DEFENCE TECHNOLOGY

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1. Missile Systems and Strategic Weapons-Ballistic missiles, cruise missiles, anti-ballistic missiles

Anti-Ballistic Missile (ABM) Systems: Layered Defence and Interception Principles

- **Anti-Ballistic Missile (ABM) Systems**
  Designed to intercept and destroy incoming ballistic missiles.
- **Terminal High Altitude Area Defense (THAAD)**
  - An American anti-missile system.
  - Intercepts ballistic missiles at high altitudes during their terminal phase.
- **S-400 Triumf**
  - Russian-made long-range air defense missile system (Surface-to-Air Missile - SAM).
  - India procured 5 systems/squadrons from Russia.
  - Upgraded version of the S-300 family of SAM systems.
- **Iron Dome**
  - Israeli air defense missile system.
  - Operates in all weather conditions.
  - Designed to intercept short-range rockets, artillery shells, and mortars.
  - Uses radar to track threats and differentiate between those likely to hit built-up areas.
  - Developed by Israel (Rafael Advanced Defense Systems) with significant US financial support.
- **Arrow-4**
  - New Ballistic Missile Shield developed by Israel in collaboration with the USA.
- **Mission Shakti**
  - DRDO (India) mission.
  - Demonstrated India's Anti-Satellite (ASAT) missile capability, allowing a rocket to destroy an orbiting satellite.
- **Phase-II Ballistic Missile Defence (BMD) interceptor AD-1 missile**
  - Tested by DRDO (India).

Ballistic Missiles: Trajectory, Stages, and Variants (SRBM, MRBM, ICBM, SLBM)

- Ballistic missiles are rocket-powered only during their initial flight phase (boost phase).
- They follow a ballistic trajectory: after boost, they are unpowered, primarily influenced by gravity and air resistance.
- Ballistic missiles typically travel outside Earth's atmosphere and re-enter to strike a target.
- Guidance systems are active during the initial launch phase and sometimes during the terminal (re-entry) phase to fine-tune impact.
- Unlike cruise missiles, which are jet-propelled, guided throughout, remain within the atmosphere, and fly parallel to the Earth's surface. BrahMos is a cruise missile, not ballistic.
- **Trajectory Stages**
  - **Boost Phase**

    Rocket engines fire, missile gains altitude and velocity, guided.
  - **Mid-course Phase**

    Engines shut off, missile coasts in space along a sub-orbital or orbital path, largely unguided.
  - **Terminal Phase**

    Missile re-enters atmosphere, descends towards target, re-entry vehicle may perform maneuvers.
- **Fractional Orbital Bombardment System (FOBS)**

  A missile is put into a stable orbit around Earth and then deorbits over a target.
- **Ballistic Missile Variants by Range**
  - **SRBM (Short-Range Ballistic Missile)**

    Range less than 1,000 km.
    - E.g., India's Prithvi series, Pakistan's Hatf IX (Nasr) (surface-to-surface, multi-tube).
  - **MRBM (Medium-Range Ballistic Missile)**

    Range 1,000 – 3,000 km.
    - E.g., India's Agni-P (1,000-2,000 km), India's Agni-II (~2,000 km), Pakistan's Shaheen-III (medium-range, surface-to-surface).
  - **IRBM (Intermediate-Range Ballistic Missile)**

    Range 1,000 – 5,500 km (often considered 3,000-5,500 km for distinction from MRBM).
    - E.g., India's Agni-IV (4,000-5,000 km).
  - **ICBM (Intercontinental Ballistic Missile)**

    Range greater than 5,500 km.
    - E.g., India's Agni-V (>5,000 km).
  - **SLBM (Submarine-Launched Ballistic Missile)**

    Launched from submarines.
    - E.g., India's K-15 (Sagarika), Dhanush (naval variant of Prithvi).
- **Indian Ballistic Missiles**
  - **Agni-P**

    Surface-to-surface MRBM, range 1,000-2,000 km.
  - **Agni-II**

    Surface-to-surface MRBM/IRBM, range around 2,000 km.
  - **Agni-IV**

    Surface-to-surface IRBM, range 4,000-5,000 km. Features two-stage solid propellant. Can deliver 1-tonne nuclear warheads.
  - **Agni-V**

    Surface-to-surface ICBM, nuclear-capable, range more than 5,000 km. Features Ring Laser Gyro-based Inertial Navigation System (RINS) and Micro Navigation System (MINS). It is solid-fuelled. Launched from Dr. APJ Abdul Kalam Island (formerly Wheeler Is-

land). India joined US, Russia, France, China in the elite ICBM club with Agni-V.

