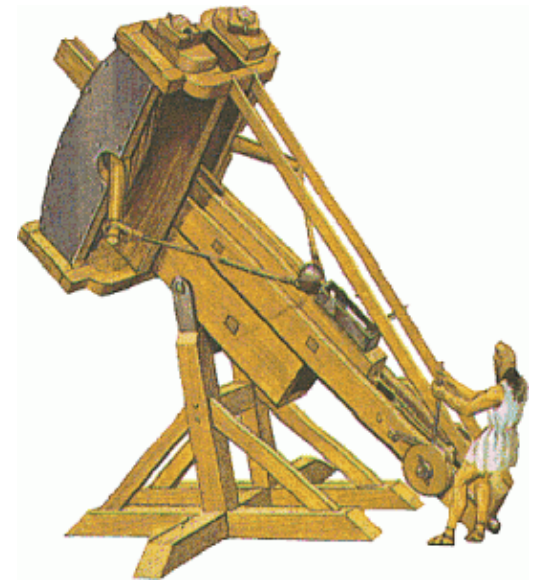


The Development of Precision Guided Munitions

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Outline:

- **Conceptualizing Precision Warfare**
- **History of PGMs:**

Early Guided Bombs in World War 2

The Korean War 1950s

The Vietnam War 1960s

The Yom Kippur War 1970s

The Gulf War 1990s

The Iraq War 2000s

Technological Discovery

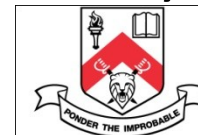
Experimentation

Implementation

- **Conditional Utility of PGMs**

Defining a Precision Weapon:

- Bomb or missile that can be aimed and directed against a single/multi targets, relying on external guidance or its own guidance system;
- Launched from aircraft, ships, submarines, and land vehicles, or even by individual soldiers on the ground;
- High probability of hitting a target; depending on timely and accurate intelligence;
- Modern PGMs:
Accuracy, Increased Range, Lethality, Flexibility and Portability;



Motivations for PGMs:

- **Political and Psychological**

- **Alternative to attrition and annihilation as a means for coercion:**

- From mass destruction to “precise, calculated, damage”;

- **Minimize collateral damage to both attacker and defender:**

- “Efficient, effective, humane tools of foreign policy”;

- **Minimize resource allocation to achieve a “decisive victory”;**

- **Military**

- **Operational need to increase lethality and efficiency against point targets;**

- **Stand-off engagement capability** → The concept of “empty battlefield”

- **Military Effectiveness:**

- From “multiple-sorties-per-target” to “multiple-targets-per-sortie” mode;

- Ability to destroy any selected target at will with minimum losses;

History of PGMs:

393 B.C. The Battle of Abacaenum
Dionysius I - “Katapeltikons”

Two types of catapults:

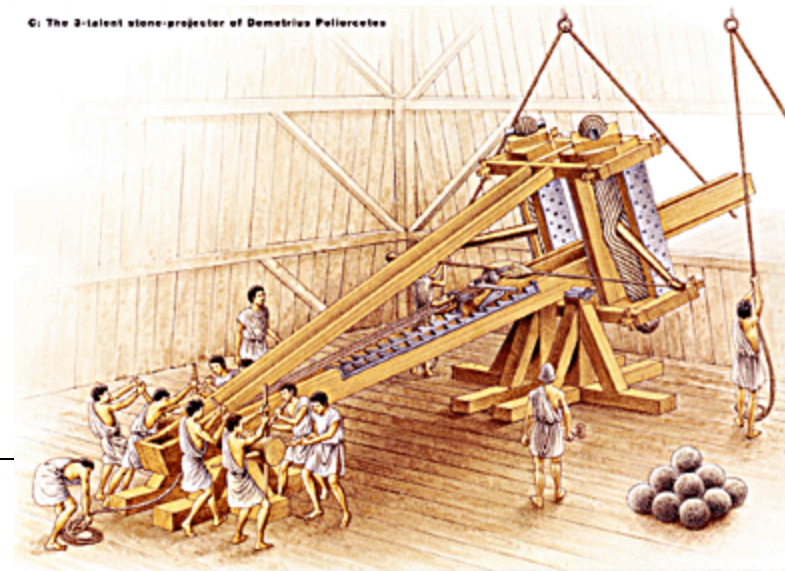
Single-armed catapult for hurling larger objects;
Double-armed machine: Ballista;

