Background Data:
Strategic Air Offensive vs. Germany

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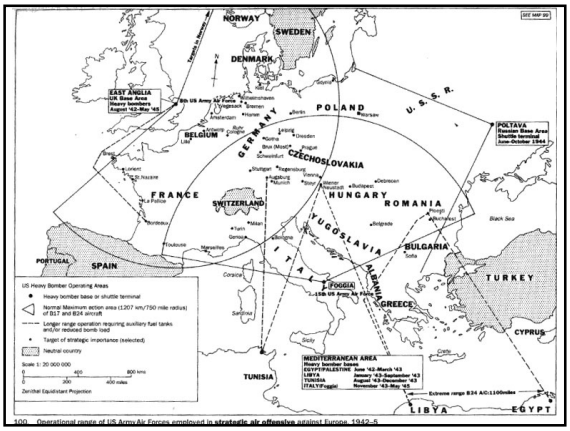
U.S. vs. British Viewpoints

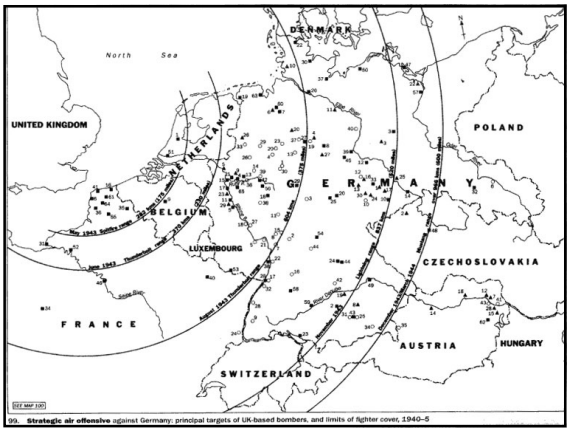
- Goal: "destruction and dislocation of the Germany military, industrial, and economic system and the undermining of the morale of the German people to the point where their capacity for armed resistance is fatally weakened"
  - U.S.: Accurate (daylight) bombing of strategic industries and services to 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?



100. Operational range of US Army Air Forces employed in strategic air offensive against Europe, 1942–5



99. **Strategic air offensive** against Germany: principal targets of UK-based bombers, and limits of fighter cover, 1940–5

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

Bombs: Numbers and types of bombs dropped by RAF Bomber Command, 1939–45, during the 389,809 sorties flown. The total came to 955,044 tons.

Type	Total no.
Fragmentation (F)	
20 lb	5,000
General purpose (GP)	
40 lb	42,939
250 lb	149,656
500 lb	531,334
1,000 lb	82,164
1,800 lb	2,141
4,000 lb	217
Semi-armour-piercing (SAP)	
500 lb	11,600
Armour-piercing (AP)	
2,000 lb	Exact figure is not known but less than 10,000
High Capacity (HC)	
2,000 lb	28,633
4,000 lb	68,000
8,000 lb	1,088
12,000 lb	193
Medium Capacity (MC)	
500 lb	403,000
1,000 lb	253,800
4,000 lb	21,000
12,000 lb Tallboy	854
22,000 lb Grand Slam	41
Incendiaries	
4 lb	80,000,000
25 lb	20,000
30 lb (Phosphorus)	3,000,000
30 lb 'J'	413,000
250 lb	7,000

Source: Macbean, J. A. and Hogben, A. S., *Bombs Gone*, (Yeovil, 1990).

