

# **Two Modern Military Revolutions: Dramatic Increases in Explosive Yields and Aiming Accuracies**

By  
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# **Two Modern Military Revolutions: Dramatic Increases in Explosive Yields and Aiming Accuracies**

There have been two military revolutions since the beginning of the atomic age: dramatic increases in explosive yields and aiming accuracies of bombs and warheads.

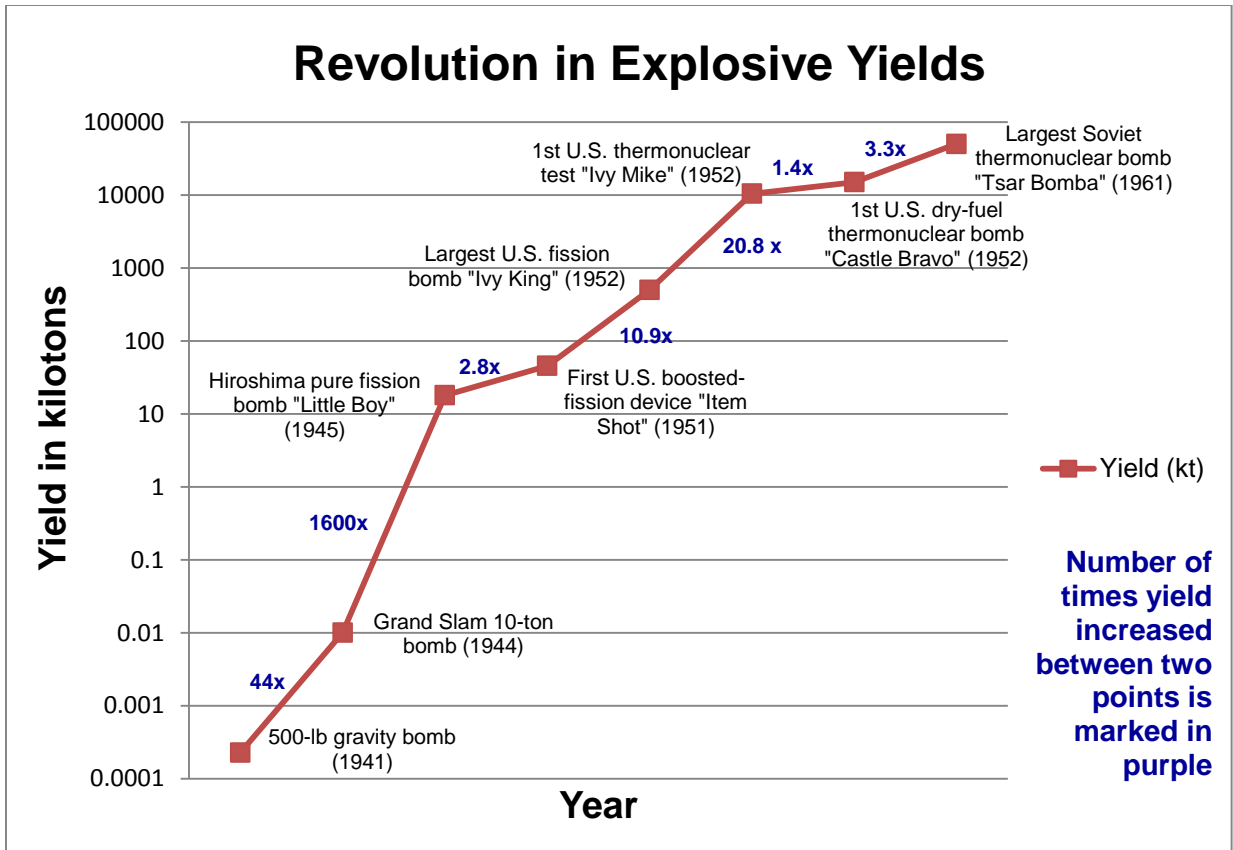
## **Measuring Explosive Yields**

The amount of energy released by a weapon when detonated is referred to as its yield. The yield of nuclear weapons is expressed in terms of the equivalent mass of TNT necessary to achieve the same energy discharge. Because the yields of nuclear weapons are so large, they are given as either kilotons (1 kt = 1,000 tons of TNT) or megatons (1 mt = 1 million tons of TNT).