Capable to alter the trajectory and firing direction of 40-
pound stones hurled from 300 yards away;

Munitions: large wooden projectiles,
iron-clad darts or heavy bolts,

“Quest for the ultimate weapon...”

Ponder the Improbable



WW1: The Advent of Air Power

Aerial bombing almost non-existent prior to WW1.

Targeting accuracy, range, payload capacity – abysmal;

BUT... early air-power theorists shaped the development of new doctrines and technologies:

→ Enemy's "vital centers" could be destroyed with well-planned bomber formations;



Interwar Years

Factors and Release Conditions

Altitude

Speed

Dive Angle

Separation effect

Bomb's Flight Path

Gravity

Aerodynamic Drag

Wind Velocity

Air Density

Air Temperature



1935: The Norden Bombsight Tests
Calculated ground and wind speeds,
altitude and closing rates;

Designed to improve the accuracy of
dropping gravity bombs;

WW2: Germany

1939 Germany starts developing guided weapons;

(Dr. Max Kramer)

1942 FX-1400 (Fritz-X) Air-to-Ship Radio-Guided Glide Bomb

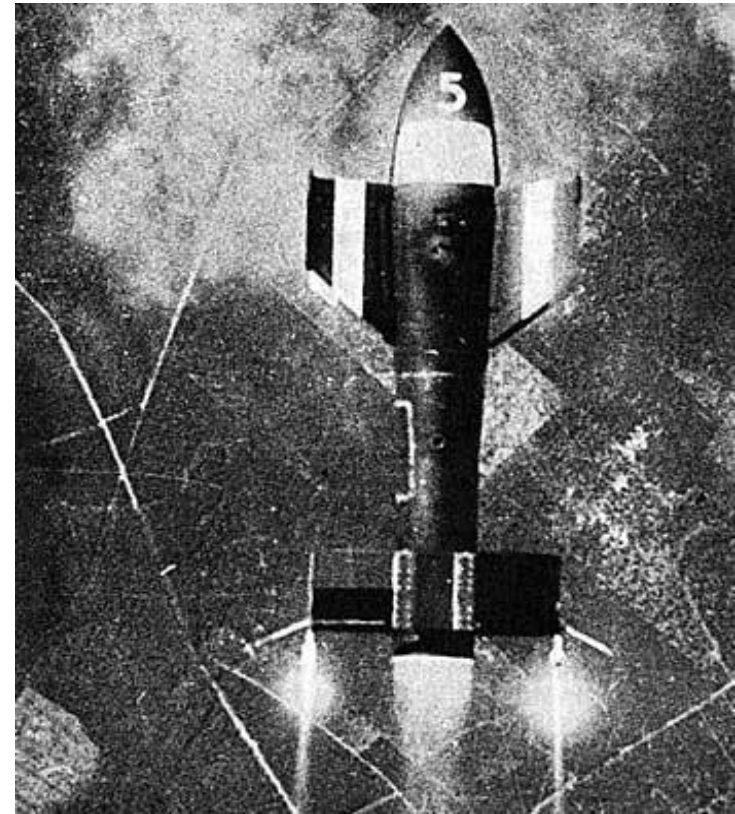
1943 2x Dropped from Dornier Do-217 bomber (Sept. 9)

- sinking the defecting ultramodern Italian battleship Roma;

