Background Data:
Strategic Air Offensive vs. Germany

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U.S. vs. British Viewpoints

• Goal: “destruction and dislocation of the Germany military, industrial, and economic system and the undermining of the morale of the German people to the point where their capacity for armed resistance is fatally weakened”
  - U.S.: Accurate (daylight) bombing of strategic industries and services to disable Germany’s war economy
  - Britain: City area (night) attacks to undermine the German people’s will to fight
Questions for Discussion: Allied Offense

- What to bomb, and what is it worth?
- Military technology - what is the most effective kind of bomb?
- How to find targets?
- How to get home safely?
- In retrospect, what was effective?
Strategic Targets

- **Target Type**
  - Military
  - Transportation
  - Industrial
  - Petrochemicals
  - Others?

- **Strategic Air Offensive**
  - US 8th Air Force
    - 333,000 sorties
    - 5500 losses (1.6% loss rate)
    - 622,000 tons of bombs
  - Britain Bomber Command
    - 374,000 sorties
    - 10,000 losses (2.7% loss rate)
    - 955,000 tons of bombs
Bomb Types

- Anti-personal
- Anti-tank
- Hardened Targets
- "Soft" Targets

Explode on contact vs. Penetrate and then explode

### Bomb Types

<table>
<thead>
<tr>
<th>Type</th>
<th>Total no.</th>
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<tbody>
<tr>
<td>Fragmentation (F)</td>
<td>5,000</td>
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<tr>
<td>General purpose (GP)</td>
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<tr>
<td>40 lb</td>
<td>42,328</td>
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<tr>
<td>250 lb</td>
<td>240,066</td>
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<tr>
<td>500 lb</td>
<td>531,034</td>
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<tr>
<td>1,000 lb</td>
<td>2,164</td>
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<tr>
<td>1,600 lb</td>
<td>1,141</td>
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<tr>
<td>2,000 lb</td>
<td>217</td>
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<tr>
<td>Semi-armour-piercing (SAP)</td>
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<tr>
<td>500 lb</td>
<td>11,400</td>
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<tr>
<td>Ammuno-piercing (AP)</td>
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<td>2,000 lb</td>
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Exact figure is not known but less than 10,000

<table>
<thead>
<tr>
<th>Capacity (IC)</th>
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<td>High Capacity (HC)</td>
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<tr>
<td>2,000 lb</td>
<td>28,633</td>
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<tr>
<td>4,000 lb</td>
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<td>8,000 lb</td>
<td>1,088</td>
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<tr>
<td>12,000 lb</td>
<td>193</td>
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<td>20,000 lb</td>
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<table>
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<th>Medium Capacity (MC)</th>
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<td>500 lb</td>
<td>403,000</td>
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<tr>
<td>1,000 lb</td>
<td>253,600</td>
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<tr>
<td>2,000 lb</td>
<td>21,000</td>
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<tr>
<td>3,000 lb</td>
<td>864</td>
</tr>
<tr>
<td>4,000 lb</td>
<td></td>
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<tr>
<td>5,000 lb</td>
<td>41</td>
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<table>
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<th>Incendiaries</th>
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<tr>
<td>25 lb</td>
<td></td>
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<tr>
<td>50 lb (Phosphorus)</td>
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<tr>
<td>90 lb</td>
<td>413,000</td>
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<tr>
<td>250 lb</td>
<td>7,000</td>
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### Round 1: Target Planning

- **RAF**: Area/City Bombing
- **USAAF**: Precision Strategic Bombing
German Radio Navigation
Knickebein

Fig. 9.1 Knickebein. Germany's first navigational and targeting system.

X-Gerät

Fig. 9.2 X-Gerät. X-Gerät was on the same principle as Knickebein but
announced the need for more accurate beams and precision timing of bomb
release, plus resistance to countermeasures. Working at about 75 megahertz,
it used three approach beams: one broad, with two fine beams within it.

Facing a target area

The layout of the X-Gerät beams near Coventry on the night of 14 November 1940

The distance from A to B is 30 km.

The distance from B to C is 60 km.

The distance from C to Coventry is 30 km (23.1 nautical miles).

Target: Coventry, target or bombing drop warning, closing pair of
draughtsman's pens in release control mechanisms.

(x-axis)

(x-axis)
German Radio Navigation
Y-Gerät

Fig. 9.3 Y-Gerät attempted high precision by commanding bomb release when the bomber, flying along its beam, had reached an exactly determined range from the base station. The range was measured by transmitting to the bomber a 300 hertz signal, carried as a modulation on the radio beam at about 43 megahertz. The bomber returned the modulation on a slightly different carrier frequency, enabling the base to measure the phase shift due to the time taken to go out and back. This gave the range. The two-way communication proved easy to jam and Y-Gerät was not successful.