### **Conversions:**

1 metric ton = 1,000 kg  
1 kt = 1,000 tons  
1 mt = 1,000 kt  
1 mt = 1,000,000 tons

The explosive yield of weapons has increased by several orders of magnitude over the past seven decades.



Weapon Description/Name	Yield (kt)	Year
WWII high explosive (H.E.) 500-lb bomb	0.000227	1941
Largest WWII H.E. bomb (Grand Slam)	0.01	1944
Hiroshima pure fission bomb (Little Boy)	16	1945
First U.S. boosted-fission device (Item Shot)	45.5	1951
Largest U.S. fission bomb (Ivy King)	500	1952
First U.S. thermonuclear weapons test (Ivy Mike)	10,400	1952
First U.S. dry-fuel thermonuclear bomb (Castle Bravo)	15,000	1954
Largest Soviet thermonuclear bomb (Tsar Bomba)	50,000	1961

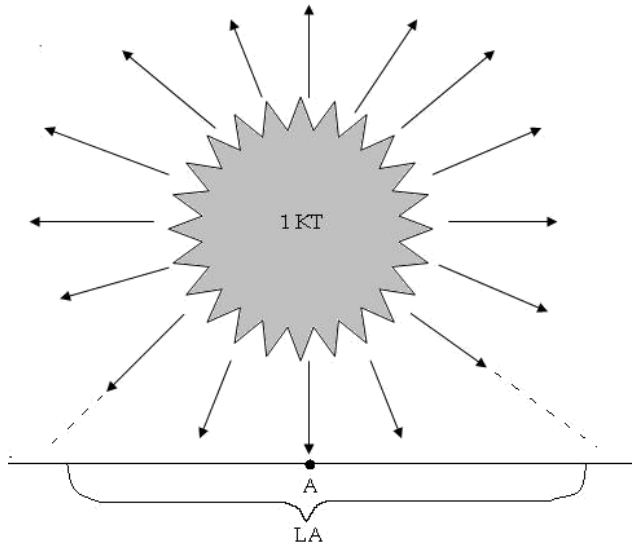
- The yield for “Tsar Bomba” was 220,000,000 times greater than the yield of a 500-lb gravity bomb.
- The yield for “Ivy Mike” was 45,760,000 times greater than the yield of a 500-lb gravity bomb.

## Lethal Area (LA)

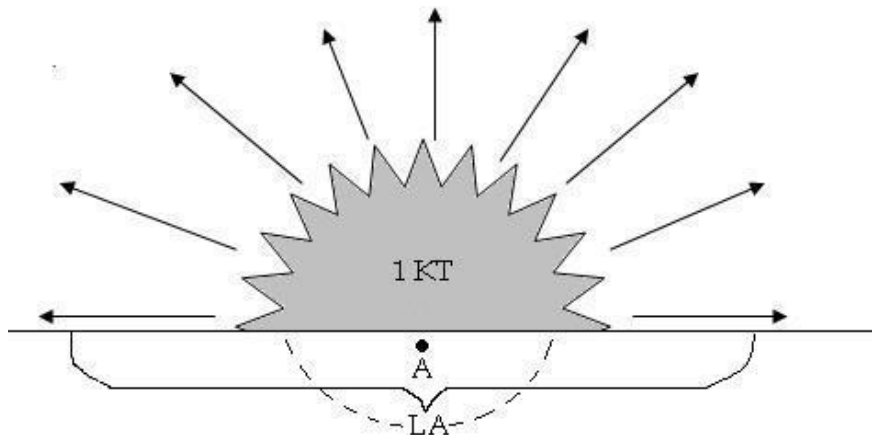
LA = area destroyed by a weapon

$$LA = y^{2/3} \times \text{constant}$$

This area is related to the explosive energy, or yield ( $y$ ), of the weapon. The larger the yield, the larger its lethal area. However, this relation between yield and lethal area is not so simple. A bomb's energy explodes spherically and much of its energy is dissipated *away* from the surface plane of the target. Therefore, even in the most efficient air burst, less than half of the bomb's energy is focused on the target's surface plane.



In the case of a ground burst (wherein the weapon is exploded on or very near the surface plane of the target) even less area of the target's surface plane is affected since most of the energy that does affect this plane penetrates the ground or "digs out" the target.



Doubling the yield of a weapon **does not** double the LA. Instead of being arithmetically related to the yield, LA is directly proportional to the  $^{2/3}$  power of the yield.

