This digital document created and presented by Richard Fleetwood. He is the founder, author, producer, and webmaster of the **SurvivalRing** *(http://www.survivalring.org)* and **Civil Defense Now!** *(http://www.survivalring.org/cd-main.htm)* websites.

SurvivalRing has as its goal the ideal of being the leading source of survival, preparedness, and self reliance information on the Internet. Linkage, assistance, and creation of digital content in areas that until now have only been hinted at or impossible to find, is being added to everyday via the Survival-Ring website and email lists.

Thousands of hours of searching, writing, and communications have been spent collecting over 2 gigabytes of digital content, as well as tens of thousands of pages of hard copy original public domain material in the areas of civil defense, survival, training, and preparedness, from all over the globe. As much as possible is being put online at his website at

http://www.survivalring.org

CHRONOLOGICAL DEVELOPMENT OF AIR BURST

NUCLEAR AND THERMAL RADIATION

FIREBALL

PRIMARY BLAST WAVE FRONT

| 20 KT | MILES | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1.0 | 1.2 | 1.4 | 1.6 |
| 1 MT | MILES | 0 | 1 | 2 | 3 | 4 | 5 | 6 | | |

Figure 2.51a. Chronological development of an air burst; 0.5 second after 20-kiloton detonation; 1.8 seconds after 1-megaton detonation.

Immediately following the detonation of a nuclear weapon in the air, an intensely hot and luminous (gaseous) fireball is formed. Because of its extremely high temperature, it emits thermal (or heat) radiation capable of causing skin burns and starting fires in flammable material at a considerable distance. The nuclear processes which cause the explosion and the radioactive decay of the fission products are accompanied by harmful nuclear radiations (gamma rays and neutrons) which also have a long range in air. Very soon after the explosion, a destructive shock (or blast) wave develops in the air and moves rapidly away from the fireball.

At the times indicated, the fireball has almost attained its maximum size, as shown by the figures given below:

	Diameter of fireball	*(feet)*
	20 kilotons	*1 megaton*
At time indicated ----------------------	1,460	6,300
Maximum ----------------------------	1,550	7,200

The blast wave front in the air is seen to be well ahead of the fireball, about 800 feet for the 20-kiloton explosion and roughly half a mile for the 1-megaton detonation.

NUCLEAR AND THERMAL RADIATION

PRIMARY BLAST WAVE FRONT

REFLECTED BLAST WAVE FRONT

COMMENCEMENT OF MACH REFLECTION
OVERPRESSURE 16 PSI

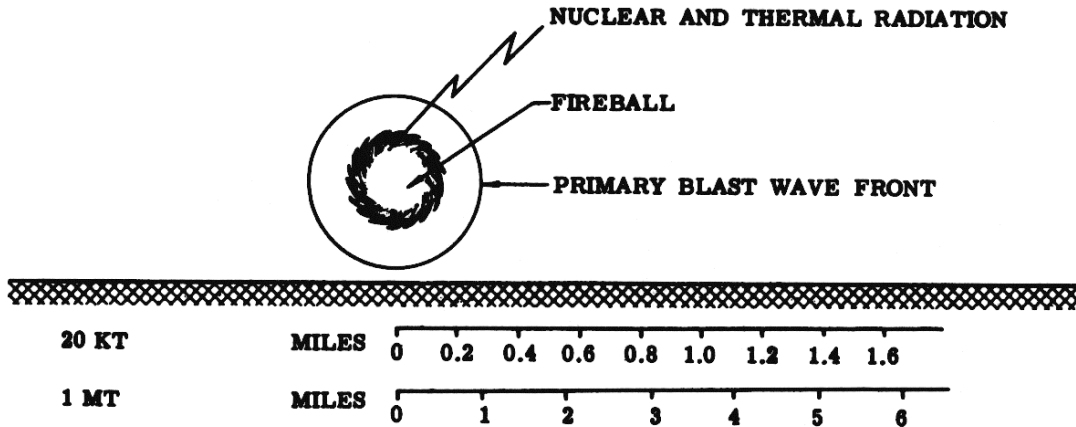| 20 KT | MILES | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1.0 | 1.2 | 1.4 | 1.6 |

| 1 MT | MILES | 0 | 1 | 2 | 3 | 4 | 5 | 6 |

Figure 2.51b. Chronological development of an air burst; 1.25 seconds after 20-kiloton detonation; 4.6 seconds after 1-megaton detonation.