Attack Profile: 20,000 ft. / 3 miles from target;
(3,400 lb. / 660 lb. explosives)
CEP: 15 ft.;

Around 750 produced and stockpiled;

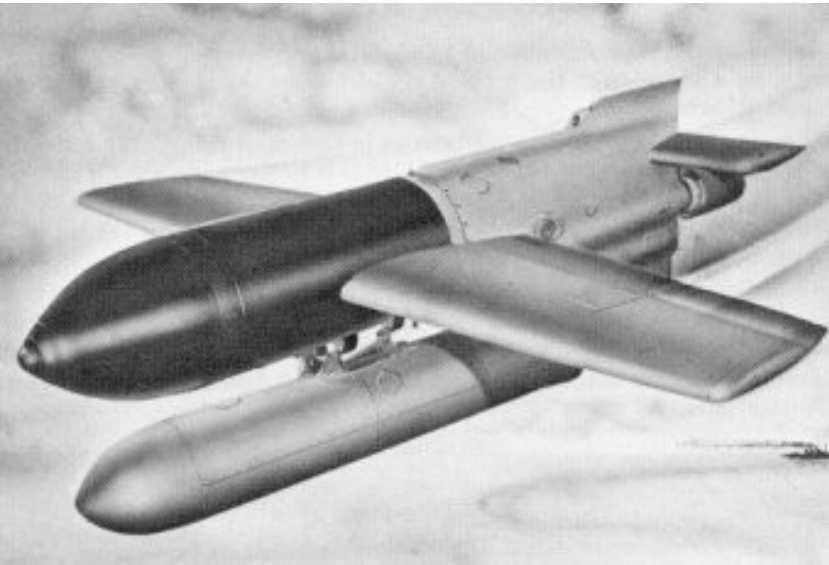
In combat, only 30% direct hits;



WW2: Germany

Henschel Hs-293 Glide Bomb (Prof. Herbert Wagner)

- Glide bomb with a conventional wing; small liquid-fueled rocket;
- Smaller than Fritz-X (1,500 lb.)
- First use in combat: Aug. 25, 1943 against Allied shipping;



Attack Profile:

Release @ 3,280 ft./6 miles from target ;

**90% direct hits in training;
40-50% in combat;**

WW2: Germany

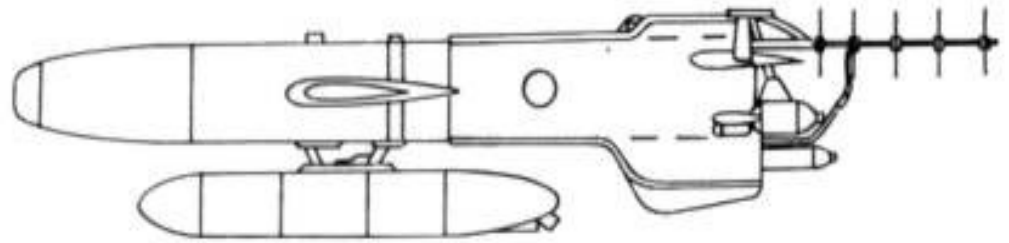
Hs-293B: Wire-guided control

293D/H: Nose-mounted television camera + radio uplink!

Range: 19 miles

Around 255 produced;

In 1944, after the D-Day landings, Do-217 aircraft used the Hs-293 to attack bridges at River See and River Selume on the Cherbourg peninsula, in an attempt to stall the Allied advance from the bridgehead.