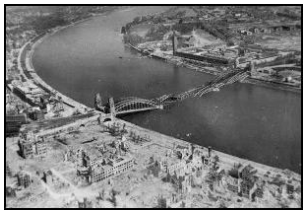
Bomb Types

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

Explode on contact
vs.
Penetrate and then explode

Round 1: Target Planning

- RAF: Area/City Bombing
- USAAF: Precision Strategic Bombing



German Radio Navigation
Knickebein

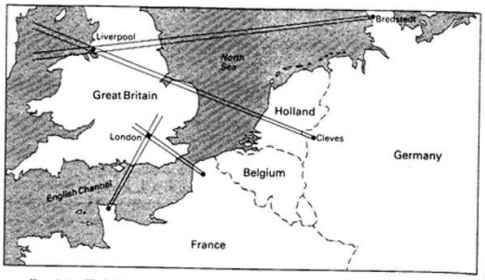


FIG. 9.1 **Knickebein** Germany's first navigational and targeting system

German Radio Navigation
X-Gerät

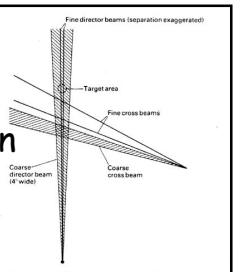


FIG. 9.2 **X-Gerät** X-Gerät was on the same principle as Knickebein but answered the need for more accurate beams and precision timing of bomb release, plus resistance to countermeasures. Working at about 75 megahertz, it used three approach beams: one broad, with two fine beams within it either serving for precision approach. The first cross beam was broad, serving to alert the crew. The second was fine, encountered normally 20 kilometres before the target. It was the signal to start a stop-watch with two hands, one moving faster than the other. The third beam, 15 kilometres further on and 5 kilometres before the target, was the signal to press the stop-watch knob again. This stopped the fast hand. When the slow hand caught up, an electrical contact caused bomb release. In other words the stop-watch measured the aircraft's time to cover 13 kilometres and allowed for another 5 kilometres to be traversed, assuming the same speed. To discount the forward distance the bombs would travel after release. Depending on height, an auxiliary hand, moving with the fast hand, was off-set backwards by an adjustable amount; this hand made the electrical contact. Jamming of X-Gerät was not very effective.

German Radio Navigation
Y-Gerät

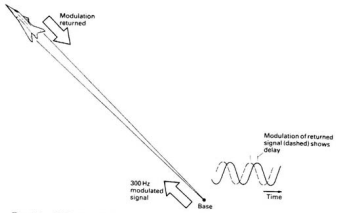


FIG. 9.3 **Y-Gerät** Y-Gerät attempted high precision by commanding bomb release when the bomber, flying along its beam, had reached an exactly determined range from the base station. The range was measured by transmitting to the bomber a 300 hertz signal, carried as a modulation on the radio beam at about 45 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.

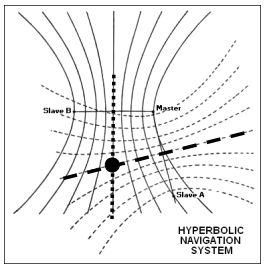
British Counter Measures

- Jamming

- Beam Bending

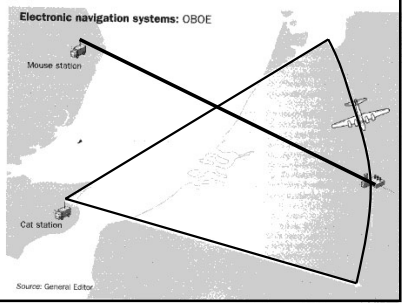
Radio Navigation
British Approach—Gee

- 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 sync'ing slaves with master



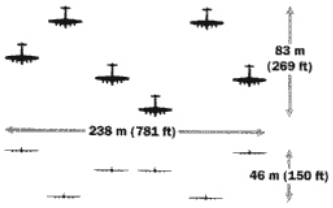
Radio Navigation:
British Approach--Oboe

- 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

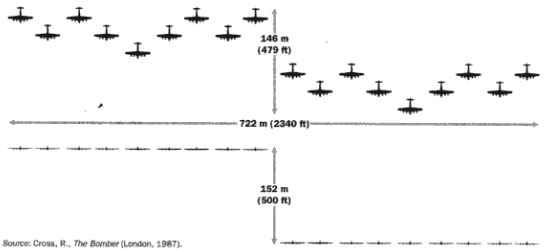
Bombers 2, Figure 3: Eighth USAAF's basic six-aircraft bombing formation.



