



A MISSILE IS A GUIDED PROJECTILE DESIGNED TO DELIVER A PAYLOAD (USUALLY EXPLOSIVE) TO A SPECIFIC TARGET

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ABSTRACT

A missile is a self-propelled, guided, or ballistic weapon designed to travel through the air to destroy a target, typically carrying an explosive warhead. Historically and broadly, it refers to any object thrown or projected at a target, such as a rock or projectile. **Key Aspects of Missiles:** Definition: A guided or unguided weapon propelled toward a target, often featuring a warhead that explodes on impact. **Types:** Guided Missile: Controlled during flight toward a target. **Ballistic Missile:** Follows a fixed trajectory, often in high-altitude arcs. **Components:** Typically include a target detection system, guidance system, flight system, and a warhead. **Etymology:** Derived from the Latin missiles, meaning "that may be thrown". **Broader Usage:** Historically and in some contexts, it can mean any projectile weapon, including stones, arrows, or bullets. Missiles are designed for long-distance, precision, or high-destructive impact.

KEYWORDS: surface-to-surface, air-to-surface, surface-to-air and air-to-air missiles, anti-ship missile.

INTRODUCTION

Dr. A.P.J. Abdul Kalam (1931–2015) was a renowned Indian aerospace scientist and statesman who served as the 11th President of India (2002–2007). Widely known as the "**Missile Man of India**" he played a pivotal role in developing India's civilian space program and military missile capabilities, including leading projects for the **Agni** and **Prithvi** missiles.

A missile is an airborne ranged weapon capable of self-propelled flight aided usually by a propellant, jet engine or rocket motor. Historically, 'missile' referred to any projectile that is thrown, shot or propelled towards a target; this usage is still recognized today with any unguided jet- or rocket-propelled weapons generally described as rocket artillery.



Figure-1: Missile Man of India [Dr. A.P.J. Abdul Kalam].

Airborne explosive devices without propulsion are referred to as shells if fired by an artillery piece and bombs if dropped by an aircraft. Missiles are also generally guided towards specific targets termed as guided missiles or guided rockets. Missile systems usually have five system components: targeting, guidance system, flight system, engine, and warhead. Missiles are primarily classified into different types based on firing source and target such as surface-to-surface, air-to-surface, surface-to-air and air-to-air missiles.

Types: Tactical guided missiles are generally categorized according to the location of the launch platform and target. There are five types, **air-to-air**, **air-to-surface**, **surface-to-air**, **antiship**, and **antitank**, or **assault**. A missile isn't exactly a bomb, but rather a guided, self-propelled projectile that carries a warhead (which can be a bomb), while a traditional bomb is an unguided explosive dropped from an aircraft and relies on gravity to reach its target. The key difference is guidance and propulsion: missiles have engines and steering to actively navigate to a target, whereas bombs just fall.

- **Bomb:** An explosive device dropped from a plane, relying on gravity for descent (e.g., a gravity bomb).
- **Missile:** A self-propelled, guided weapon system that can steer itself toward a target, often carrying a bomb as its warhead.
- **Rocket:** Can be a missile's propulsion system or an unguided projectile, while a missile is typically a more sophisticated, guided weapon.

Think of it this way: A bomb is the payload (the explosive part), and a missile is the delivery system that actively guides that payload to its destination.

1. Air-to-air missiles (AAMs) are specialized, rocket-propelled guided weapons launched from aircraft to destroy airborne targets like fighters, bombers, and cruise

missiles. Modern AAMs are categorized by range—short-range (heat-seeking) or long-range (radar-guided)—and employ advanced technologies like ramjets, active radar homing, and dual-pulse motors to achieve high speeds, often exceeding Mach 4-5, with ranges surpassing or for advanced systems.

An air-to-air missile (AAM) is defined as a type of missile designed to be launched from an aircraft to engage and destroy other airborne targets, typically utilizing rocket propulsion to achieve high thrust for short durations. An air-to-air missile (AAM) is a missile fired from an aircraft for the purpose of destroying another aircraft in flight. AAMs are typically powered by one or more rocket motors, usually solid fueled but sometimes liquid fueled. Ramjet engines, as used on the Meteor, are emerging as propulsion that will enable future medium- to long-range missiles to maintain higher average speed across their engagement envelope.