WW2: Allies

ATSC VB-1/VB-2 Azon

VB-3/VB-4 Razon Guided Bombs

- The Azon series: first operational U.S. guided bombs;

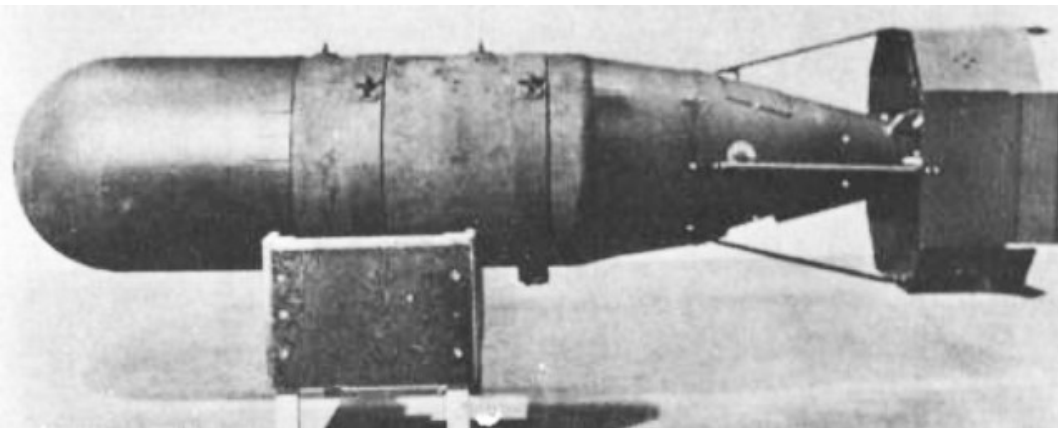
VB-1 Azon - 'Azimuth Only'

Radio command link controlled tail-kit attached to a standard 1,000 lb. bomb body;

- Enters production in June 1943; Deployed from Feb. 1944;

- Used extensively in Burma for bridge dropping strikes:

1,357 AZONs destroyed 41 bridges, including the famous Kwai River bridge.



WW2: Allies

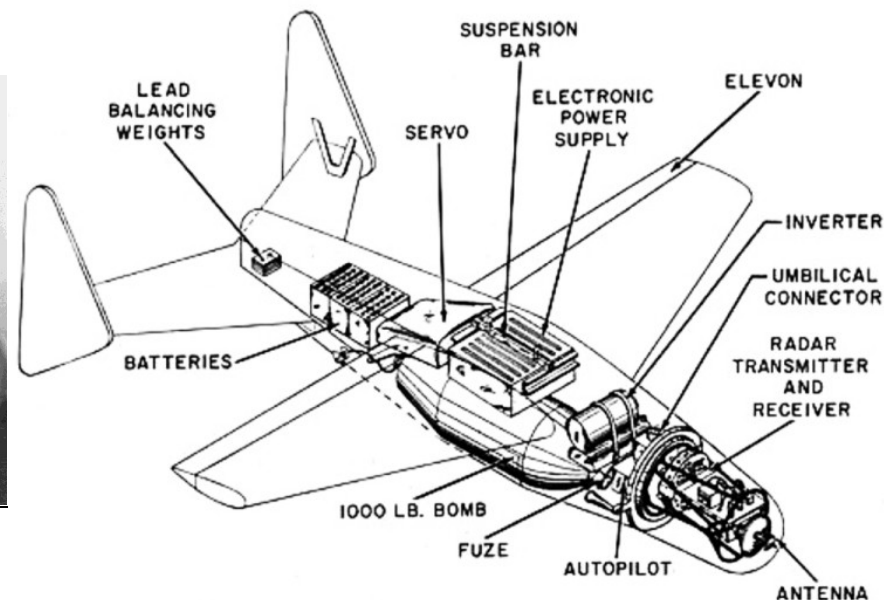
SWOD MK 9 / ASM-N-2 Bat Glide Bomb

(Special Weapon Ordnance Device)

- Radar-guided glide-bomb, developed by the U.S. Navy;
 - Arguably the most advanced of the early guided bombs;
 - Designed as a standoff anti-ship weapon, with a secondary role of attacking coastal targets ;
- **The Bat was the first fully automatic fire and forget guided weapon;**
- **First use: April 1945 near Borneo;**