Example

If you increase the yield of your weapon 1,000 times, it would increase the LA only 100 times.

$$\text{Yield}_1 = 1 \text{ ton}$$

$$\text{Yield}_2 = 1,000 \text{ tons (1 kiloton or 1 kt)}$$

Both weapons are exploded over the target at the same relative height.

$$\begin{aligned} \text{LA of Yield}_2 &= (1,000 \text{ tons})^{2/3} \times \text{constant} \\ &= (\sqrt[3]{1,000 \text{ tons}})^2 \times \text{constant} \\ &= (10)^2 \times \text{constant} \\ &= 100 \times \text{constant} \end{aligned}$$

Since  $\text{Yield}_1 = 1$  ton, the 1,000-fold increase in  $\text{Yield}_2$  only results in a 100-fold increase in the LA, or area destroyed.

Example

The British Grand Slam was a 10-ton earthquake bomb. Compare that to a fission bomb with a yield of 10 kt. Even though the yield of the fission bomb is a thousand times larger than that of the Grand Slam, the LA of the fission bomb is **not** a thousand times larger than that of the Grand Slam.

$$\begin{aligned} \text{LA of Yield}_G &= (10 \text{ tons})^{2/3} \times \text{constant} \\ &= (\sqrt[3]{10 \text{ tons}})^2 \times \text{constant} \\ &\cong (2.154 \text{ tons})^2 \times \text{constant} \\ &\cong 4.642 \text{ tons} \times \text{constant} \end{aligned}$$

$$\begin{aligned} \text{LA of Yield}_F &= (10,000 \text{ tons})^{2/3} \times \text{constant} \\ &= (\sqrt[3]{10,000 \text{ tons}})^2 \times \text{constant} \\ &\cong (21.544 \text{ tons})^2 \times \text{constant} \\ &\cong 464.144 \text{ tons} \times \text{constant} \end{aligned}$$

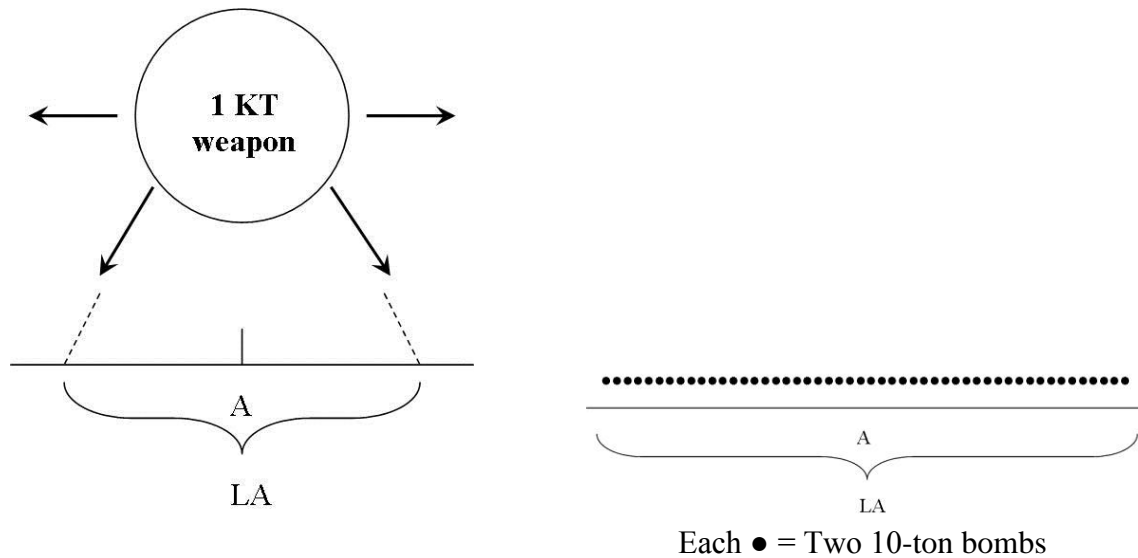
$$\begin{aligned} \frac{\text{LA of Yield}_F}{\text{LA of Yield}_G} &= \frac{464.144 \text{ tons}}{4.642 \text{ tons}} \cong 100 \end{aligned}$$

LA of the fission bomb is 100 times larger than the Grand Slam's.

## Equivalent Kilotonage (EKT)

EKT = the number of one kiloton bombs it would take to destroy an area destroyed by a much larger number of smaller conventional weapons.