Guidance Systems

Infrared (IR) Homing (Heat-Seekers): Typically used for short-range, dogfighting missiles (e.g., AIM-9X Sidewinder) by tracking an aircraft's engine heat.

Active Radar Homing (ARH): Used for medium/long-range "fire-and-forget" missiles (e.g., AIM-120 AMRAAM), allowing the pilot to engage and break away while the missile guides itself.

Range Classification

Short-Range (SRAAM): Optimized for close-in combat (approx. or less).

Beyond-Visual-Range (BVRAAM): Capable of engaging targets over with advanced variants like the European Meteor reaching over using ramjet technology.

Propulsion: Most use solid-fuel rocket motors, while modern long-range missiles often use ramjets for sustained high speed throughout the flight envelope.



Figure-2: Air-to-Air Missile.

Notable Examples

AIM-120 AMRAAM (USA): Primary Western medium-range radar-guided missile.

Meteor (Europe): Long-range, ramjet-powered missile.

R-37M (Russia): Hypersonic, very-long-range missile (Mach 6).

PL-15 (China): Long-range, active radar-guided missile.

Astra Mk 2 (India): Indigenous, dual-pulse motor missile.

AIM-260 JATM (USA): Future, top-priority, long-range missile.

Modern warfare relies on these missiles for air dominance, with "no-escape zones" defined by speed and maneuverability rather than just maximum sensor range.

2. Air-to-surface missile (ASM) or air-to-ground missile (AGM) is a guided weapon launched from aircraft (bombers, fighters, drones, helicopters) to destroy land or sea targets. Unlike unguided bombs, they use self-contained guidance (GPS, laser, TV, radar) and propulsion (rocket/jet) for precision, long-range stand-off, and high-speed, often surpassing 300 km range. An air-to-surface missile (ASM) or air-to-ground missile (AGM) is a missile designed to be launched from military aircraft at targets on land or sea. There are also unpowered guided glide bombs not considered missiles. The two most common propulsion systems for air-to-surface missiles are rocket motors, usually with shorter

range, and slower, longer-range jet engines. Some Soviet-designed air-to-surface missiles are powered by ramjets, giving them both long range and high speed.

Types & Targeting

Anti-Ship/Anti-Surface: BrahMos (450-600km range, 3x speed of sound) RBS-15 (300km) Kh-59MK2 (285km).

Anti-Tank/Tactical: Hellfire (laser seeker) Maverick (TV camera).

Anti-Radiation (Radar): Rudram (India), designed to destroy surveillance radars and communication stations.

Guidance Systems: Use inertial navigation, GPS/GLONASS, and terminal infrared or active radar seekers to achieve high precision, often within 1-3 meters.



Figure-3: Air-to-Surface Missile.

Standoff Capability: Allows aircraft to launch missiles from safe distances outside the reach of enemy air defenses, a critical feature for modern combat.

Propulsion: Generally powered by solid-fuel rocket motors for shorter range, or turbojets/ramjets for longer-range supersonic, or in some cases, hypersonic speeds.

Prominent Examples

- **BrahMos:** Supersonic cruise missile (India/Russia).
- **AGM-114 Hellfire:** Common anti-tank missile.
- **AGM-65 Maverick:** Tactical TV-guided missile.
- **Rudram Series:** Indian anti-radiation missiles.
- **RBS-15 Gungnir:** Swedish long-range anti-ship/land missile.

3. Surface-to-air missiles (SAMs) are ground- or sea-launched guided weapons designed to destroy aircraft, helicopters, UAVs, and other missiles. As primary modern anti-aircraft systems, they use radar or infrared guidance to provide air defense, ranging from man-portable (Stinger) to long-range strategic systems (S-400, Patriot).

Function: Designed to intercept and destroy aerial threats to protect ground assets, including bombers, fighters, and cruise missiles. A surface-to-air missile (SAM), also known as a ground-to-air missile (GTAM) or surface-to-air guided weapon (SAGW), is a missile designed to be launched from the ground or the sea to destroy aircraft or other missiles. It is one type of anti-aircraft system; in modern armed forces, missiles have replaced most other forms of dedicated anti-aircraft weapons, with anti-aircraft guns pushed into specialized roles.

Types by Range

- **Short-Range (VSHORAD/QRSA):** Mobile, quick-reaction systems like the Stinger or Trishul (500m to 9 km).
- **Medium-Range (MRSAM):** Systems such as the 9K37 BUKS-300, and Barak 8.
- **Long-Range (LRSAM):** Strategic, high-altitude systems like the S-400 and Patriot.

