STRATEGIC BOMBING, THE NUCLEAR REVOLUTION, AND CITY BUSTING

A presentation by
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QUESTIONS TO BE ANSWERED

I. How was city busting viewed and done before and during WWII?

II. The nuclear weapons revolution: How militarily significant was it?

III. Why, initially, did developing ever larger nuclear weapons seem logical?

IV. Precision Guidance: How did its advent constitute a counter revolution and how has it affected nuclear weapons deployments?

V. City busting: Why might its morality still be an issue today?
UNTIL MODERNITY, TARGETING CITIES WAS FROWNED UPON

Sun Tzu, *The Art of War*, 500 BC

“To subdue the enemy without fighting is the supreme excellence. Thus, what is of supreme importance in war is to attack the enemy’s strategy. Next best is to disrupt his alliances by diplomacy. The next best is to attack his army. And the worst policy is to attack cities.”
SHERMAN’S MARCH TO THE SEA:
PRECURSOR TO CITY BUSTING
Atlanta, Georgia

AMERICAN CIVIL WAR

Field Artillery and Fire

A six-month campaign
Few if any civilians killed
Residences, churches, and hospitals spared
FRENCH SUBMARINE WARFARE THEORY:
FIRST MODERN MUSINGS ON STRATEGIC WEAPONRY
FRENCH HOPED SUBMARINES MIGHT HELP NEUTRALIZE UK & ITS FLEET BY BLOCKADE

Gymnote class

Narval

Gustave Zede class

Sirene class
EVEN UNRESTRICTED SUB WARFARE IN WWI, THOUGH, HAD MIXED RESULTS
WORLD WAR I TRENCH WARFARE:
ITS HORRORS REKINDLED INTEREST IN ATTACKING POLITICAL CAPITALS DIRECTLY
Pitting Military against Military: Battle of the Somme

WORLD WAR I

*Trench Warfare, 4-plus months*

300,000-plus dead
Produced no strategic results
1st Try at Strategic Aerial Bombing: Gotha Raids
London, England
WORLD WAR I
Conventional Bombs, 857 dead
INTERWAR AERIAL THEORISTS CHAMPION STRATEGIC BOMBING

Giulio Douhet  Hugh Trenchard  Billy Mitchell
RAF INTERWAR EXPERIENCE BACKED AIR POWER THEORIES

- Waziristan - India’s Northwest Frontier
- Kurdistan
- British Somaliland
- Iraq
DITTO, ITALIAN AERIAL BOMBINGS IN SECOND ITALO-ETHIOPIAN WAR
INITIAL WWII EXPERIENCE:
FAILED ATTEMPTS AT PRECISION BOMBING
CAUTIONARY CASES OF CITY BUSTING

Rotterdam: May 1940

London: September 1940

Berlin: August 1940
RAF DAYTIME ATTACKS ON HEAVILY DEFENDED, FORTIFIED U-BOAT PENS HAD LITTLE SUCCESS
The area around this rail yard is marked by stray bombs
• Initially, RAF Bomber Command relied on crews’ claims regarding how much damage they inflicted.

• By 1941, though, the Air Ministry developed infrared cameras that could be attached to the bombers to take aerial photographs of the targets being bombed.

• Lord Cherwell, Churchill’s science advisor, instructed D.M. Butt of the War Dept. Secretariat to conduct a study of RAF German bombing runs using these cameras.

• Butt compared the damage reported by the bomber crews with that shown by night-time aerial photos taken of 633 targets in June and July of 1941.

• Report revealed only 10% of the bombers flying against night-time Ruhr industrial sites found their way to within 75 square miles of their intended targets, (let alone the 1,000 yards pilots claimed). Of all the bombing operations examined, only 5% of the bombers got as close to their targets.
The Butt Report promoted a debate over whether to reduce the bombing effort and transfer resources to the Army and Navy or to continue the bombings as before.

In response, Lord Cherwell produced another study, the “Dehousing Paper,” which argued that given the RAF’s limited success in destroying precise targets, the most effective use of the bombers would be to destroy German housing because it would affect German morale.