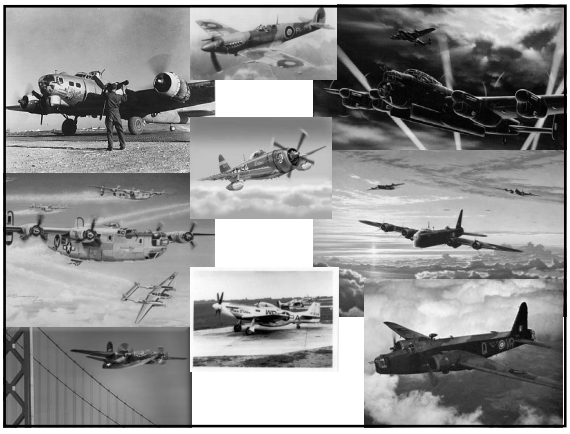
Source: Cross, R., *The Bomber* (London, 1987).

Formation Defense

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



Source: Cross, R., *The Bomber* (London, 1987).



Video Interlude

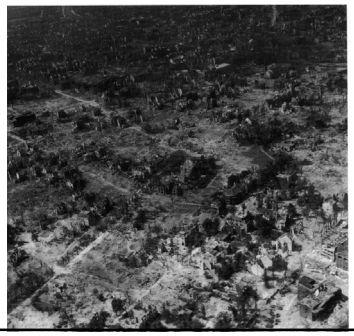
- Bomber Tactics

Bomb Effects

Cologne After 1000 bomber raid 1942

Bomb Effects

Dortmund 1945

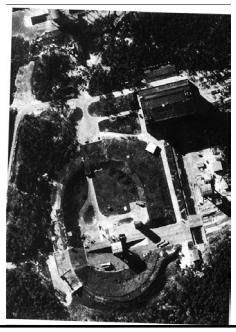


Bomb Effects

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.

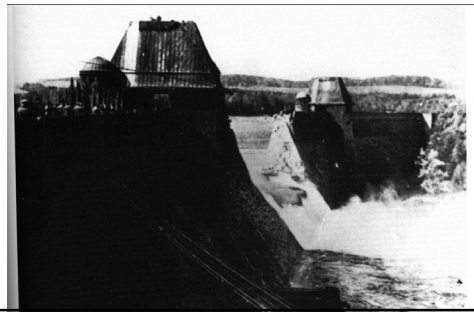


Bomb Effects

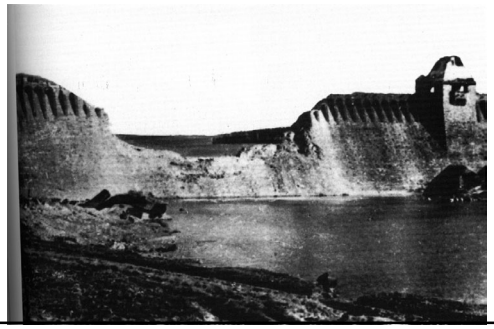
Phillips factory, Eindhoven, 1942, attacked by 93 aircraft.
148 civilians killed, production stopped for 6 months

Bomb Effects

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

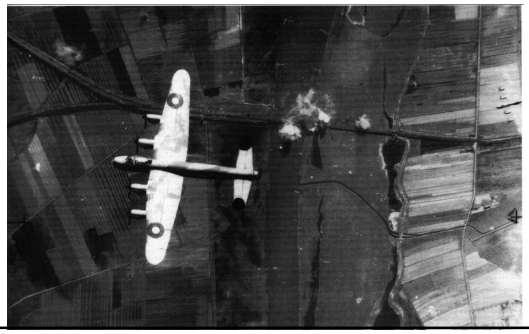


Bomb Effects



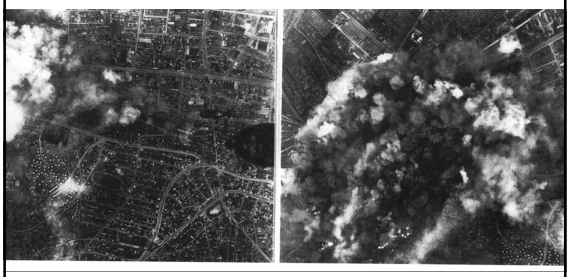
Bomb Effects

Lancaster and Grand Slam Bomb (22,000 lbs.)