Guidance Systems: Use radar, infrared homing, or electro-optical systems for tracking.



Figure-4: Surface-to-Air Missile.

Prominent Examples

- **S-400 Triumf (Russia):** Capable of engaging targets up to 400 km away at altitudes up to 30 km, with a max speed of Mach 14.
- **Barak 8 (India/Israel):** Defends against aircraft, UAVs, and anti-ship missiles.
- **MIM-104 Patriot (USA):** A widely used long-range air defense system.
- **NASAMS (Kongsberg/Raytheon):** A network-centric short-to-medium range system.

4. Anti-Ship Missile: SAMs are integral to modern air defense, providing 360-degree coverage and rapid response to incoming threats. India is advancing its maritime strike capabilities with the development of the **Long-Range Anti-Ship Missile (LR-AShM)**. A hypersonic glide missile designed for the Indian Navy. Capable of speeds up to Mach 10 and a range exceeding 1,500 km, this weapon is designed to evade radars by flying at low altitudes, posing a significant threat to all classes of warships.

- **LR-AShM (India):** A 46-foot, two-stage solid-propellant hypersonic missile with a >1,500 km range. It uses a "quasi-ballistic" trajectory to evade defenses.
- **Hypersonic Speed:** Operating at Mach 10, the missile can reach targets 1,500 km away in roughly 15 minutes.
- **Low-Altitude Trajectory:** The missile flies low to avoid radar detection until the terminal phase.
- **Versatility:** Designed for coastal defense batteries and for launch from warships.
- **Global Context:** Other advanced anti-ship missiles include the US Navy's SM-6 Block IB (hypersonic, in development) and China's YJ-12, with reports suggesting Iran is acquiring advanced Chinese supersonic missiles (CM-302).

The LR-AShM project, along with Project Vishnu's scramjet-powered missiles, highlights a shift towards faster, more evasive anti-ship technologies to counter regional threats.



Figure-5: Anti-Ship Missile.

An anti-ship missile (AShM or ASM) is a guided missile that is designed for use against ships and large boats. Most anti-ship missiles are of the sea-skimming variety, and many use a combination of inertial guidance and active radar homing. A large number of other anti-ship missiles use infrared homing to follow the heat that is emitted by a ship; it is also possible for anti-ship missiles to be guided by radio command all the way. Anti-ship cruise missiles (ASCMs) are modern long-range weapons of naval combat, designed specifically to target ships. Due to their stealth, accuracy, and low-cost, ASCMs have become weapon of choice for militaries around the world.

5. Anti-Tank Guided Missiles (ATGMs) are specialized, precision-guided weapons designed to destroy heavily armored vehicles, featuring advanced guidance systems like Imaging Infrared (IIR) and laser, with modern systems utilizing "fire-and-forget" technology. Recent advancements (as of Jan 2026) include India's 3rd Gen MPATGM and Nag M2, which use tandem warheads to defeat reactive armor, often launched from tripods, vehicles, or helicopters.

Guidance Systems: Ranging from early wire-guided systems to modern laser-guided and IIR "fire-and-forget" missiles, allowing operators to move immediately after firing. An anti-tank guided missile (ATGM), anti-tank

missile, anti-tank guided weapon (ATGW) or anti-armor guided weapon is a guided missile primarily designed to hit and destroy heavily armored military vehicles. ATGMs range in size from shoulder-launched weapons, which can be transported by a single soldier, to larger tripod-mounted weapons, which require a squad or team to transport and fire, to vehicle and aircraft mounted missile systems.

Types of Warheads: Most rely on High Explosive Anti-Tank (HEAT) or tandem warheads designed to penetrate Explosive Reactive Armor (ERA).

Launch Platforms: These weapons are highly versatile, capable of being deployed by individual soldiers (Man-Portable), on light vehicles, or on attack helicopters (e.g., Helina).



Figure-6: Anti-Tank Guided Missiles.

Key Developments (2025-2026)

- **India:** The DRDO successfully tested the 3rd Gen MPATGM in January 2026, featuring an indigenous IIR seeker. The Indian Army is procuring 2,484 Nag Mark M2 missiles, which offer a 4 km range and fire-and-forget capability.
- **International:** Upgraded systems like the Russian Khirizantema-M are being developed with increased, potentially hypersonic, speeds to counter modern threats.