The Dehousing Paper estimated that if the UK dedicated 5,000 bombers to the task, they could turn one-third of Germany’s population “out of house and home” by mid 1943.
Dehousing: 
Raid On Dresden, Germany 
WORLD WAR II 
H.E. AND INCENDIARY BOMBS
25,000 Killed
Deadlier Still: US Fire Bombing of Tokyo

WORLD WAR II

Firebombing, 85,000-100,000 dead
Hiroshima

WORLD WAR II

Nuclear Bomb, 60-70,000 dead
THE NUCLEAR WEAPONS REVOLUTION:
HOW MILITARILY SIGNIFICANT WAS IT? WHY, INITIALLY, DID MAKING EVER LARGER BOMBS SEEM LOGICAL?
DESTRUCTIVE EFFICIENCY: FROM SIX MONTHS TO A SECOND

Atlanta, Civil War (took 6 months)

Dresden, WWII (2 days)

Tokyo fire bombing, WWII (3 hours)

Hiroshima, WWII (1 second)
FORCES REQUIRED: FIRST ARMIES THEN JUST A SINGLE BOMBER

• **Battle of Atlanta:** ~75,000 troops; ~9,000 casualties

• **Fire Bombing of Dresden:** >1,200 bombers, >800 fighters; 8 bombers lost

• **Fire Bombing of Tokyo:** 334 B-29 bombers; 14 bombers lost

• **Hiroshima:** One B-29; no bomber losses
INITIAL NUCLEAR WEAPONS DEVELOPMENT
WHY, INITIALLY, DID MAKING EVER LARGER BOMBS SEEM LOGICAL?
YIELD

• Yield = The amount of energy released by a weapon when detonated.

• Nuclear weapon yields are expressed as the amount of TNT needed to achieve the same energy discharge.

• The detonation of a nuclear weapon with a yield of one ton (i.e., .001 kilotons, or kt) = the energy released by the detonation of 1,000 kilograms (kg) of TNT.

• The detonation of a nuclear weapon with a yield of one kiloton (1 kt) = the energy released by the detonation of one million (1,000,000) kg of TNT.

• The detonation of a nuclear weapon with a yield of one megaton (mt) = the energy released by the detonation of one billion (1,000,000,000) kg of TNT.
## Increases in Bomb Yields: 1941-1961

<table>
<thead>
<tr>
<th>Weapon Description/Name</th>
<th>Yield (kt)</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>WWII high explosive (H.E.) 500-lb bomb</td>
<td>0.000227</td>
<td>1941</td>
</tr>
<tr>
<td>Largest WWII H.E. bomb (Grand Slam)</td>
<td>0.01</td>
<td>1944</td>
</tr>
<tr>
<td>Hiroshima pure fission bomb (Little Boy)</td>
<td>15</td>
<td>1945</td>
</tr>
<tr>
<td>First U.S. boosted-fission device (Item Shot)</td>
<td>45.5</td>
<td>1951</td>
</tr>
<tr>
<td>First U.S. thermonuclear weapons test (Ivy Mike)</td>
<td>10,400</td>
<td>1952</td>
</tr>
<tr>
<td>Largest Soviet thermonuclear bomb (Tzar Bomba)</td>
<td>50,000</td>
<td>1961</td>
</tr>
</tbody>
</table>
VISUALIZING A KILOTON

Source: Visualizing the Frightening Power of Nuclear Weapons
http://www.visualnews.com/2012/04/24/visualizing-the-frightening-power-of-nuclear-bombs
YIELDS OF SPECIFIC MUNITIONS

10 tons = 0.01 kilotons

GRAND SLAM
10 TONS
WWII EARTHQUAKE
BOMB USED BY THE RAF

15,000 tons = 15 kilotons

LITTLE BOY
15 KILOTONS
BOMB DROPPED ON HIROSHIMA (USA)

45,500 tons = 45.5 kilotons

ITEM SHOT
45.5 KILOTONS
BOOSTED FISSION WEAPON TEST (USA)
<table>
<thead>
<tr>
<th>Item Shot</th>
<th>45.5 Kilotons</th>
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<tr>
<td>45,500 tons</td>
<td>45.5 kilotons</td>
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<table>
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<tr>
<th>Ivy Mike</th>
<th>10,400 Kilotons</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,400,000 tons</td>
<td>10,400 kilotons</td>
</tr>
<tr>
<td></td>
<td>10.4 megatons</td>
</tr>
</tbody>
</table>
10,400,000 tons =
10,400 kilotons =
10.4 megatons