British Counter Measures

- Jamming
- Beam Bending
Radio Navigation
British Approach—Gee

- 3 xmiters: Master, A, B
  - START: Master emits pulse
  - 1 ms: Slave A emits pulse
  - 2 ms: Master emits double sync pulse
  - 3 ms: Slave B emits pulse
  - Repeats every 4 ms/250 per s
- Difference in time between master and slaves defines a unique point where two hyperbolas intersect
- Limited precision because of difficulty in syncing slaves with master

Radio Navigation: British Approach--Oboe

- Many stations placed around England
- Any can be a Cat or Mouse
- Very accurate! 110m @400km
- Used by Pathfinders to mark targets
Formation Defense
MGs and Mutual Support

Bombers 2, Figure 3: Eighth USAAF’s basic six-aircraft bombing formation.


Formation Defense

Bombers 2, Figure 4: Eighteen-aircraft bombing formation introduced in September 1942.

Video Interlude

• Bomber Tactics
Bomb Effects
Cologne After 1000 bomber raid 1942

Bomb Effects
Dortmund 1945
Bomb Effects
Hamburg, after a shattering assault in 1943:
40,000 dead and 70% of the city destroyed

Bomb Effects
Peenemunde before and after concentrated attack, 1943.
44 aircraft lost. The first V2 fell on London in 1944.
Bomb Effects
Phillips factory, Eindhoven, 1942, attacked by 93 aircraft. 148 civilians killed, production stopped for 6 months.

Bomb Effects
Mohne dam after raid by highly trained crews, at night. 8 of 18 planes failed to return.
Bomb Effects

Lancaster and Grand Slam Bomb (22,000 lbs.)
Challenge of Precision Bombing
Le Havre, 1944

Challenge of Precision Bombing
Emmerich, 1943
Paulliac, 1944, target markers have just been released.

Paulliac, 1944, 5 minutes later.
Target indicators bursting over Frankfurt, 1944, laid by Pathfinders
Night Photography
Fires and Searchlights Ruin Photos
Ground Radar
Map and H2S view of the Zuider Zee dam

Ground Radar
Map and H2S view of Oslo Fjord, 1943, during an anti-shipping strike
Bomber Vulnerability
Heavy bomber hit by flak at 45000 feet

Round 2: Allied Technology Development
Questions for Discussion: German Defense

- How to make bombing more expensive
  - by destroying bombers
  - by leading bombers off target
- How to detect incoming raids?
- How to coordinate response to incoming raids?
- How to engage bombers at night?

German Radars

- Higher frequencies/shorter wavelengths than comparable British radars
- Ability to tilt and rotate
- For coast and inland defense
- 100 km range at 10,000 feet

![Freya radar](image-url)
German Radars

- Wurzburg tracking radars
  - Elevation and azimuth easily positioned
- 25 km range

German Night Fighter

Airborne Radar

**Fig. 10.1 Stag Antlers** The stag antler antennas of the Lichtenstein interception radar (shown here on a Messerschmitt 110) enabled leading fighter aces to build up unsurpassed scores. Paradoxically, the antlers mobilised both an outdated technology and...
Night Fighter Defense

- No effective night escorts until late in the war
- Surface radars & human controllers vector night fighters to bombers
- Bombers illuminated by searchlights makes them visible
- Nightfighters attack from below and behind, very difficult to see
- Affects the targets in the end: destroy the German airforce!

Round 3: German Response
Defensive Technologies and Response

- Searchlights
- AA Guns
- Proximity Fuze
- Airborne Radars for interception
- Fly high
- Fly high
- Window/Chaff
- Window/Chaff

Offensive Technologies and Response

- Longer range, heavier bombers
- Longer range escorts with drop tanks
- Surface radars for night target identification
- Gyrostabilized bomb sights
- Guided bombs
- Better interceptors (Jet and Rocket Fighters)
- Jamming
- Distribute production
Measure-Counter Measure-Counter-Counter Measure

- “The atom bomb ended the war, but radar won it.”
  - Radar-Jamming-Higher Frequency or Frequency Agile Radar
  - Radar-Window-Doppler Radar that discriminates between slow moving strips of metal and airplanes
  - Beam Radio Navigation-Jamming or Beam Bending-Alternative Non-Beam Navigation Approaches

U.S. Strategic Bombing Survey

- [http://www.anesi.com/ussbs02.htm](http://www.anesi.com/ussbs02.htm)
  - “The city attacks of the RAF prior to the autumn of 1944, did not substantially affect the course of German war production. German war production as a whole continued to increase.”
  - “The city area raids have left their mark on the German people. Far more than any other military action ... these attacks left the German people with a solid lesson in the disadvantages of war. It was a terrible lesson; conceivably that lesson, both in Germany and abroad, could be the most lasting single effect of the air war.”
U.S. Strategic Bombing Survey

- "Conventionally the air forces designated as "the target area" a circle having a radius of 1000 feet around the aiming point of attack. While accuracy improved during the war, Survey studies show that, in the over-all, only about 20% of the bombs aimed at precision targets fell within this target area."
- Schweinfurt Raids: Massed attacks against ball-bearing plants successfully and dramatically reduced production but at unsustainable cost in crew losses (long range penetration without benefit of fighter escort—formation flying didn't work)
- Loss of planes vs. loss of pilots

German Aircraft Production

<table>
<thead>
<tr>
<th>Year</th>
<th>1939</th>
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