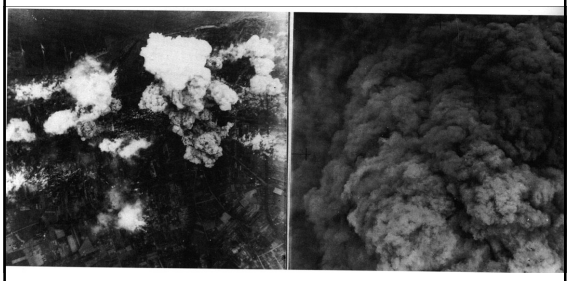
Challenge of Precision Bombing

Le Havre, 1944



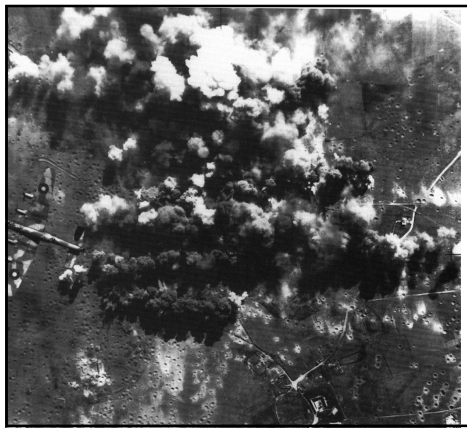
Challenge of Precision Bombing

Emmerich, 1943



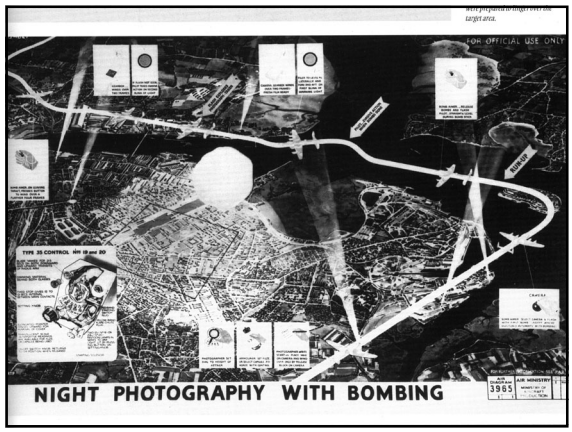
Paulliac, 1944, target markers have just been released

Paulliac, 1944, 5 minutes later



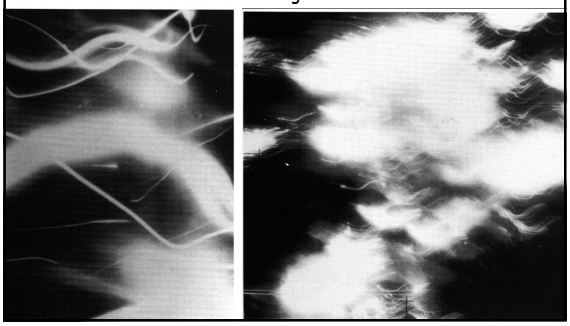
Cap Griz Nez 1944

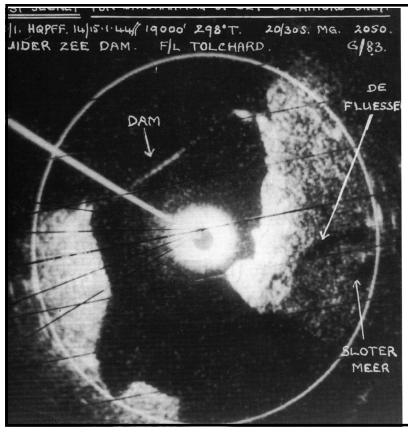
Target indicators bursting over Frankfurt, 1944, laid by Pathfinders



