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UNIT VI - FUNDAMENTALS OF ROCKET PROPULSION

Analyze Missile Structures and Classifications

Missiles of India include both **ballistic and cruise missile systems** with strategic and tactical importance. These missiles have been developed through various missile programs since independence, with the Integrated Guided Missile Development Program (IGMDP) being the most important and successful. The development of these missile systems signifies India's aim to maintain the balance of power and strategic stability in the Asia-Pacific region and attain great power status.

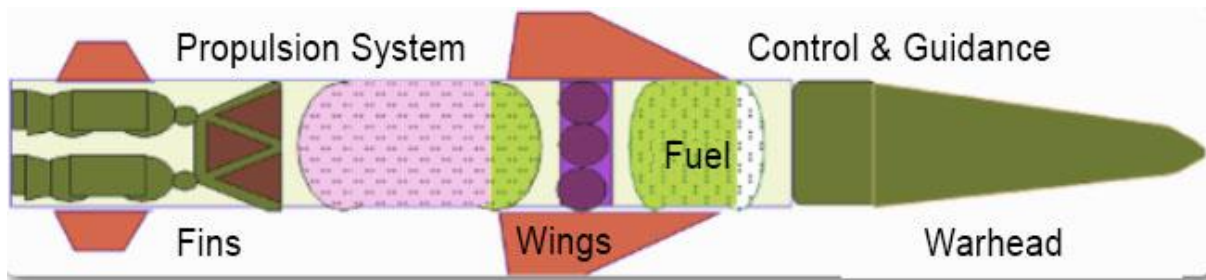
Prithvi, Akash, Agni, Brahmos, Sagarika, etc. are the missiles that have been developed to counter the geopolitical challenges and potential threats to India. They aim to strengthen both offensive and defensive capacities during any conflict scenario.

What is a Missile?

A missile is a guided airborne ranged weapon capable of self-propelled flight usually by a jet engine or rocket motor. Missiles have five system components:

- Guidance system
- Targeting system
- Flight system
- Engine

- Warhead



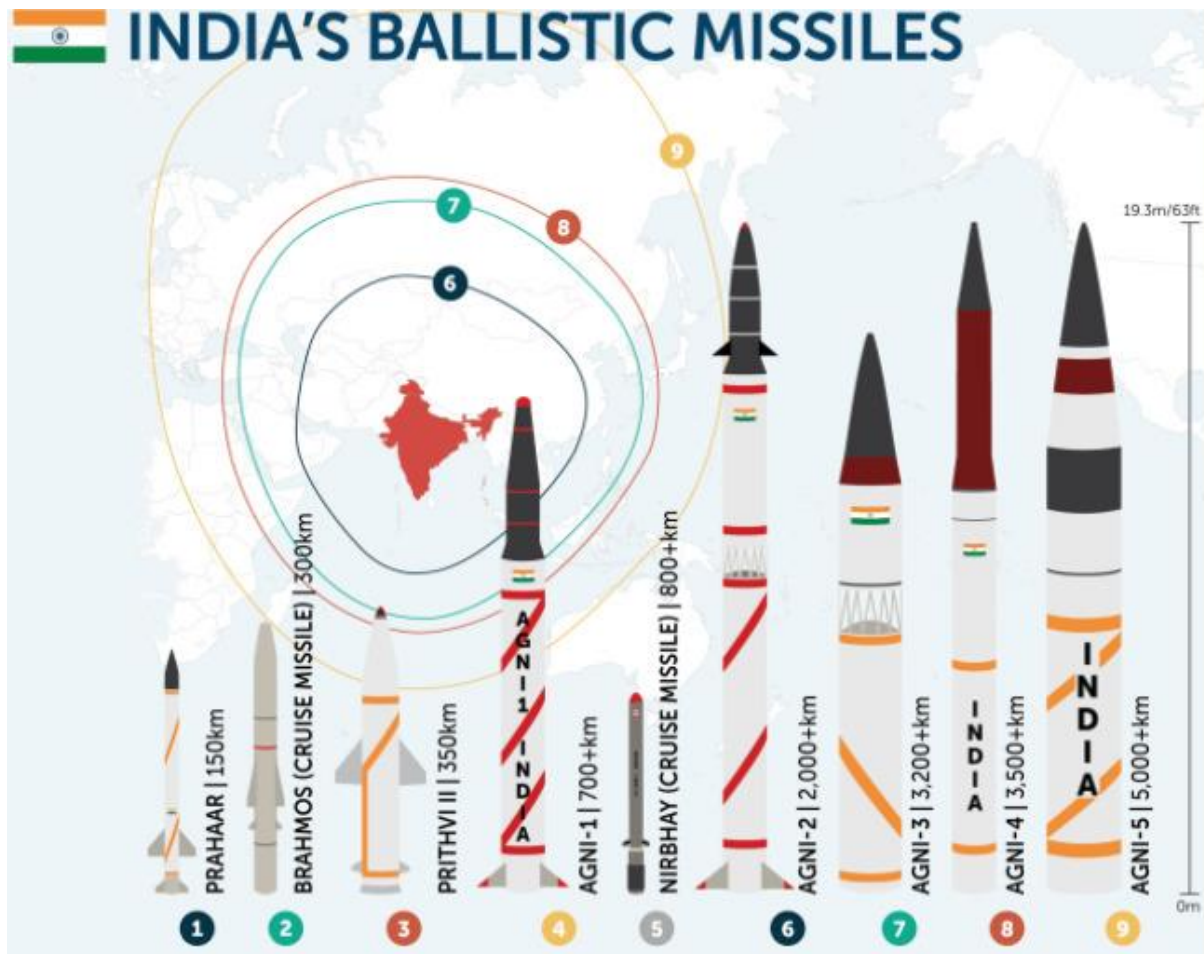
Features of India's Missile Systems

Indigenous technology, quick reaction capability, high accuracy, and lethality are the hallmarks of India's missile systems:

- **Accuracy:** India's missiles incorporate advanced guidance technologies like inertial navigation systems, satellite navigation, radar, and optical seekers to achieve pinpoint accuracy. This enables precise targeting and minimum collateral damage.
 - Missiles like **Agni-V** and **BrahMos** have consistently hit targets with high bulls-eye precision.
- **Quick deployment:** Most of India's missiles use solid fuels, lending them quick reaction capability. Shorter preparation and launch times give flexibility to armed forces for a faster response.
 - Agni and Prithvi missiles in special transport-erector-launcher vehicles can fire in under 15 minutes.
- **High lethality:** Powerful indigenous propulsion systems give Indian missiles extended ranges and heavy warheads to inflict major damage.
 - **BrahMos**, with its supersonic speed, is one of the deadliest cruise missiles globally.

Different Types of Missiles in India

India's current missile capabilities serve to strengthen conventional military readiness, provide credible nuclear deterrence, and secure national interests in line with geopolitical realities.



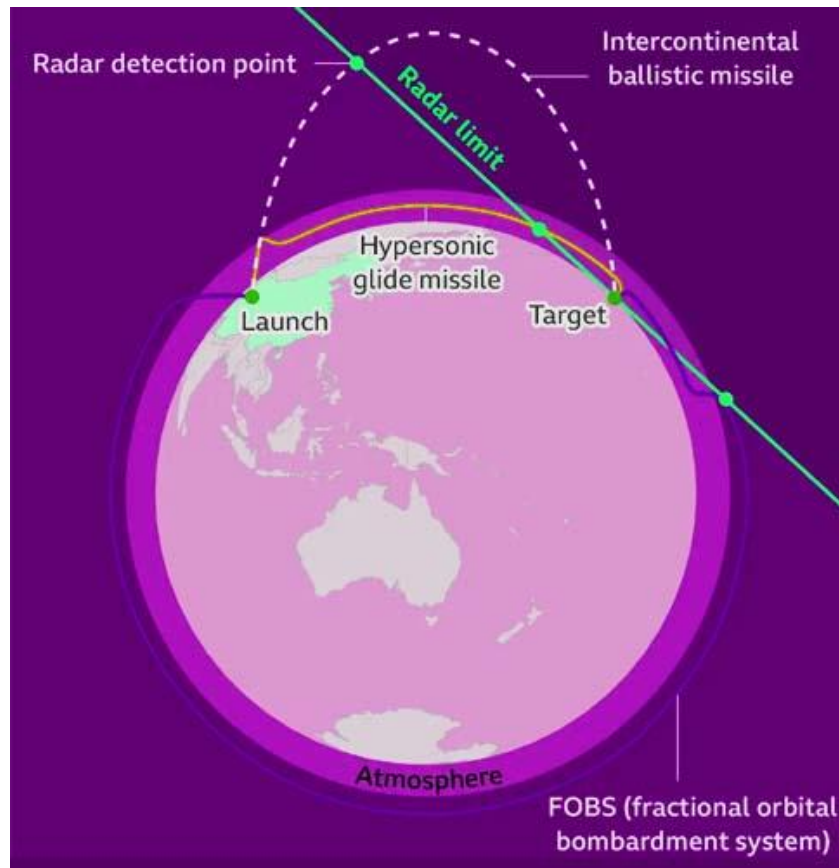
Types of Missiles Based on Speed

Missiles are classified based on their speed to that of sound, expressed as Mach.