50,000,000 tons =
50,000 kilotons =
50 megatons
Grand Slam
10 tons TNT

Little Boy
15 KT

Item Shot
45.5 KT

Ivy Mike
10,400 KT or 10.4 MT

Tzar Bomba
50,000 KT or 50 MT
LOGRITHMIC PORTRAYAL OF INCREASING YEILDS: 1941-1961

<table>
<thead>
<tr>
<th>Year</th>
<th>Yield in kilotons</th>
<th>Number of times yield increased</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1941</td>
<td>0.5</td>
<td>44x</td>
<td>500lb gravity bomb (1941)</td>
</tr>
<tr>
<td>1944</td>
<td>1500x</td>
<td>3.0x</td>
<td>Hiroshima pure fission bomb &quot;Little Boy&quot; (1945)</td>
</tr>
<tr>
<td>1945</td>
<td>3.0x</td>
<td></td>
<td>&quot;Grand Slam&quot; (1944)</td>
</tr>
<tr>
<td>1951</td>
<td>1.4x</td>
<td>10.9x</td>
<td>First U.S. boosted-fission device &quot;Item Shot&quot; (1951)</td>
</tr>
<tr>
<td>1952</td>
<td>20.8x</td>
<td>3.0x</td>
<td>Largest U.S. fission bomb &quot;Ivy King&quot; (1952)</td>
</tr>
<tr>
<td>1952</td>
<td>3.3x</td>
<td></td>
<td>1st U.S. dry-fuel thermonuclear bomb &quot;Castle Bravo&quot; (1952)</td>
</tr>
<tr>
<td>1952</td>
<td>1.4x</td>
<td></td>
<td>1st U.S. thermonuclear test &quot;Ivy Mike&quot; (1952)</td>
</tr>
<tr>
<td>1961</td>
<td>100000</td>
<td></td>
<td>Largest Soviet thermonuclear bomb &quot;Tzar Bomba&quot; (1961)</td>
</tr>
</tbody>
</table>

- Yield in kilotons
- Number of times yield increased between two points is marked in purple
HOW YIELD RELATES TO BLAST/LETHAL AREA
BLAST EFFECTS

15 psi
Complete destruction of reinforced concrete structures, such as skyscrapers, will occur within this ring. Between 7 psi and 15 psi, there will be severe to total damage to these types of structures.

7 psi
Severe damage to complete destruction of reinforced concrete structures, such as skyscrapers, will occur within this ring.

5 psi
Complete destruction of ordinary houses, and moderate to severe damage to reinforced concrete structures, will occur within this ring.

2 psi
Severe damage to ordinary houses, and light to moderate damage to reinforced concrete structures, will occur within this ring.

1 psi
Light damage to all structures, and light to moderate damage to ordinary houses, will occur within this ring.

0.25 psi
Most glass surfaces, such as windows, will shatter within this ring, some with enough force to cause injury.

Source: http://meyerweb.com/eric/tools/gmap/hydesim.html?inpyield=1000
BLAST AREA
500 POUND BOMB: WWII H.E. BOMB (0.000227 KT)
BLAST AREA
GRAND SLAM: LARGEST WWII H.E. BOMB (0.01 KT)
BLAST AREA
HIROSHIMA: FISSION BOMB (15 KT)
BLAST AREA
ITEM SHOT: FIRST BOOSTED-FISSION DEVICE (45.5 KT)
BLAST AREA
IVY MIKE: FIRST U.S. THERMONUCLEAR TEST (10,400 KT OR 10.4 MT)
BLAST AREA
TZAR BOMBA: LARGEST SOVIET THERMONUCLEAR BOMB (50,000 KT OR 50 MT)
QUALIFYING THE NUCLEAR REVOLUTION:
LETHAL AREA, EQUIVALENT KILOTONAGE, AND THEIR RELATION TO YIELD
LETHAL AREA (LA)

LA is the area destroyed by a weapon. Because most explosives release their energy in a spherical fashion and roughly half of the explosive power is directed away from the plane of the target, the lethal area of any given munition does not scale identically with yield but instead is directly proportional to the 2/3 power of the yield (y):

\[ \text{LA} = y^{2/3} \times \text{constant} \]
U.S. CIVIL DEFENSE PROPOINENTS ADOPTED BLACKETT’S ARGUMENTS

“Doubling bomb power does not double destruction”

“...if there were a bomb 100 times as powerful, it would reach out only a little more than 4 1/2, not 100 times as far.”

“At Nagasaki, almost 70 percent of the people a mile from the bomb lived to tell their experiences.”

