories of weapons is far from a simple matter, but several points should be made. From a strategic point of view, there are certain arguments against nuclear weapons.

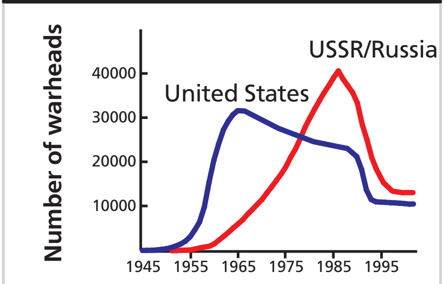
Nuclear vs. Conventional	
Conventional	20 Kton → 1000 km^2
Nuclear	20 Kton → 10 km^2

First of all, processing 3.5kt of Uranium ore utilizing a hi-tech enrichment process is generally much more involved than producing 20kt of TNT. Second, a comparison, of the "coverage" of a 20kt nuclear device with that of 20kt of shells containing conventional explosives reveals that conventional explosives will be at least 2 orders of magnitude more efficient. (A 20kt bomb covers ~10km^2. 20kt of TNT, deployed in 2,000,000 artillery shells of ~10kg each, covers 1000km^2).

Kt-scale artillery barrages were employed during the World War I (WWI) and were not uncommon during WWII (up to millions of shells fired in several days on a km-scale front). The key characteristics of nuclear weapons are: a) their unprecedented power which is released in one instant of time, and b) their ease of delivery. These two factors facilitate the deployment of the accumulated labors of many years or even decades at one time (e.g., 10 nuclear bombs built in 10 years and deployed simultaneously).

While it is true that nuclear stockpiles have been considerably reduced – by the US from the mid-1960s onwards, and by the USSR from the late 1980s – many other countries have developed or are attempting to develop a nuclear capability. 5 nuclear countries signed the Nuclear Non-Proliferation Treaty: the USA (nuclear weapons since 1945), the USSR (1949), the UK (1952), France (1960) and China (1964). Since then, nuclear weapons have been developed (or are officially claimed to have been developed) in India (1974), South Africa

Nuclear Stockpiles



Nuclear Proliferation

USA	1945	India	1974
Russia	1949	Pakistan	1998
UK	1952	North Korea	2006
France	1960	(South Africa)	1982
China	1964		

(1982), Pakistan (1998) and North Korea (2006). South Africa's nuclear arsenal was disposed of after the apartheid regime collapsed.

Regarding the efficacy of international sanctions to deter or prevent a country from obtaining nuclear weapons, it should be noted that as the USSR was developing its nuclear program (1945-1949), countless thousands of its citizens died of starvation and cases of cannibalism became disturbingly frequent. India, Pakistan and North Korea were and remained among the poorest countries in the World, and South Africa was subjected to a severe economic boycott. Despite these realities, the aforementioned countries developed nuclear weapons. The claim that international isolation and sanctions can prevent a given country from obtaining a nuclear capability is at best questionable [1]. It is therefore of paramount importance that the probable consequences of a nuclear strike be assessed in a serious and realistic manner.

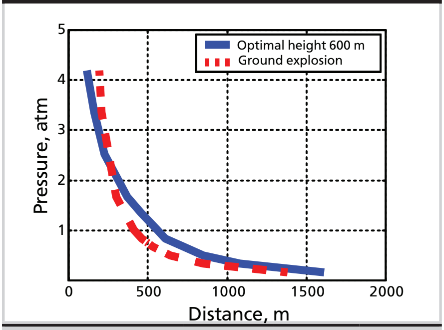
[1] Prof. M. van Creveld from the Hebrew University, the author of the article "Tactics" in *Encyclopaedia Britannica*, was cited as: "They'll build, buy, borrow, burgle it – but they'll have it".

Nuclear weapons' effects

There are 5 'hit factors' involved in the detonation of a nuclear device: shock wave, light (or thermal) emission, ionizing radiation, radioactive contamination, electromagnetic pulse.

Nuclear Explosion
Shock wave
Light emission
Ionizing radiation
Radioactive contamination
Electromagnetic pulse

Shock wave



Destruction & Losses (Yield –15 kton)

	Radius	Killed	Injured
Total destruction	0.6 km	80%	10%
Severe	1.3 km	15%	35%
Medium-light	2 km	<10%	<30%

1. The shock wave – causing the collapse of buildings – is usually viewed as the major factor. It is generally assumed that the destruction within the radius of a 1atm-overpressure shock wave will be total, whereas an area subjected to a 0.3atm-overpressure shock wave will suffer severe destruction. For a Hiroshima-size device, the radius of total destruction is ~0.5km, and of severe destruction ~1km. Where the device is detonated above ground at optimal height (e.g. 600m in Hiroshima), the destruction zone is larger by tens of percent than in the case of a ground level detonation.

For the total destruction zone, projected casualties are: 80% killed, 10% injured (with 10% remaining functional despite light injuries). For the severe destruction zone: 15% killed, 35% injured and 50% functional.

Standard bomb shelters and reinforced areas of civilian structures should be able to withstand a 1atm overpressure shock wave. Buildings designed for areas prone to seismic activity can withstand 2-3atm overpressure shock waves. In Hiroshima, one such building, 200m(!) from ground zero, remained nearly intact.