- **Prithvi series**

  Surface-to-surface SRBM. Prithvi-II is a ballistic missile.

- **Dhanush**

  Naval variant of the Prithvi missile; an SLBM/SSM.

- **K-15 (Sagarika)**

  Submarine-Launched Ballistic Missile (SLBM).

- **Mission Divyastra (DRDO)**

  Refers to India's Multiple Independently Targetable Re-Entry Vehicle (MIRV) technology, associated with advanced ballistic missiles.

Cruise Missiles: Guidance, Propulsion, and Terrain-Following Capabilities

- BrahMos: Short-range, supersonic cruise missile.
- BrahMos: Joint venture between India (Brahmaputra) and Russia (Moskva).
- BrahMos: Achieves speed of Mach 2.8 to 3.0.
- BrahMos: Original flight range up to 290 km; extended versions exceed 400 km (e.g., 450 km, 500 km+).
- BrahMos: Cruising altitude typically very low, including sea-skimming, up to 15 km, not 30 km.
- Nirbhay: India's indigenously developed subsonic cruise missile (by DRDO).
- Cruise Missile Propulsion: Generally uses jet engines (turbojet or turbofan) for sustained flight; ramjets for supersonic speeds (e.g., BrahMos).
- Cruise Missile Guidance: Utilizes Inertial Navigation System (INS), Global Positioning System (GPS), and advanced systems like Terrain Contour Matching (TERCOM) or Digital Scene Matching Area Correlation (DSMAC).
- Cruise Missile Terrain-Following: Capability to fly at extremely low altitudes, following the contours of the terrain to avoid radar detection and air defenses.

Emerging Technologies in Missile Warfare: AI, Swarm Missiles, and Directed Energy Defences

- **Mission Shakti:** India's Anti-Satellite (ASAT) missile test.
- Developed and conducted by Defence Research and Development Organisation (DRDO).
- Demonstrates India's capability to intercept and destroy satellites in low earth orbit, thereby enhancing strategic deterrence.
- **DURGA-II (DRDO):** Stands for Directed-Energy Urja for Ranging & Abatement - II.
- It is a Directed Energy Weapon (DEW) developed by DRDO.
- DEWs are emerging technologies that use highly focused energy (e.g., laser, microwave beams) to damage, disable, or destroy targets.
- DEWs have applications in missile defence, counter-drone operations, and other strategic warfare scenarios.

Hypersonic Missiles: Technology, Capabilities, and Strategic Implications

- **Shorya Missile**

  India's canister-launched, surface-to-surface strategic missile.

- **Speed**

  Hypersonic, capable of reaching speeds up to Mach 7.5.

- **Range**

  Operational range is 700-1900 km; initial versions commonly cited around 750 km.

- **Key Test**

  Successfully test-fired on 24 September 2011 from Chandipur, Odisha.

India's Indigenous Missile Development Programs (e.g., Agni, Prithvi, BrahMos, Akash)

- **Integrated Guided Missile Development Program (IGMDP)**

  Launched in 1983 under Dr. A.P.J. Abdul Kalam. Developed five missile systems: Prithvi, Agni, Trishul, Akash, Nag.

- **Dr. A.P.J. Abdul Kalam**

  Popularly known as the 'Missile Man of India'. Flew Sukhoi-30 MKI fighter.

- **Missile Technology Control Regime (MTCR)**

  India became a member in 2016. China is not a member.

- **Organizations**
  - **Defence Research and Development Organisation (DRDO)**

    R&D wing of the Ministry of Defence (formed 1958). Developed most indigenous missile systems (Agni, Prithvi series, Pinaka, Akash).
  - **Bharat Dynamics Limited (BDL)**

    Produces missiles developed by DRDO (e.g., Akash).
  - **Bharat Electronics Limited (BEL)**

    Engaged in components for air defence systems (e.g., Akashier).
  - **Ordnance Factory Board (OFB)**

    Engaged in projects like 'Dhanush' (howitzer).

