

India's Aerial Defence

1 Missiles

A missile is a self-propelled guided projectile designed to be launched into the air and directed towards a specific target. Missiles can be classified into different types based on their propulsion systems, flight paths, and intended use.

- **Ballistic missiles** are initially propelled by rockets and follow an unpowered, arched trajectory to reach their target. They can carry either nuclear or conventional warheads and are classified into short-range, medium-range, intermediate-range, and long-range missiles.
- **Cruise missiles** are unmanned, self-propelled guided missiles that maintain low, horizontal flight paths to avoid anti-missile systems. They have significant payload capacity and high precision. Cruise missiles can be launched from air, land, ship, or submarine. They are classified as subsonic, supersonic, or hypersonic based on their speeds.
- **Quasi-ballistic missiles** combine features of both ballistic and cruise missiles. They initially follow a ballistic trajectory and then transition to a low-altitude, high-speed cruise trajectory.
- **Hypersonic missiles** are designed to travel at speeds equal to or greater than Mach 5. They are highly maneuverable and can alter their flight paths. Hypersonic weapons can be in the form of hypersonic glide vehicles, hypersonic cruise missiles, or hypersonic aircraft.

Missiles play a crucial role in defense technology, providing nations with the ability to strike targets accurately and efficiently across various ranges.

1.1 Types of missiles

1.1.1 Ballistic Missiles

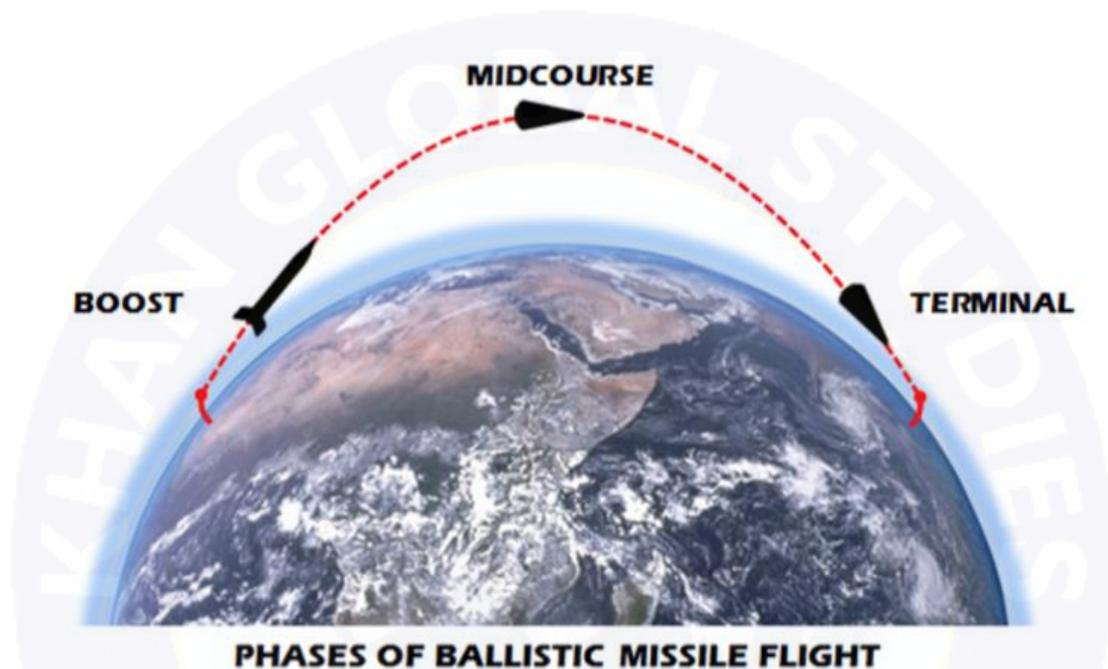
Ballistic missiles are initially propelled by rockets and follow an unpowered, arched trajectory to reach their target. These missiles are capable of carrying either **nuclear** or **conventional warheads**. Launch platforms include ships and land-based facilities. Notable examples from the Indian defence arsenal are **Prithvi I**, **Prithvi II**, **Agni I**, **Agni II**, and **Dhanush**.

Classification of Ballistic Missiles

- **Short-range:** Tactical missiles with a range less than 1,000 kilometres.
- **Medium-range:** Theatre missiles with a range between 1,000 and 3,000 kilometres.

- **Intermediate-range:** Missiles with a range between 3,000 and 5,500 kilometres.
- **Long-range:** Intercontinental or strategic missiles with a range exceeding 5,500 kilometres.

Three Stages of Ballistic Missile Flight



- **Boost Phase:** Starts at launch and ends when rockets cease firing; usually lasts three to five minutes and occurs within the atmosphere.
- **Midcourse Phase:** Follows the boost phase, comprises the longest portion of the flight; ICBMs can reach speeds around 24,000 kilometres per hour.
- **Terminal Phase:** Begins when warheads re-enter Earth's atmosphere and ends upon impact; strategic warheads can exceed speeds of 3,200 kilometres per hour.

