The nature of weapon tests

- **High Altitude Air Blast:**
  fireball > 100,000 ft (>3000m)

- **Low Altitude Air Blast:**
  fireball < 100,000 ft (without touching ground)

- **Surface Blast:**
  fireball in touch with surface

- **Subsurface Blast:**
  Underwater burst

- **Underground Blast**
  underground conditions
High Altitude tests

e.g. Dominic tests on the Christmas Island 1962 shortly before test ban in 1963;

The electromagnetic pulse (EMP) from these tests sent power line surges through Oahu, knocking out street lighting, blowing fuses and circuit breakers, and triggering burglar alarms.

Main purpose is the development of an EM pulse over a large area.

KINGFISH, 1962; 1000 kT
Thor Missile Airburst; 320,000 Feet

STARFISH PRIME, 1962; 1450 kT
Thor Missile airburst; 248 miles,
Long distance observation

The blast from Starfish was seen at 800 miles distance from Honolulu, Hawaii. Originated Auroral light phenomena through $\beta$-radiation induced excitation effects in atmosphere.
High Altitude Delivery
Low Altitude Tests

Pressure surge downward, shock front emission: Fireball evolution

\[ R = 110 \ W^{0.4} \]  \hspace{1cm} (W = yield in kT of TNT)

SWANEE, 97kT; B52 parachute fall 3000ft

YESO, 3000kT; B52 drop free fall to 8300ft
Development of the Airburst

0.5 s: Shock-front fireball evolution

1.2 s: Shock-front re-bounce

3 s: double shock-front upwards motion

10 s-30 s: Surge and stem evolution
Event: Yukon
Date: May 8, 1962
Yield: 100 Kilotons
ATOMIC WEAPONS ORIENTATION PARTS 5 and 6

EFFECTS OF ATOMIC WEAPONS

A SPECIAL WEAPON ORIENTATION : THE THERMONUCLEAR WEAPON

FILM #0800070 (Two Films Combined)
Underwater Blast

Formation of spray dome & condensation cloud from erupted water

Baker
(fat man design)
Bikini Atoll
1946; 23 kT
First Moments

- Eruption through water surface
- Formation of spray dome (4 ms)
- Spherical cloud condensation (1 s)
- Break through of erupted water

- formation of base surge (2 s)
The formation of surge & cloud

Cloud development

Surge development

2.50b. Chronological development of a 100-kiloton shallow underwater burst: 12 seconds after detonation.

2.50c. Chronological development of a 100-kiloton shallow underwater burst: 20 seconds after detonation.
Cloud expansion & fallout

2.80c. Chronological development of a 100-kiloton shallow underwater burst: 2.5 minutes after detonation.

2.81c. Chronological development of a 100-kiloton shallow underwater burst: 1 minute after detonation.
Cloud Evolution
The Baker test

These were the first "weapons effects" tests ever conducted - tests designed specifically to study how nuclear explosions affect other things - rather than tests of the behavior of a weapon design (as was Trinity). The purpose of the tests was to examine the effects of nuclear explosions on naval vessels, planes, and animals.

The closest ship to surface zero was the USS Saratoga. Eight ships were sunk or capsized, eight more were severely damaged. Sunk vessels were the USS Saratoga (2 being hit by 90 ft wave, 3 front being swept by wave), USS Arkansas, the Nagato, LSM-60 (obviously), the submarines USS Apogon and USS Pilotfish, the concrete dry dock ARDC-13, and the barge YO-160.
The damage to the Atoll by Baker and subsequent tests - Bravo

Atoll before the Bravo test

Atoll after the Bravo test

Population had been removed, numerous tests followed until the early sixties
Entire island is contaminated with radioactivity; population is still not allowed to return: 2001 the US government granted $563,315,500 reparations to the Bikinians.
For details see: http://www.bikiniatoll.com/home.html
Underground tests

In underground tests most of the released energy goes into crater formation. Only a fraction of the energy goes into blast depending on explosion depth. The shape of the crater depends on depth of explosion; new applications are bunker breaking small nuclear weapon developments.

Crater volume:
\[ V_c \approx 10^5 \cdot W \text{ m}^3 \]
SEDAN EVENT
Sedan test parameters and results

- The **104 kT** thermonuclear device was buried **635 feet** below ground level.
- The force of the detonation released seismic energy equivalent to an earthquake of 4.75 magnitude on the Richter Scale.
- The blast moved 6.5 million cubic yards of earth and rock up to 290 feet in the air.
- The resulting crater was 1280 feet across and 320 feet deep.
Crater formation in underground test

Blast vaporizes material within radius $r = 2\cdot W^{1/3}$ m
($W$ in kilotons (kT) of TNT)

Blast melts material within $r = 4\cdot W^{1/3}$ m

Blast induced seismic shock crushes material within $r = 50\cdot W^{1/3}$ m

Gas release and seismic waves cause eruption and crater formation. Crater volume $V_c \approx 10^5 W$ m$^3$.
(Example Sedan $\sim 10$million m$^3$)
Nuclear Cratering

Ground Surface Before Explosion

Ground Surface After Explosion

Chimney

Retarc

Crater

Cavity
Nuclear Bunker Busters

Needs to contain most of the released energy underground to break structure by underground shock and energy release (no air venting). Underground structures are difficult to break, even by surface nuclear explosions. Underground explosion cause ground motion and seismic shocks.

Shock enhancement for the explosion of a $W$ kT nuclear bomb as function of depth.

$R_s = \frac{R}{W^{1/3}}$  

Scaled burial depth

1 kT bomb 1 m underground would have same effect as 35 kT bomb 1 m above ground.

Or 10 kt bomb 2 m underground would enhance explosion yield by a factor of 20.

At low depths most of released energy is lost in blast rather than translated into seismic energy.
bunker breaking nuclear missile systems

New dreams of the pentagon to address the perceived threat from third world underground “terrorist” bunker systems.

**How a “Mini-Nuke” Could Be Used**

- The tactical weapon is aimed at underground targets. The weapon can destroy targets below ground or burst at high or medium altitudes. Underground detonations limit “collateral damage,” or the number of deaths.
- Rocket motors fire and the bomb, with a hardened-nose case, buries itself below ground 10 to 20 feet.
- The burst is time-delayed after impact. Ground shock waves from the explosion also cause damage.

1. A combat aircraft releases the “mini-nuke” bomb assembly at heights ranging from 5,000 feet to as low as 50 feet.
Penetration limits

240 kT conventional warhead

2-4 m penetrating depth of missile, most of energy is lost in release to atmosphere rather than in seismic shock, material liquefies at impact.
Long Rod Penetration versus Velocity

Typically ~900 m/sec = 2700 ft/sec

A needle 12 ft long, 12 inches diameter

B61-11 Length

Impact Velocity

Depth
High Velocity Kinetic Penetration

A GBU-28 undergoes a high-velocity sled test, penetrating several meters of concrete.
Containment of nuclear blast

Natural limit of penetration (set by deformation and liquidisation of penetrating missile) ~ 20 m

Containment depth corresponds to explosive yield W. Present standard 300 kT earth penetrating Warhead would need to penetrate to 500 m (instead of 20 m) to fully contain the energy underground. Even 0.1 kT warhead needs a 40 m depth for containment.
Bomb test characteristics

**The effects of Nuclear weapons**
- Blast damage
- Thermal damage
- Radiation damage
- EM-pulse
- Scaling laws
- Protection and shielding

**Distance effects**
- Fall-out
- Atmospheric distribution

**Effects on population**
- Radiation effects
- Fallout conditions
- Short range Medical consequences
- Long term medical consequences

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