These systems are essential for modern warfare, providing infantry and light vehicles the ability to destroy main battle tanks (MBTs).

6. Ballistic missile is a rocket-propelled weapon that is guided during its ascent but follows a free-fall trajectory for most of its flight. It delivers warheads - containing either conventional explosives or potentially biological, chemical or nuclear munitions - over varying distances. A ballistic missile is a type of missile that follows a ballistic trajectory and is powered only during a relatively brief initial period—most of the flight is unpowered. Short-range ballistic missiles (SRBM) typically stay within the Earth's atmosphere, while larger missiles travel outside the atmosphere. The type of ballistic missile with the greatest range is an intercontinental ballistic missile (ICBM). The largest ICBMs are capable of full orbital flight.

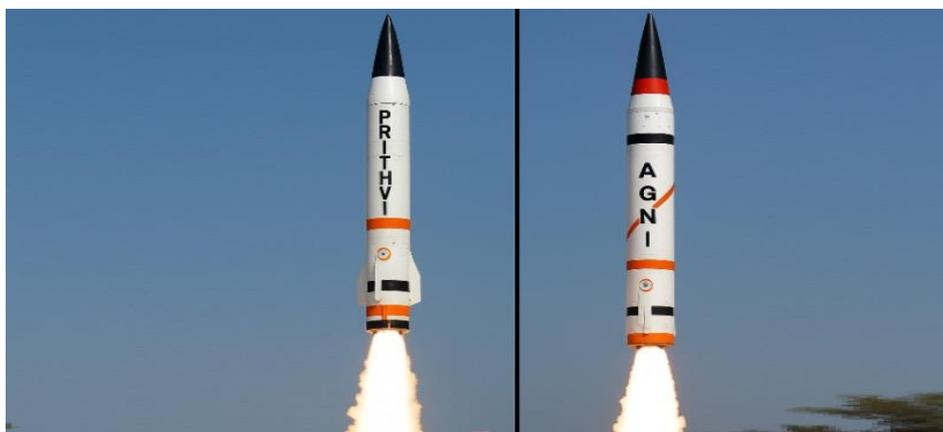


Figure-7: Prithvi & Agni Missile.

These missiles are in a distinct category from cruise missiles, which are aerodynamically guided in powered flight and thus restricted to the atmosphere. During

midcourse phase, ICBM [Intercontinental Ballistic Missile] can travel around **24,000 kilometers per hour (15,000 miles per hour)**. Terminal Phase begins when

the detached warhead(s) reenter the Earth's atmosphere and ends upon impact or detonation. Missile speed is 6–8 kilometers per second (22,000–29,000 km/h; 13,000–18,000 mph) at intercontinental ballistic missile ranges. Missile speeds and blast effects vary significantly based on whether they are cruise or ballistic, with modern advancements focusing on hypersonic capabilities that combine extreme velocity with high destruction potential.

Missile Speed Classifications

- ❖ **Hypersonic Missiles:** Travel at speeds exceeding Mach 5 (roughly 3,800 mph or 6,100 km/h). Examples include the Russian Avangard (Mach 20–27) and the Iranian Fattah-1 (Mach 13–15).
- ❖ **Supersonic Cruise Missiles:** Travel faster than the speed of sound, such as the BrahMos (Mach 2.8).
- ❖ **Intercontinental Ballistic Missiles (ICBMs):** During the midcourse phase, ICBMs can travel around 24,000 km/h (15,000 mph). Re-entry speeds often exceed 15,000 mph.
- ❖ **Subsonic Cruise Missiles:** Travel below the speed of sound (e.g., Mach 0.8).

Blast and Destructive Effects

Kinetic Energy: Hypersonic missiles, like the Avangard, generate enormous kinetic energy upon impact (equivalent to 21 tons of TNT) even without an explosive warhead.

Destruction Radius: High-explosive (HE) payloads on missiles can create significant damage radii. For example, a 561kg HE payload in a cruise missile can create a damage radius of up to 1.07 km, while a 3,600kg payload on an ICBM can extend to 1.47 km.

Terminal Phase: During re-entry, missiles are difficult to detect, and warheads are often equipped to airburst to maximize destruction.

Key Modern Systems

Fattah-1 & Fattah-2 (Iran): Hypersonic missiles capable of penetrating advanced defense systems like the Iron Dome, reaching speeds up to Mach 20.