When the primary air blast wave from the explosion strikes the ground, another blast wave is produced by reflection. At a certain distance from ground zero, which depends upon the height of burst and the energy yield of the weapon, the primary and reflected wave fronts fuse near the ground to form a single, reinforced Mach front (or stem).

The time and distance at which the Mach effect commences for the air bursts at the given heights are as follows:

Explosion yield	Height of burst (feet)	Time after detonation (seconds)	Distance from ground zero (miles)
20 kilotons ------------------	1, 760	1.25	0.35
1 megaton -----------------	6,500	4.6	1.3

The overpressure at the earth's surface is then 16 pounds per square inch.

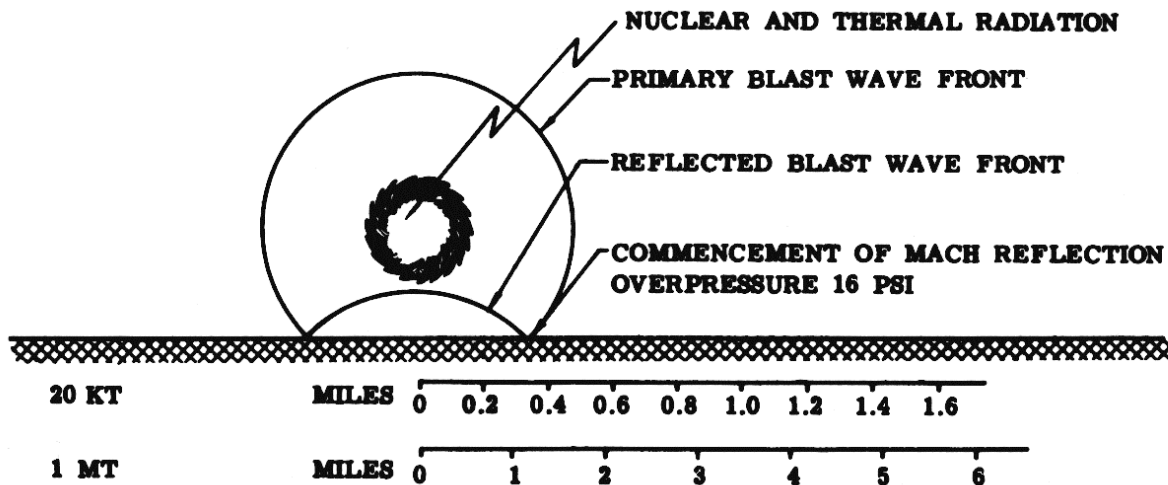Significant quantities of thermal and nuclear radiations continue to be emitted from the fireball.
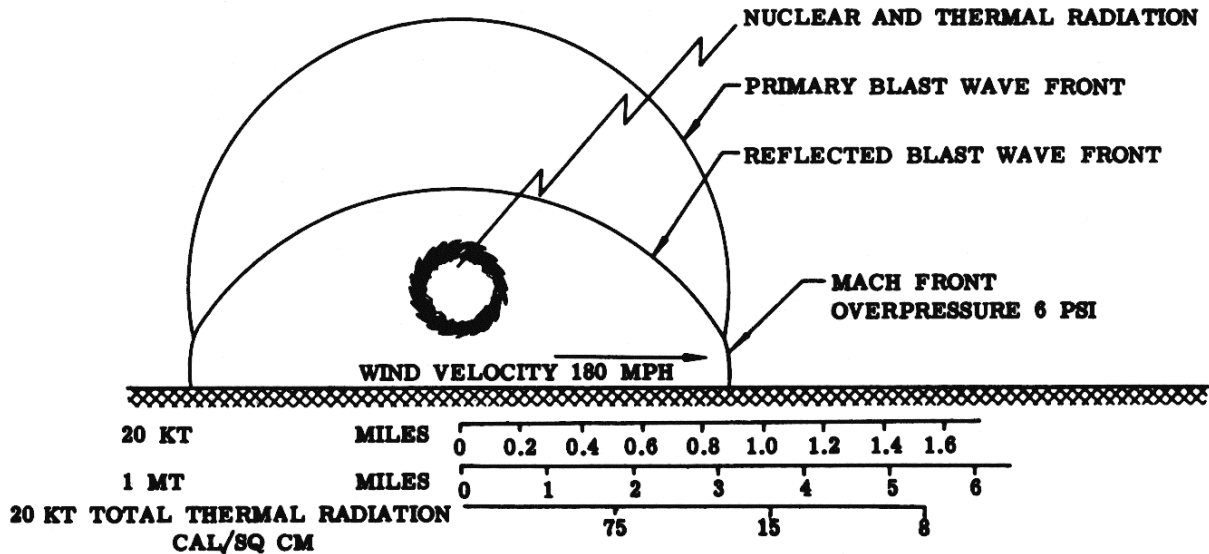
Figure 2.51c. Chronological development of an air burst; 3 seconds after 20-kiloton detonation; 11 seconds after 1-megaton detonation.