“Beyond 2 miles, the explosion will cause practically no deaths at all.”
PRECISION GUIDANCE:
HOW ITS ADVENT CONSTITUTED A COUNTER REVOLUTION AND HOW IT AFFECTED NUCLEAR WEAPONS DEPLOYMENTS
AIMING ACCURACIES: 1941-2011

Decreasing Inaccuracy of Weapons

- Median miss distance (ft)
CEP REVISITED

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

\[ \text{PT} = \text{point target} \]
\[ r = \text{radius} \]
\[ \text{CEP} = \pi r^2 \]

50% of bombs aimed
A 10-FOLD REDUCTION IN INACCURACY REDUCES THE # OF WEAPONS (N) NEEDED TO DESTROY A POINT TARGET 100-FOLD

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

If \( \text{LA}=1 \) square mile and your \( \text{CEP}=1 \) square mile, \( N=1 \) weapon\(^*\)

While \( N \) is inversely proportional to the \( \frac{2}{3} \) power, it is directly proportional to the square of \( r \) (\( r^2 \)). Thus, reductions in inaccuracies of \( \text{CEP} \) 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 1000 yards \((r_1)\) to 100 yards \((r_2)\), the number of weapons necessary to destroy the target is reduced not 10 but 100-fold.

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

\[r_1 = 1000 \text{ yards}, \quad r_2 = 100 \text{ yards}\]

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

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

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

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

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

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

\[N_1 = 10,000\]

\[N_2 = 100\]

\[\frac{N_1}{N_2} = \frac{10,000}{100} = 100\text{-fold difference in the number of weapons necessary.}\]
INCREASING YIELD 10-FOLD, ON THE OTHER HAND, ONLY REDUCES THE # OF WEAPONS NEEDED 5-FOLD

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.

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

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

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

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

\[ N = \frac{1,000,000}{464} \]

\[ N = 2,155 \text{ in comparison to 10,000 for } N_1 \text{ above, or approximately } \frac{1}{5} \text{ the number.} \]
THANH HOA RAILROAD AND HIGHWAY BRIDGE  
VIETNAM  
LASER-GUIDED BOMBS, DELIVERED BY EIGHT BOMBERS APRIL 27, 1972

Previous efforts to destroy the bridge entailed over 800 failed sorties
PRECISION GUIDANCE MADE RELIANCE ON LOWER YIELD WARHEADS POSSIBLE

1962: Titan II W53 warhead 9 mt

1985: Pershing II W85 5 kt
...AS WELL AS MAJOR REDUCTIONS IN TOTAL U.S.-RUSSIAN ARSENAL MEGATONAGE

http://www.johnstonsarchive.net/nuclear/nwhmt.html
AND MAJOR U.S.-RUSSIAN QUANTITATIVE REDUCTIONS AS WELL
CITY BUSTING REDUX?
WHY ITS MIGHT MORALITY MIGHT STILL BE AN ISSUE TODAY
MUST WE TARGET CITIES AGAIN TO MAKE FURTHER REDUCTIONS?

“….the British have forsaken military targets and will achieve deterrence by threatening, explicitly or implicitly, to destroy the enemy’s cities, industrial centers, and communications…It would appear that all the nuclear powers will have to follow the United Kingdom if or as they move toward a world without nuclear weapons. ….The shift from military to civilian targeting, which seems barbaric, thus may be a feature of the path to ‘global zero’ along with the phased, verified elimination of nuclear weapons.”

“A much steeper reduction, to around 500 warheads total, was debated within the administration but rejected, sources said. Known as the ‘deterrence-only’ plan, it would have aimed U.S. warheads at a narrower range of targets related to the enemy’s economic capacity and no longer emphasized striking the enemy’s leadership and weaponry in the first wave of an attack…. Obama…‘decided we did not need to do deterrence-only targeting now,’ but did not rule it out.”

EQUIVALENT KILOTONAGE (EKT)

EKT is the number of one kiloton bombs it would take to destroy an area destroyed by a much larger number (N) of smaller conventional weapons. Again, because roughly half of the energy of most bombs is directed away from the plane of the intended target, a larger number of smaller weapons can create a lethal area similar to that of a single large yield weapon. The equation for this proportionality is

$$\text{EKT} = N y^{2/3}$$
Example

EKT of 100 10-ton bombs, or 100 .01kt bombs

\[
EKT = N y^{2/3}
\]

\[
EKT = (100)(.01)^{2/3}
\]

\[
EKT = (100)(.0464)
\]

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.)