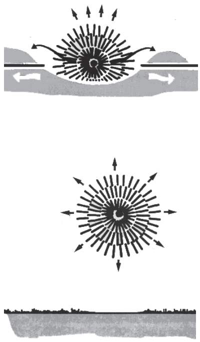
2. Light (thermal) emission causes fires and skin burns. In Hiroshima, it led to massive fires (that developed into a firestorm which claimed a significant number of casualties) due to traditional Japanese construction methods utilizing extremely flammable materials. This factor is far less significant with regards to modern, concrete-based construction.

3. Ionizing radiation may be lethal in the case of kt-scale devices at distances of several hundred meters. Persons exposed to lethal doses of radiation do not die immediately but rather remain functional for a period of several days to about 2 weeks. It is also instructive to recall that as a result of the 2 bombs used against Japan ~1,200 people died of exposure to radiation over a period of decades, whereas over 100,000 died immediately from the shock wave and fires.

Ionizing radiation	
	γ , n
E	**~ 1–10 MeV**
$L_{1/2}$	**~ 150 m (50% attenuation)**

4. Radioactive contamination (fallout) is produced only in ground explosions, and therefore was absent in both Hiroshima and Nagasaki. The radiation level does not increase immediately. The fallout begins to form about ~0.5 hour after the explosion, after the radioactive dust particles fall from the ~10km-high radioactive cloud ("mushroom"). The radiation level reaches maximum at ~1 hour after the explosion. This level of contamination can easily be lethal downwind of the explosion if no measures are taken. The radiation level

Radioactive contamination (Fallout)

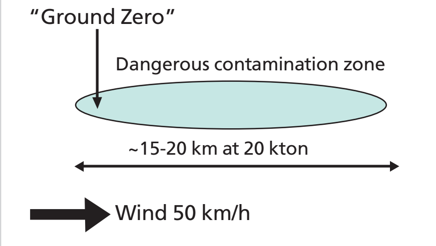


Ground burst: formation time: 0.5–24 hours

Air burst: no fallout !

Radioactive contamination	
Lethal Dose	**LD_{50} = 350 R**
Acceptable dose	**40 R**
Cancer	
natural	**20%**
40R	**+0.7% in 15–20years**
Dangerous contamination zone	
1 h	**100 R/h**
7 h	**10 R/h**
48 h	**1 R/h**
Natural background	**0.4 R/year**

Radioactive contamination (ground explosion)



decreases by a factor of 10 after ~7 hours and by additional factor of 10 after ~2 days (48 hours). At this stage it is generally safe to remain in the contaminated area for several hours at a time, allowing rescue operations to commence.

It must be stressed that general radiation safety standards are far more stringent, by several orders of magnitude, than those pertaining to nuclear attack. E.g., a 25R (roentgen) dose of radiation does not lead on average to a change in blood count, and a 40R dose over 4 days is considered acceptable. (The lethal dose is 300-600R). According to present standards up to 0.1R per year is considered acceptable for the general public under normal conditions (and 5R/year for professionals), whereas natural background radiation is about 0.25-0.4R per year. According to currently available data, 40R dose causes additional 0.7% of cancer cases within 15-20 years (on top of 20% of natural cancer occurrence).

A 30-cm-thick layer of concrete (or a 45-cm-thick layer of earth) attenuates the fallout radiation by a factor of 40. This is the required Protection Factor according to the US Federal Emergency Management Agency's standard for public fallout shelters.

Fallout Shelter
US FEMA TR-87

- **Protection factor PF=40**
  (30cm concrete, OR 45cm earth)
- **Ventilation**
- **Water storage, etc.**

5. Electromagnetic Pulse can disrupt not only wireless communications, but also electronics (primarily computers and other CMOS-based circuits). It has no direct influence on people.

Awareness and Preparedness

Civil defense efforts can be extremely effective. According to a 1979 report of the Office of Technology Assessment of the US Congress, full-scale civil defense measures (including population dispersion) can lead to 3-5 fold decrease in casualties.

In addition to the direct saving of lives and property, there is an additional psychological factor of great importance: civil defense activity will increase public awareness and prevent panic, which otherwise may claim, as occurred in London in 1940, more casualties than the bombs themselves and lead to the collapse of social order.

As discussed in section 2, it is difficult to completely rule out the possibility that an aggressor will obtain nuclear weapons. This being the case, the key issue of deterrence becomes one's ability to survive attack and to limit its consequences to a minimum. The realization that the effects of a nuclear attack will be limited to direct damage and will not cause national collapse is likely to cause a potential aggressor to think twice. To quote E. Teller: "Civil defense … will not eliminate the danger of nuclear war. It will considerably diminish its probability". E.g., in Israel all new buildings have blast shelters, which can be upgraded to fallout shelters rather cheaply.

It is impossible to estimate *post factum* to what extent the (very limited) US efforts in the area of civil defense contributed to the fact that a third world war was avoided. The fact is that it was, and instead, the USSR collapsed.

Acknowledgements

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Further reading

1. Samuel Glasstone and Philip J. Dolan, *The Effects of Nuclear Weapons*. United States Department of Defense, 3rd edition (1977).

2. Office of Technology Assessment, Congress of the United States. *The Effects of Nuclear War* (1979).

3. Cresson H. Kearny, *Nuclear War Survival Skills*. Oak Ridge National Laboratory (1977). 3rd edition: Oregon Institute of Science & Medicine (1999).