As time progresses, the Mach front (or stem) moves outward and increases in height. The distance from ground zero and the height of the stem at the times indicated are as follows:

Explosion yield	Height of burst (feet)	Time after detonation (seconds)	Distance from ground zero (miles)	Height of stem (feet)
20 kilotons ---------	1, 760	3	0.87	185
1 megaton ---------	6,500	11	3.2	680

The overpressure at the Mach front is 6 pounds per square inch and the blast wind velocity immediately behind the front is about 180 miles per hour.

Nuclear radiations from the weapon residues in the rising fireball continue to reach the ground. But after 3 seconds from the detonation of a 20-kiloton weapon, the fireball, although still very hot, has cooled to such an extent that the thermal radiation is no longer important. The total accumulated amounts of thermal radiation, expressed in calories per square centimeter, received at various distances from ground zero after a 20-kiloton air burst, at 1,760 feet, are shown on the scale at the bottom of the figure (for further details, see Chapter VII). Appreciable amounts of thermal radiation are still received from the fireball at 11 seconds after a 1-megaton explosion; the thermal radiation emission is spread over a longer time interval than for an explosion of lower energy yield.

REFLECTED BLAST—
WAVE FRONT

PRIMARY BLAST—
WAVE FRONT

RATE OF RISE
20 KT   200 MPH
1 MT   250 MPH

NUCLEAR RADIATION

HOT GASEOUS
BOMB RESIDUE

MUSHROOM STEM

MACH FRONT—
OVERPRESSURE 1 PSI

WIND VELOCITY 40 MPH

AFTERWINDS

20 KT	MILES	0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6

1 MT	MILES	0	1	2	3	4	5	6	7	8	9	10

30   20   8   5
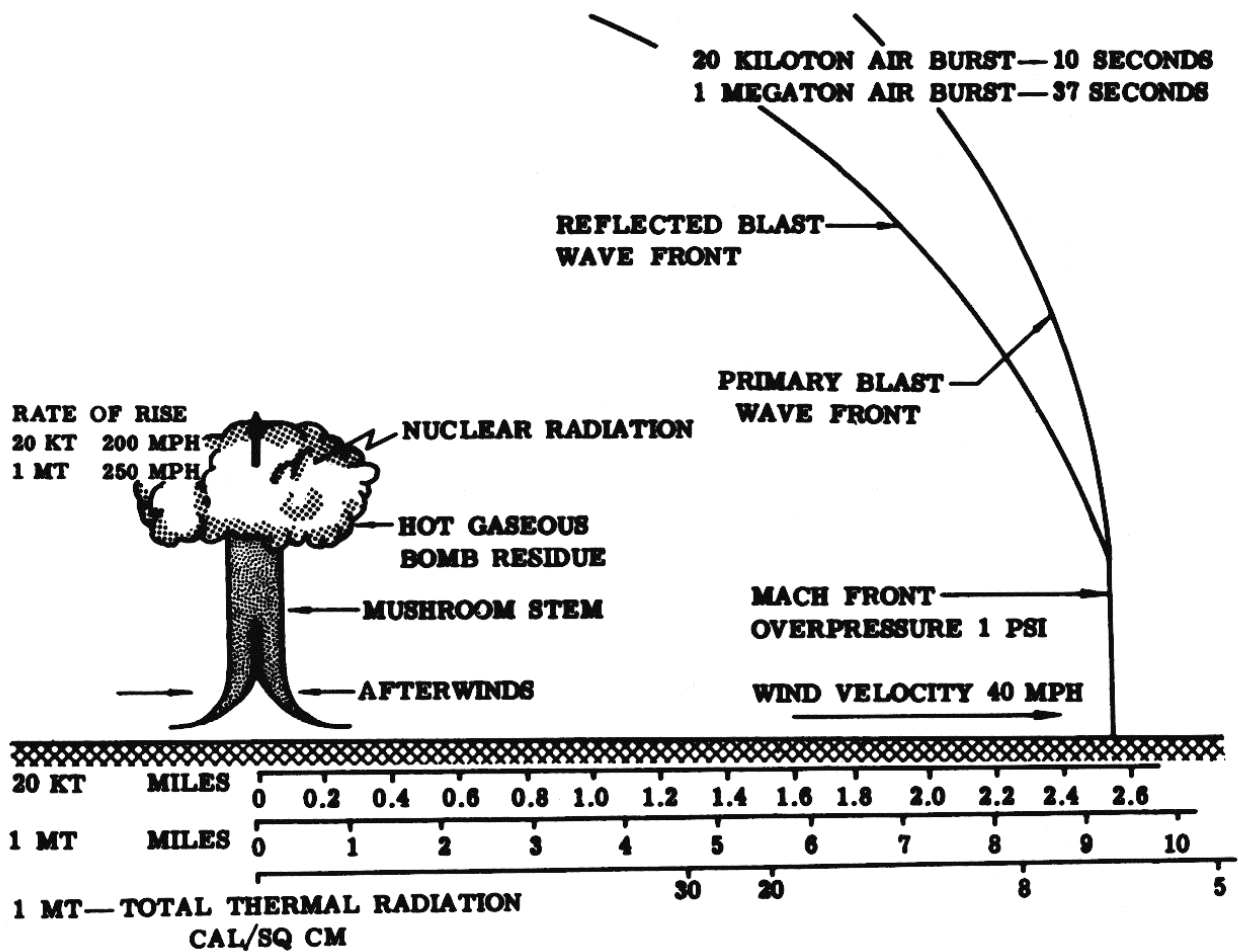
1 MT—TOTAL THERMAL RADIATION
CAL/SQ CM

Figure 2.51d. Chronological development of an air burst; 10 seconds after 20-kiloton detonation; 37 seconds after 1-megaton detonation.

At 10 seconds after a 20-kiloton explosion at an altitude of 1,760 feet the Mach front is over 2 1/2 miles from ground zero, and 37 seconds after a 1-megaton detonation at 6,500 feet, it is nearly 9 1/2 miles from ground zero. The overpressure at the front is roughly 1 pound per square inch, in both cases, and the wind velocity behind the front is 40 miles per hour. There will be slight damage to many structures, including doors and window frames ripped off, roofs cracked, and plaster damaged. Glass will be broken at overpressures down to 1/2 pound per square inch. Thermal radiation is no longer important, even for the 1-megaton burst, the total accumulated amounts of this radiation, at various distances, being indicated on the scale at the bottom of the figure. Nuclear radiation, however, can still reach the ground to an appreciable extent; this consists mainly of gamma rays from the fission products.