Night Photography

Fires and Searchlights Ruin Photos



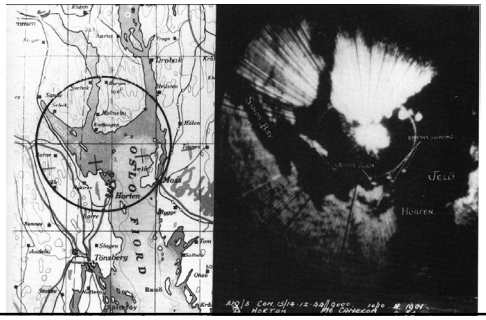


Ground Radar

H2S view of the Zuider Zee dam

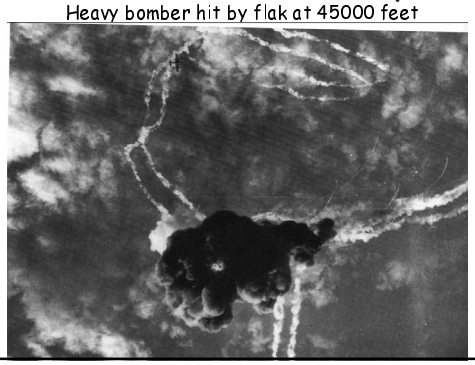
Ground Radar

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

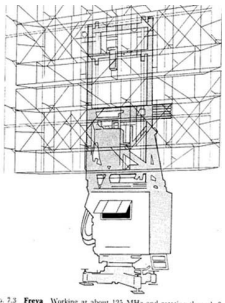


Fig. 7.3 **Freya** Working at about 125 MHz and rotating through 3 degrees, Freya was the main German surveillance radar throughout t Second World War, deployed for both coastal and inland surveillance.

- 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

German Radars

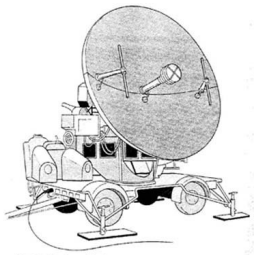
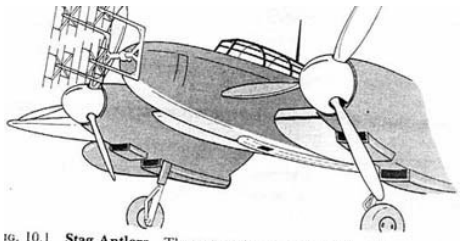


Fig. 8.2 **Wurzburg** Wurzburg was primarily a target-tracking radar, combining a parabolic antenna with a central rotating dipole to obtain conical scanning. It provided accurate azimuth and elevation. Frequency was about 560 MHz. The vertical rods are secondary radar (identification friend or foe (IFF)) antennas.

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

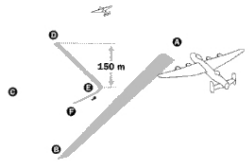
German Night Fighter

Airborne Radar



IG. 10.1 **Stag Antlers** The stag antler antennas of the Lichtenstein ai terception radar (shown here on a Messerschmitt 110) enabled leading ghter aces to build up unsurpassed scores. Paradoxically, the antler mbolised both an outdated

Bombers 2, Figure 2:
The Corkscrew Manoeuvre



A If the fighter attacks from the port side, the bomber pilot banks at 45° and dives to port at full throttle.
B After descending for about 300m. (1,000ft) the pilot starts climbing. He is still turning to port.
C Halfway through the climb he banks to starboard, but continues to climb. This reduces his speed sharply which sometimes induces the attacking fighter to overshoot.
D After regaining the same altitude, and while still turning to starboard, the pilot starts another dive.
E He descends half the distance of the previous dive, then turns to port.
F If the pilot has not shaken off the fighter, he can repeat the manoeuvre.

Source: Cross, R., *The Bomber* (London, 1987).

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
  - "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

Year	1939	1940	1941	1942	1943	1944	1945
Bombers	737	2852	3373	4337	4649	2287	
Fighters	739	3349	4251	6764	14162	30781	6040
Recon	163	971	1079	1067	1117	1686	216
Seaplane	100	269	183	238	259	141	
Transport	145	388	502	573	1028	443	
Gliders		378	1461	745	442	111	8
Liaison	46	170	431	607	874	410	11
Training	588	1870	1121	1078	2274	3693	318
Jets						1041	947