3M22 Zircon (Russia): A scramjet-powered, hypersonic cruise missile with a top speed of Mach 9.

BrahMos-II (India/Russia): Hypersonic missile intended to reach Mach 5+. Mach (specifically Mach number) in missile terminology represents the ratio of a missile's speed to the local speed of sound, acting as a measurement of speed. Mach 1 is the speed of sound (~761 mph or 1,225 km/h at sea level), making Mach 2 twice the speed of sound, and so on.

Key Details Regarding Missile Speeds

- ❖ **Subsonic:** Less than Mach 1.
- ❖ **Transonic:** Approximately Mach 1.
- ❖ **Supersonic:** Speeds from Mach 1 to Mach 5.
- ❖ **Hypersonic:** Speeds exceeding Mach 5.

- ❖ **Variable Speed:** Because the speed of sound changes with temperature and altitude, a constant Mach number does not equal a constant speed in kilometers or miles per hour.

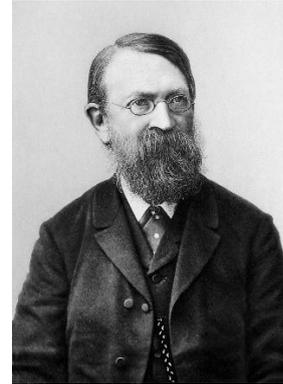


Figure-8: Ernst Mach.

Named after Austrian physicist **Ernst Mach** [Ernst Waldfried Josef Wenzel Mach, Austrian German: [18 February 1838 – 19 February 1916) was an Austrian-Czech physicist and philosopher who contributed to the understanding of the physics of shock waves], it is used to understand the aerodynamic stresses on a missile as it approaches or exceeds the speed of sound.

A missile body (or casing) is the primary structural framework—comparable to an aircraft fuselage—designed to house the guidance, warhead, and propulsion systems while protecting them from atmospheric pressure and aerodynamic heating. Usually cylindrical, it is constructed from materials like carbon steel, aluminum, titanium, or advanced composites to handle high speeds.

- ❖ **Nose Cone:** The forward most section, designed in various aerodynamic shapes (cone, ogive, Haack series) to manage drag, especially at supersonic/hypersonic speeds.
- ❖ **Midsection:** Houses the warhead and guidance systems, acting as the main airframe.
- ❖ **Tail Section:** Contains the rocket motor or jet engine, nozzles, and often includes fins for stability and maneuverability.

Material and Design Aspects

- ❖ **Materials:** High-strength metals like stainless steel, Inconel, and titanium are common.
- ❖ **Construction:** Large missile bodies are typically produced by rolling sheets and welding, while smaller or specialized bodies may use additive manufacturing (3D printing).
- ❖ **Aerodynamics:** Designed to minimize drag and manage heat at high speeds. The body integrates these components into a cohesive unit that facilitates flight control, whether it is a guided missile or a ballistic rocket.



Figure-9: Indian Missiles.

Bharat Dynamics Limited (BDL), a public sector undertaking under the Ministry of Defense, is the primary manufacturer of missiles for the Indian Armed Forces, producing systems like Nag, Akash, and Astra in collaboration with DRDO. Other key players include

BrahMos Aerospace (joint venture with Russia) for cruise missiles, Kalyani Rafael Advanced Systems (joint venture with Israel) for Spike missiles, and Bharat Electronics Limited (BEL).



Figure-10: Logo of missile manufacturers of India.

Key missile suppliers and manufacturers for India

Bharat Dynamics Limited (BDL): Manufactures ATGMs (Nag, Milan, Konkurs), SAMs (Akash), and surface-to-surface missiles (Prithvi, Agni).

BrahMos Aerospace: Produces the BrahMos supersonic cruise missile.

Kalyani Rafael Advanced Systems (KRAS): Manufactures Spike anti-tank guided missiles and missile kits.

Bharat Electronics Limited (BEL): Involved in manufacturing missile systems and avionics, including the Barak-8.

Defense Research and Development Organization (DRDO): Designs and develops the missiles, which are then produced by BDL and other partners.