The fireball is no longer luminous, but it is still very hot and it behaves like a hot-air balloon, rising at a rapid rate. As it ascends, it causes air to be drawn inward and upward, somewhat similar to the updraft of a chimney. This produces strong air currents, called afterwinds. For moderately low air bursts, these winds will raise dirt and debris from the earth's surface to form the stem of what will eventually be the characteristic mushroom cloud.
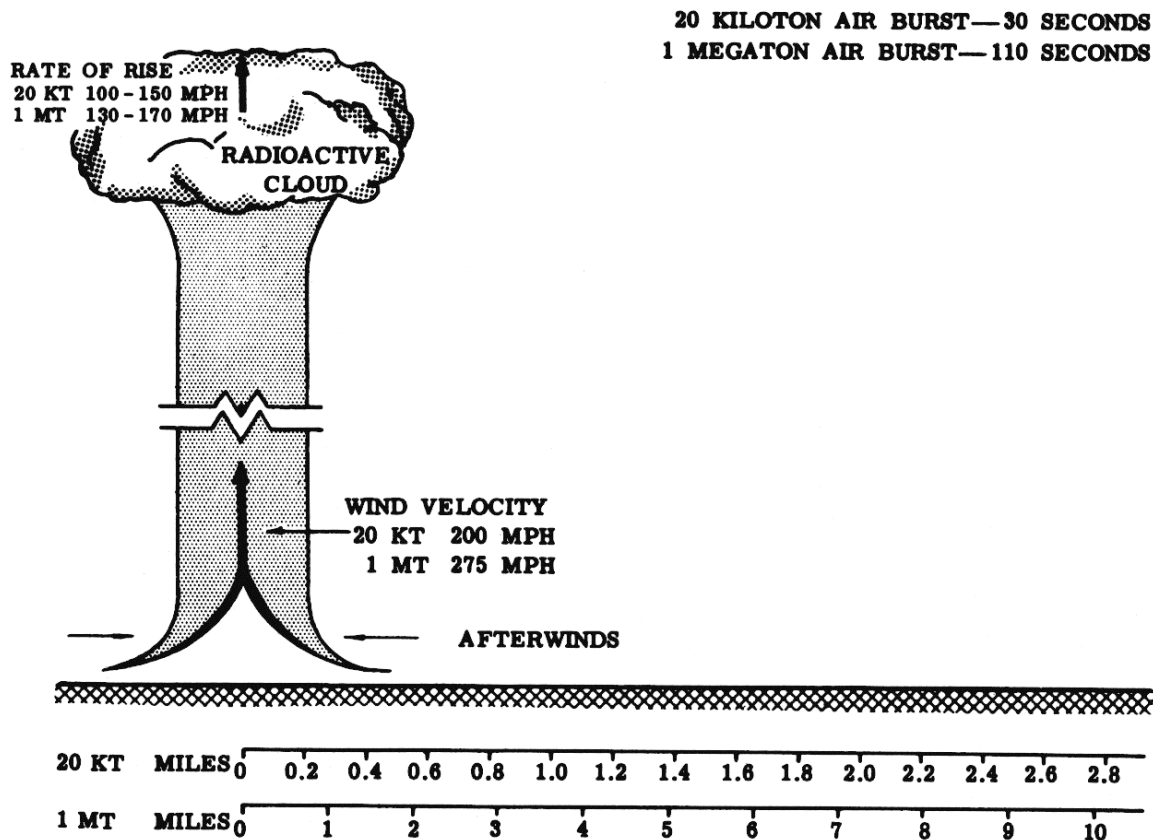
Figure 2.51e. Chronological development of an air burst; 30 seconds after 20-kiloton detonation; 110 seconds after 1-megaton detonation.

The hot residue of the weapon continues to rise and at the same time it expands and cools. As a result, the vaporized fission products and other weapon residues condense to form a cloud of highly radioactive particles. The afterwinds have velocities of 200 or more miles per hour, and for a sufficiently low burst they will continue to raise a column of dirt and debris which will later join with the radioactive cloud to form the characteristic mushroom shape. At the times indicated, the cloud from a 20-kiloton explosion will have risen about 1 1/2 miles and that from a 1-megaton explosion about 7 miles. After about 10 minutes, the maximum heights attained by the clouds will be about 7 miles and 14 miles, respectively. Ultimately, the particles in the cloud will be dispersed by the wind and, unless there is precipitation, there will usually be no early (or local) fallout. Only if the height of burst is less than about 600 feet for a 20-kiloton and 3,000 feet for a 1-megaton explosion would appreciable early fallout be expected.

Although the cloud is still highly radioactive, very little of the nuclear radiation reaches the ground. This is the case because of the increased distance of the cloud above the earth's surface and the decrease in the activity of the fission products due to natural radioactive decay.