- **Subsonic missile:** Missiles that travel slower than sound are known as "**subsonic.**"
 - **Examples:** U.S. Harpoon anti-ship missile, Indian **Prithvi** short-range ballistic missile
- **Supersonic missile:** Missiles that travel faster than the speed of sound (**Mach 1**) but less than **Mach 5** are called "**supersonic.**"
 - **Examples:** Russian Iskander tactical ballistic missile, Indian **BrahMos** supersonic cruise missile.
- **Hypersonic missile:** The term "hypersonic" means that the speed of missiles should be at least five times faster than the speed of sound (over Mach 5).
 - **Examples:** China's **DF-ZF** hypersonic glide vehicle, **Russia's Avangard**, and **Shaurya/Sagarika** missiles of India (Max speed - 7.5 Mach), etc.

Types of Missiles in India Based on Trajectory

- **Ballistic Missiles:** Ballistic missiles have a ballistic lofted trajectory and work on the principle of unpowered free-fall flight after the boost phase. Examples are India's Agni and Prithvi series of ballistic missiles.
 - **Hypersonic Glide Vehicle:** Ballistic missiles attaining **hypersonic velocities** during the **re-entry phase** are hypersonic ballistic missiles.
 - **Examples of HGVs:** China DF-17 missile mounts hypersonic glide vehicle, Russia Avangard boost-glide system
 - India is in the “**Technology demonstration**” stage of the HGVs.
- **Cruise Missiles:** It is a guided missile used against **terrestrial or naval targets**, that remain in the atmosphere (unlike ballistic missiles) and flies the major portion of its flight path at an approximately constant speed, before hitting the target.
 - **Subsonic Cruise missiles:** These cruise missiles travel at **less than Mach 1**.
 - **Examples:** U.S. **BGM-109 Tomahawk** long-range subsonic cruise missile, **Indian Nirbhay** subsonic cruise missile.
 - **Supersonic Cruise missiles:** Cruise missiles traveling at supersonic speeds are called supersonic cruise missiles.
 - **BrahMos:** Joint Indo-Russian BrahMos is the fastest supersonic cruise missile reaching close to Mach 3 speed.
 - **Hypersonic Cruise missiles:** Cruise missiles powered using **scramjet engines** to realize speeds greater than **Mach 5** are designated as hypersonic cruise missiles.
 - **3M22 Zircon:** Russia's 3M22 Zircon can fly over Mach 8 as a hypersonic cruise missile.
 - **BrahMos II:** Said to be based on Zircon, BrahMos Aerospace is working on the **BrahMos-II** variant to attain hypersonic cruise speeds above Mach 8.
 - **Fractional Orbital Bombardment System (FOBS):** It is a warhead delivery system that uses a low Earth orbit towards its target destination. Just before reaching the target, it deorbits through a retrograde engine burn.
 - Instead of ICBMs which follow a probable trajectory, FOBS can avoid early warning systems by approaching from the south polar region without the revelation of targets.
 - **Example:** Russia developed this technology in the 1960s. Recently, China has tested this system too.



Types of Missiles Based on the Launch Mode

Launch Mode	Description	Examples
Surface-to-Surface	Launched from land-based platforms to strike ground targets	Prithvi, Agni, and BrahMos
Surface-to-Air	Launched from land to intercept aerial threats like aircraft, helicopters, and drones	Akash, MRSAM
Air-to-Surface	Air launched to attack ground-based targets	Helina anti-tank missile fired from Rudra helicopter
Air-to-Air	Launched from aircraft against hostile aerial targets	Astra BVR air-to-air missile fired from Tejas
Ship-to-Ship	Naval anti-ship missiles launched from warships/submarines	BrahMos anti-ship cruise missile fired from ships
Ship-to-Air	Naval surface-to-air missiles for fleet air defence	Barak-8 LR-SAM deployed on ships
Submarine-launched	Fired from submerged submarines	K-15 submarine-launched ballistic missile
Shoulder-fired	Man-portable missiles fired from launchers carried by infantry	FIM-92 Stinger and Igla shoulder-fired SAMs

Based on Strategic Importance

Strategic missiles encompass missiles that give a strategic edge over an opponent or provide credible deterrence to a country. In India and other powerful countries, these missiles are part of the nuclear triad.