Ponder the Improbable



The Korean War

VB-3/VB-4 Razon Guided Bombs ASM-A-1 Tarzon (VB 13)

- Largest bomb used in combat during the Korean War:
Tarzon - 12,000-pound (5,400 kg) bomb;
 - Used in strikes against North Korean bridges and other hardened targets;
 - Due to safety and cost issues, it was withdrawn in 1951;
Could not fit inside the bomb bay of a B-29!
 - Only 33 Tarzon combat drops / 27 successful;
- Korean War guided bomb experience nearly similar to WW2;
- Conventional weapon R&D lost priority;
- U.S. guided weapons program stops for the next 15 years...

[Tallboy, Range and Azimuth Only]



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Ponder the Improbable



1950s:

Inventory of U.S. fighter aircrafts optimized for nuclear combat;

Aircraft designed for high-speed, low-level delivery of small nuclear weapons;

“Nuclear training will in every instance take precedence over non-nuclear familiarization and qualification.”

The Vietnam War

- **New operational requirements:**
 - supply interdiction;
 - collateral damage mitigation;
- **Shift in national security policy** (Flexible Response) and **military doctrine** (Limited War);
- **Introduction of operationally effective television, infrared, laser, and visually guided munitions;**



During the Vietnam War, the USAF and USN drop 26,690 guided weapons – only 1% of all bombs dropped (3,376,000 bombs)

The Vietnam War

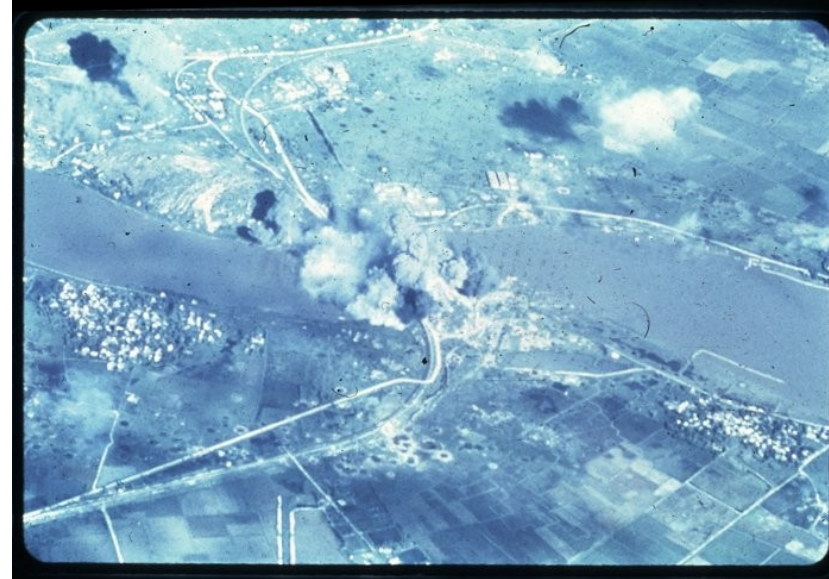
USAF: Laser Guided Bombs: Paveway 1

1965 - USAF Laser Guided Bomb (LGB) program

1966 - Two different prototypes tested;

1968 - First operational tests in Vietnam;

1971 - Full production (920 kits per month)/
Variety of LGBs



Thanh Hoa Bridge over the Song Ma River,
North Vietnam (May 2, 1972)

1972-1972:

10,651 LGBs dropped over SEA (5,107 direct hits)



1. Nose Seeker;
2. Guidance and Control Unit (GCU);
3. Canards and Tail Fins;

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The Yom Kippur War and the 1970s

Electro-Optical Guided Bombs used by the IDF:

- 88 Walleye Is (84 Direct Hits 96%) 70 tanks, 18 bridges
- 32 HOBOS (25 Direct Hits 78%)
- While the number of targets destroyed by GD is small, the results are decisive in stopping Arab tanks during the later stages of the war;
- Desert environment provided ideal contrast conditions for the electro-optical seekers → **demonstrated the capabilities of new gen .PGMs;**

----->

Shaped the direction and character of American, Soviet, and Israeli strategic perspectives and debates on the future of warfare!