From the previous discussion of LA it should be clear that a one kiloton weapon cannot produce as much destruction to the surface plane of a target as 100 10-ton bombs.



### Example

EKT of 100 10-ton bombs, or 100 0.01 kt bombs

$$\text{EKT} = Ny^{2/3}$$

$$\text{EKT} = (100)(.01)^{2/3}$$

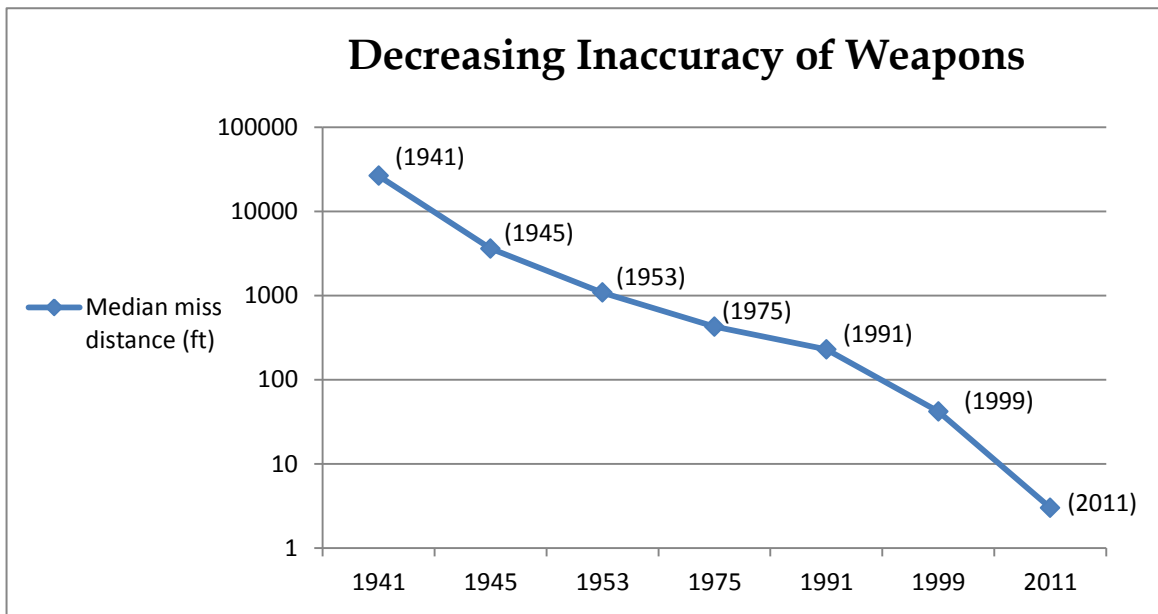
$$\text{EKT} = (100)(.0464)$$

EKT = About 5 one-kiloton nuclear bombs

(i.e., it would take approximately 5 one-kiloton bombs to produce the same destructive effect as 100 10-ton bombs.)

## Aiming Accuracies

The aiming accuracy of bombs and warheads has improved drastically since World War II began. The aiming accuracies are measured by the median distance from a target that a bomb or warhead will fall. There is an inverse relationship between the median distance and the aiming accuracy of the bomb or warhead: the smaller the median distance, the greater the aiming accuracy.



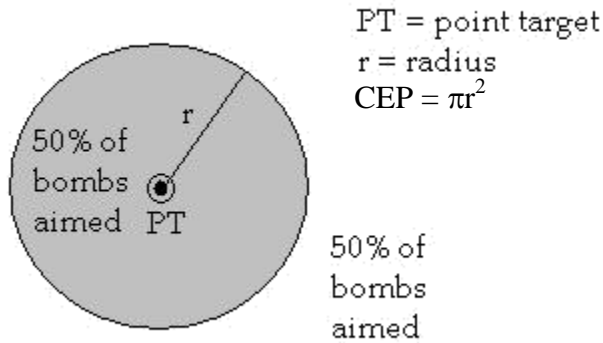
The accuracy of a bomb is commonly given in terms of the circle of error probable (CEP) – the area around a target in which half of the aimed weapons will hit.

Year	Median miss distance (ft)
1941	26,400
1945	3,608
1953	1,082
1975	426
1991	229
1999	42
2011	3

## Circle of Error Probable (CEP)

CEP = area described by a circle with the target at its center within which 50% of the bombs dropped or weapons aimed will fall.