CONCLUSION

Missiles are delivery systems that typically use chemical propellants to launch and, in conventional variants, utilize high-explosive chemical compounds (like HMX [octogen], RDX, TNT) in their warheads to produce destructive, rapid-release energy upon detonation. They are not technically classified as "a" single chemical, but

rather a complex machine containing energetic materials. [Charoo S. Garg, Jimit S. Patel, Kiran M. Patel, Jignesh B. Patel, Divyang H. Shah and Prof. Dr. Dhruvo Jyoti Sen; *Chemistry of 1,3,5 trinitroperhydro-1,3,5-triazine: Internationale Pharmaceutica Scientia*: 1(2), 11–17, 2011. (ISSN: 2231–5896, Index Copernicus Value: 4.82)]

HMX ($C_4H_8N_8O_8$ High Melting Explosive), or octogen, is a powerful, man-made, high-temperature nitroamine explosive used primarily in military applications, including rocket fuels, plastic explosives, and nuclear devices. It is a colorless, crystalline solid that decomposes at temperatures of (534°C) and above.

Key Aspects of HMX

Properties: It is a high-melting explosive (HME) that is relatively insensitive compared to other explosives, making it safe for specialized, high-heat applications.

Uses: Due to its stability at high temperatures, it is used in rocket propellants, burst charges for military munitions, and detonators in mining.

Production: It is produced through the chemical processing of hexamine, ammonium nitrate, nitric acid, and acetic acid.

Safety: It is considered toxic, and exposure can occur through breathing contaminated air or swallowing contaminated soil/water.

RDX is produced through the chemical processing of hexamine, ammonium nitrate, nitric acid, and acetic acid.

Properties: It is a high-melting explosive (HME) that is relatively insensitive compared to other explosives, making it safe for specialized, high-heat applications. RDX ($C_3H_6N_6O_6$), Cyclotrimethylenetrinitramine) is a highly powerful, white crystalline, and toxic military-grade explosive, first synthesized in 1898. It is widely used in demolition and plastic explosives, such as C-4, due to its high detonation velocity. It is also known as hexogen, cyclonite, or T4. **Properties:** A white crystalline solid, odorless, and tasteless.

Performance: More powerful and faster than TNT.

Uses: Used in military, engineering, and controlled demolition applications.

Safety: It is toxic and can cause health issues if ingested or inhaled.

Composition: Frequently mixed with other ingredients to form plastic explosives (e.g., 91% RDX in C-4)

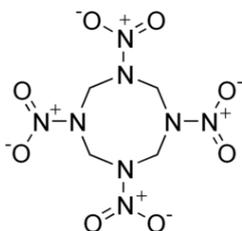
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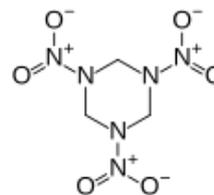
Safety: It is considered toxic, and exposure can occur through breathing contaminated air or swallowing contaminated soil/water.

Missile explosives, housed in the warhead, are designed for maximum destruction using high-energy compounds like RDX, HMX, or TNT to shatter targets via blast, fragmentation, or shaped charges. Modern missiles utilize advanced, stable explosives detonated by precise fuzes (impact, proximity) to destroy hardened targets, aircraft, or bunkers.

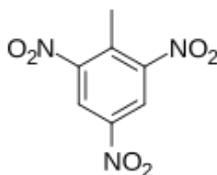
TNT (2,4,6-trinitrotoluene) is a yellow, odorless, high-explosive chemical compound ($C_6H_2(NO_2)_3CH_3$) widely used in military shells, bombs, and industrial blasting due to its stability against shock and friction. It also serves as a standard unit of energy (4.184 KJ/ton) for measuring explosive force.



HMX: 1,3,5,7-Tetranitro-1,3,5,7-tetrazocane.



RDX: 1,3,5-Trinitro-1,3,5-triazinane.



TNT: 2-Methyl-1,3,5-trinitrobenzene.

Key details regarding missiles and chemical explosives

- ❖ **Warhead Contents:** Conventional missiles carry explosives, which are chemical substances (compounds containing nitro groups) designed to detonate upon impact.
- ❖ **Propulsion:** The missile itself is powered by solid or liquid chemical propellants (e.g., ammonium perchlorate) to reach its target.
- ❖ **Types of Warheads:** While many use traditional chemical high explosives, missiles can also deliver nuclear biological, or chemical weapons (toxic agents).
- ❖ **Mechanism:** Chemical explosives in missiles work by generating rapid, immense heat and gas expansion, creating a blast wave and fragmentation.

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