1986: Raid on Libya

Pave Tack pod

High-resolution,
Thermal-imaging sensor,
Highly accurate ranging info
for target detection and tracking



+ Terrain-following Radar

Ability to penetrate enemy
territory at night, in all types
of weather, and at altitudes
as low as 200ft.



+ Low-Level LGB (Paveway III)



Capability to attack pinpoint targets at night.



The Gulf War and the 1990s

- By the early 1990s, the arsenal of guided bombs covers the **spectrum of day or night with the flexibility of laser guided bombs** and the extreme accuracy and standoff capability of the **GBU-15** electro-optical glide bombs family;
- **Desert Storm:** 20,400 PGMs out of 265,000 bombs (less than 10%)
...but accounted for 75% of total damage;

Targets: airports, C2 centers, missile launchers, radar stations, Iraqi forces

GBU-12 LGB

GBU-15 EOGB

GBU-24 LGB

GBU-27 LGB

AGM-65 Maverick



Increased reliance on PGMs shaped the diffusion of RMA theory, processes, and debate in the 1990s;

PGM Guidance Technologies – 2000s

Technology	Key Features
Semi-active laser homing	Very high precision, vulnerable to weather & countermeasures
Electro-Optical (VIS/IIR)	Autonomous, flexible retargeting with datalink
GPS/IMU	Autonomous/All Weather vulnerable to countermeasures;
Scene Matching (EO)	Autonomous/electro-optical imaging from space, Image-enhancing algorithms, scene-matching guidance
Terrain Mapping	Autonomous
Active Radar/MMW Radar (Millimeter Wave)	Autonomous, engagement of selective moving targets, all weather capability
LADAR (Light Direction & Ranging)	Flexible targeting, Autonomous selective targeting;

Major Ongoing PGM Programs – 2000s

Long-Range/CM	Medium Range	Short-Range
JASSM (USA) Joint Air-to-Surface Standoff Missile	JSOW (USA) Joint Standoff Weapon	PAVEWAY II-IV (USA)
TLAM (USA) Tomahawk Land Attack Missile	LOCAAS (USA) Low Cost Autonomous Attack System	JDAM (USA) Joint Direct Attack Munition
SLAM-ER (USA) Standoff Land Attack Missile - Exp. Resp.	NLOS/PAM-LAM (USA) Non-Line of Sight Launch System	SDB (USA) Small Diameter Bomb
STORM SHADOW (UK)	SPICE (ISRAEL)	HELLFIRE LONGBOW (USA)
KPED 350 TAURUS (GER/SWE)	DELILAH (ISRAEL)	VIPER STRIKE (USA)
BRAHMOS (INDIA/RUS)	RAPTOR (SOUTH AFRICA)	AASM (FRANCE) Armement Air-Sol Modulaire
		SPIKE-ER (ISRAEL)
		LIZARD (ISRAEL)

Conditional Utility of PGMs:

- Without timely and accurate intelligence to provide targets, PGMs are effectively useless; targets must be meticulously selected and assessed;
- Determining the strategic outcomes of a PGM attack or an enemy's reaction to it remains elusive;
- The Fog of War remains: technology that aims to distinguish between combatants and non-combatants does not exist;
- Adversaries may interpret heavy reliance on PGMs as signaling a lack of will, weakening deterrence;
- Collateral damage can't be avoided, missiles go astray;
- “Quick decisive victories with minimum casualties?”

“One may be tempted to believe that moderate courage coupled with great intelligence will be more effective than moderate intelligence and great courage...

If we read history with an open mind, we cannot fail to conclude that , among all military virtues, the energetic conduct of war has always contributed most to glory and success.”

- Carl von Clausewitz, *On War*