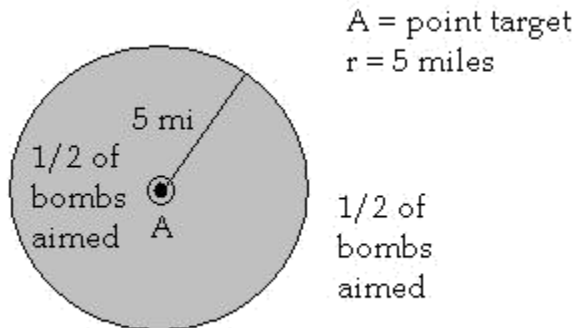
$$\text{CEP} = \pi r^2$$



### Example

The Butt Report filed in August of 1941 claimed that only about  $\frac{2}{5}$  or approximately  $\frac{1}{2}$  of the aircraft flown in moonlit missions that claimed to have found the target in July came within 5 miles of it.

Therefore, if the target = A and only  $\frac{1}{2}$  of payloads fall within 5 miles of the target, then the radius of the circle with the target A at its center within which  $\frac{1}{2}$  of aimed weapons fall is 5 miles. More simply,  $r = 5$  miles.



In this case,  $\text{CEP} = \pi 5^2$   
 $= \pi 25$   
 $\cong 75 \text{ mi}^2$



## Number of Weapons Necessary to Destroy a Target (N)

$$N = \frac{\text{CEP}}{\text{LA}} = \frac{\pi r^2}{y^{2/3}} = \frac{r^2}{(\sqrt[3]{y})^2} \times \text{constant}$$

If LA=1 square mile and your CEP=1 square mile, N=1 weapon\*

While N is inversely proportional to the  $^{2/3}$  power, it is directly proportional to the square of r ( $r^2$ ). Thus, reductions in inaccuracies of CEP are *much more* important to reducing the numbers of weapons necessary to destroy a target than increasing the yield.

\* It is assumed that the weapon will be 100% reliable in hitting its target.

### Example

If the yield of your weapon is kept constant at 1,000 kg but you reduce your inaccuracy 10-fold from 1,000 yards ( $r_1$ ) to 100 yards ( $r_2$ ), the number of weapons necessary to destroy the target is reduced not 10 but *100-fold*.

$$N = \frac{r^2}{(\sqrt[3]{y})^2} \times \text{constant}$$

$$r_1 = 1000 \text{ yards}$$

$$r_2 = 100 \text{ yards}$$

$$N_1 = \frac{(1000 \text{ yd})^2}{(1000 \text{ kg})^{2/3}}$$

$$N_2 = \frac{(100 \text{ yd})^2}{(1000 \text{ kg})^{2/3}}$$

$$N_1 = \frac{1,000,000}{(\sqrt[3]{1000})^2}$$

$$N_2 = \frac{10,000}{(\sqrt[3]{1000})^2}$$

$$N_1 = \frac{1,000,000}{(10)^2}$$

$$N_2 = \frac{10,000}{(10)^2}$$

$$N_1 = 10,000$$

$$N_2 = 100$$

$$\frac{N_1}{N_2} = \frac{10,000}{100} = 100\text{-fold difference in the number of weapons necessary.}$$

Increasing the yield 10-fold, on the other hand, (from 1,000 kg to 10,000 kg) reduces the number of weapons only 5-fold.

$$N = \frac{r^2}{(y)^{2/3}}$$

$$N = \frac{1,000 \text{ yds}^2}{(10,000 \text{ kg})^{2/3}}$$

$$N = \frac{1,000,000}{(\sqrt[3]{10000})^2}$$

$$N = \frac{1,000,000}{(21.55)^2}$$

$$N = \frac{1,000,000}{464}$$

$N = 2,155$  in comparison to 10,000 for  $N_1$  above, or approximately  $\frac{1}{5}$  the number.

Indeed, to produce the same 100-fold decrease in the number of weapons necessary to destroy a target that a 10-fold increase in accuracy produces, you would have to increase the yield of your weapon 1,000-fold:

$$N = \frac{r^2}{(y)^{2/3}}$$

$$N = \frac{(1,000 \text{ yds})^2}{(\sqrt[3]{1,000,000 \text{ kg}})^2}$$

$$N = \frac{1,000,000}{(100)^2}$$

$$N = 100$$