- **Intercontinental ballistic missile (ICBM):** These missiles are long-range missiles that are capable of delivering nuclear warheads across continents.

- It is a part of India's Nuclear Triad.
- **Agni-V** is **India's first Intercontinental Ballistic Missile(ICBM)**, with a range of around 5000-8000 km. It brings the entire Asia-Pacific region within its reach.
- **Mission Divyastra** successfully tested the Agni-V missile using **MIRV (Multiple Independently Targetable Re-entry Vehicle)** technologies, capable of striking multiple targets hundreds of kilometers apart with a single missile.
- **Sub-surface ballistic nuclear (SSBN):** A nuclear-powered submarine carrying and launching ballistic missiles armed with nuclear weapons.
- **K-15 Sagarika** (750 km) and **K-4 (3500 km, in development)** are the Submarine-launched ballistic Missiles (**SLBMs**), that complete India's nuclear triad by enabling second-strike capability from underwater locations.
- K-15 Sagarika has been deployed in Arihant class SSBN.

Based on Tactical Importance

Tactical missiles are employed in battlefield and frontline combat situations to strike and neutralize enemy assets and capabilities. India boasts an array of tactical missiles.

- **Prithvi Missiles:** The Prithvi series includes short-range surface-to-surface ballistic missiles.
 - **Prithvi-I** (150km) and **Prithvi-II** (350 km) for battlefield roles and hitting strategic targets close to the border.
 - **Prithvi-III** naval variant (350 km) to boost coastal and seaborne deterrence from warships.
- **BrahMos Missile:** BrahMos is the fastest supersonic missile in the world.
 - It is a Mach 3 "**fire-and-forget**" missile, inducted in all three services of the Indian Armed Forces.
 - Its variants include land, ship, submarine, and air-launched missiles.
 - **BrahMos II**, the hypersonic cruise missile, is currently in the developing phase.

Types of Missiles Based on Propulsion

Missiles utilize different types of propulsion and guidance systems based on their range, launch platform, and targets. Key missile propulsion systems are:

- **Solid Propulsion:** It uses solid propellants like Hydroxyl-terminated polybutadiene (HTPB) fuel. It is simple, low-cost, and reliable.

- **Example: Prithvi, Brahmos.**
- **Liquid Propulsion:** It employs liquid fuels (Hydrazine - N_2H_4 , Liq. hydrogen, etc.) and oxidizers (Nitrogen tetroxide - N_2O_4 , Liq. oxygen, etc.).
 - It has higher efficiency and throttle ability.
- **Example: Agni series, Akash.**
 - Recently, India has successfully tested the Agni-Prime missile with solid propellant, making it lighter than other Agni series missiles.
- **Hybrid Propulsion:** It uses a combination of solid and liquid propellants.
 - **Example:** Used in Brahmos hypersonic cruise missile prototype.
- **Cryogenic:** It uses liquid oxygen and hydrogen. It has a very high energy density.
 - **Example:** Employed in long-range **Agni-V ICBM**.
- **Ramjet/Scramjet:** Air-breathing engines are used for hypersonic ballistic and cruise missiles.
 - **Example:** Under development (India's **HGV** and **Brahmos-II**).

Based on Guidance Systems

Guidance systems enable missiles to accurately reach targets. Various guidance technologies are:

- **Command Guidance:** External commands guide missiles through radio/wire links.
 - **Example: Nag anti-tank missile.**
- **Inertial Guidance:** Onboard computers and motion sensors provide autonomous course correction.
 - **Example: Agni ballistic missiles.**
- **Terrain Mapping:** This compares onboard terrain maps to radar altimeter data for accuracy.
 - **Example: Prithvi missiles.**
- **Laser Homing:** It guides toward a target illuminated by a laser designator.
 - **Example: Helina anti-tank missile, Anti-Tank Guided Missile for MBT Arjun, etc.**
- **Radar/GPS:** This updates position using satellite navigation and matches it to targeting data.
 - **Example: Brahmos cruise missile.**