- **Ballistic Missiles (Surface-to-Surface)**
  - **Prithvi**

    India's first indigenous surface-to-surface missile. Test fired from Chandipur, Odisha.
  - **Dhanush**

    Naval variant of Prithvi III. Short Range Ballistic Missile (SRBM), can carry conventional/nuclear warheads, range ~350-600 km.
  - **Agni Series**

    Surface-to-surface ballistic missiles, nuclear-capable, developed by DRDO.
    - **Agni-I**

      Single-stage, solid-fuel, range 700-1200 km.
    - **Agni-P (Prime)**

      Canisterised, two-stage solid propellant, range up to 2000 km. Canisterisation reduces launch time, improves storage/handling.
    - **Agni-V**

      India's longest-range Intercontinental Ballistic Missile (ICBM) (5000+ km). Three-stage solid-fuelled engine. Canister-launched. Nuclear-capable (more than one tonne warhead). Uses Multiple Independently Targetable Re-entry Vehicle (MIRV) technology (associated with Mission Divyastra). Indigenously developed by DRDO.
  - **Prahaar**

    Short-range (150-200 km) surface-to-surface missile. Single stage, solid propellants. Can fire multiple missiles in one salvo.
  - **Pralay**

    Conventional Short-Range Ballistic Missile (SRBM). Surface-to-surface.
  - **Shaurya**

    Surface-to-surface strategic missile (canister-launched), land variant of K-15 SLBM, known for high maneuverability and potentially hypersonic capabilities.
  - **K-4**

    Submarine-Launched Ballistic Missile (SLBM), fitted to Arihant-class submarines.

- **Cruise Missiles**
  - **BrahMos**

    Indo-Russian (DRDO + NPO Mashinostroyeniya) supersonic cruise missile. Name from Brahmaputra (India) & Moskva (Russia) rivers. Multi-platform capable (submarine, ship, air, land). World's fastest supersonic cruise missile. Initial range 290 km, extended to 600 km post-MTCR. Integrated with Sukhoi-30 MKI fighter. Test site: Chandipur. India delivered BrahMos to the Philippines (April 2024).

- **Nirbhay**

  India's first indigenous long-range subsonic cruise missile. Multi-platform capable.

- **Air Defence Missiles (Surface-to-Air)**
  - **Akash**

    Medium Range Surface-to-Air Missile (MRSAM) system, uses radar. Developed by DRDO, produced by Bharat Dynamics Limited (BDL).
  - **Akash-NG (New Generation)**

    Surface-to-air missile, strike range ~80km, high indigenous content (~96%), developed for the Indian Air Force.
  - **Trishul**

    Short-range (around 9 km) supersonic surface-to-air missile.
  - **Quick Reaction Surface-to-Air Missile (QRSAM)**

    DRDO-developed, solid fuel propellant, range 25-30 km. Equipped with electronic countermeasures (ECM).
  - **Barak-8 (LRSAM)**

    Long Range Surface-to-Air Missile, jointly developed by India and Israel. Naval version attached to frigates/destroyers, range ~70-100 km.
  - **VSHORADS (Very Short Range Air Defence System)**

    DRDO-developed Man-Portable Air Defence System (MANPADS) to neutralize aerial threats.
  - **Igla Missile**

    Russian-origin Short-Range Man-Portable Infrared Homing Surface-to-Air Missile (MANPADS).
  - **S-400 'Triumf'**

    Russian-developed long-range Surface-to-Air Missile (SAM) system (India procures). Max speed up to Mach 14. Designed for quick deployment.
  - **NASAMS II**

    Advanced air defence system India plans to procure from the United States.

- **Air-to-Air Missiles**
  - **Astra**

    India's first indigenous Beyond-Visual-Range (BVR) Air-to-Air Missile. Developed by DRDO. Range ~90 km. Successfully test-fired from LCA Tejas.

- **Anti-Tank Guided Missiles (ATGMs)**
  - **Nag**

    "Fire and forget" ATGM. Uses IR imaging for guidance. Test fired at Pokhran.
  - **Helina (HELINA) / Dhruvastra**

    Helicopter-launched versions of Nag ATGM. Indigenously developed by DRDO. Range ~7-8 km. Test fired from Advanced Light Helicopter (ALH).

- **Anti-Radiation/Air-to-Surface Missiles**
  - **Rudram-1 (earlier known as NGARM)**

    India's first indigenous anti-radiation missile. Air-to-surface missile. Test fired from Sukhoi 30 MKI.
  - **RudraM-II**

    Air-to-Surface missile.

- **Anti-Satellite (ASAT) Missile**
  - **Mission Shakti**

    India's first Anti-Satellite Missile program (tested in 2019).

- **Other Weapon Systems / Platforms**
  - **Pinaka**

    Multi-Barrel Rocket Launcher (MBRL) system. Developed by DRDO. Test fired from Pokhran range.
  - **Smart Anti Airfield Weapon (SAAW)**

    Indigenously developed precision strike glide bomb. ~120 kg class, range ~100 km. Launched from Hawk-i air-