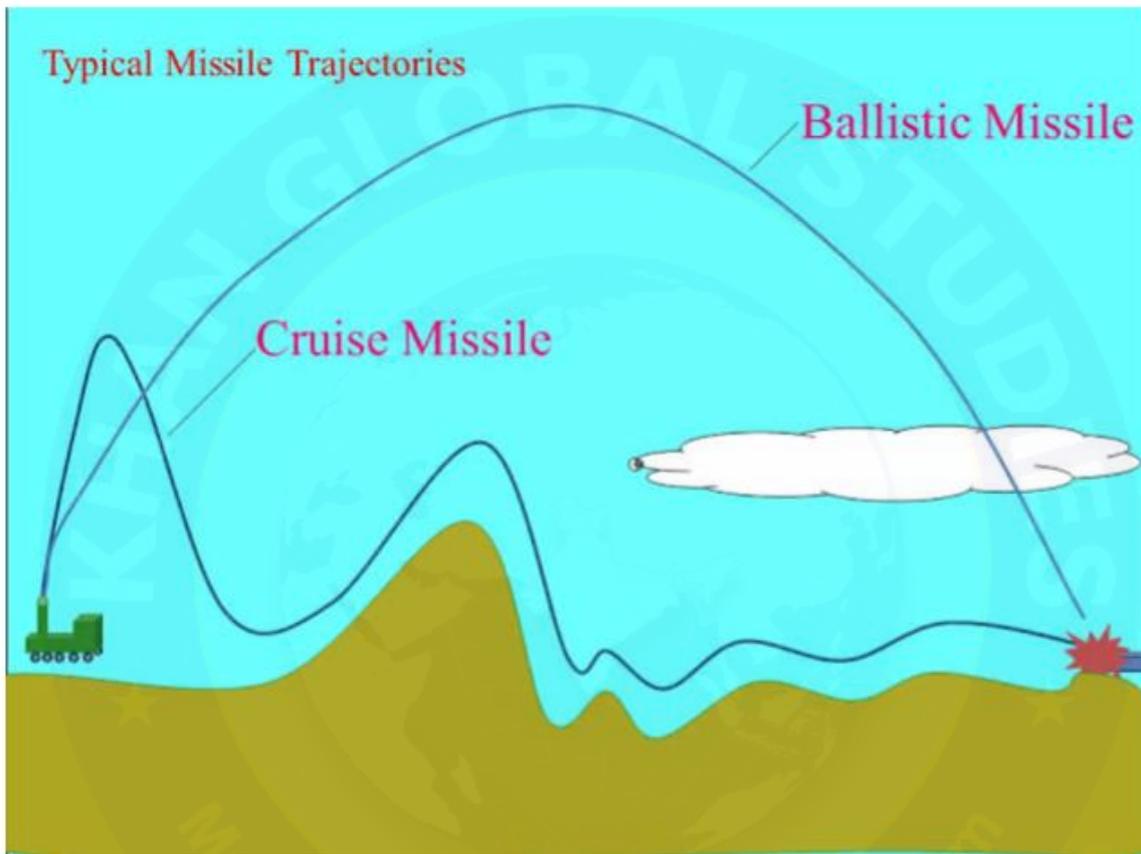
1.1.2 Cruise Missiles

Cruise missiles are unmanned, self-propelled guided missiles with significant payload capacity and high precision. They **maintain low, horizontal flight paths** to avoid anti-missile systems. These can be launched from **air, land, ship, or submarine**.

Classification of Cruise Missiles

- **Subsonic cruise missiles:** Travel below the speed of sound, approximately at 0.8 Mach. Example: Tomahawk missile of the USA.

- **Supersonic cruise missiles:** Travel at speeds between 2-3 Mach, with high kinetic energy due to their speed and warhead mass. Example: BrahMos missile.
- **Hypersonic cruise missiles:** Travel at speeds exceeding 5 Mach; under active development in several countries.



1.1.3 Quasi-Ballistic Missiles

A **quasi-ballistic missile** incorporates features of both **ballistic missiles** and **cruise missiles**. Specifically, it follows a **ballistic trajectory** during the initial portion of its flight. Subsequently, it transitions to a **low-altitude, high-speed cruise trajectory**. This hybrid flight path allows the missile to take advantage of the benefits of both ballistic and cruise missile technologies.

1.1.4 Hypersonic Missiles

A **hypersonic missile** is designed to travel at speeds equal to or greater than **Mach 5**, which is approximately 1 to 5 miles per second or 1.6 to 8.0 km/s. What distinguishes these missiles from ballistic missiles is their **manoeuvrability**. Unlike ballistic missiles that adhere to a predetermined course, hypersonic missiles have the capability to alter their flight paths.

Types of Hypersonic Weapons

Hypersonic weapons come in various forms:

- **Hypersonic Glide Vehicle (HGV):** These are warheads that, following an initial ballistic launch, manoeuvre and glide through the atmosphere at hypersonic speeds.
- **Hypersonic Cruise Missile:** These missiles utilise air-breathing engines such as **scramjets** to achieve hypersonic speeds.
- **Hypersonic Aircraft:** Similar to hypersonic cruise missiles, these aircraft also employ air-breathing engines like scramjets to reach high velocities.

Russia has claimed its first use of the **Kinzhal hypersonic missile** in the Ukraine conflict, targeting a large underground arms depot in western Ukraine. The missile, capable of speeds exceeding **Mach 5**, was likely launched from a **MiG-31 warplane**

Countries with Hypersonic Missiles as of 2023

- **United States:** Actively developing and testing, \$3.8 billion budget for 2022.
- **China:** Possesses operational missile, focus on cruise missiles and glide vehicles.
- **Russia:** Research since the 1980s, deployed missile in Ukraine in 2019.
- **India:** Entered hypersonic research in September 2020.
- **Other Developed Countries:** Australia, France, Germany, and Japan in development phase.
- **Nascent Research Countries:** Iran, Israel, and South Korea conducting foundational research.

1.2 Integrated Guided Missile Development Programme (IGMDP)

- **Programme Inception:** Conceived by Dr. A P J Abdul Kalam to achieve self-sufficiency for India in missile technology.
- **Government Approval and Feasibility Study:** Approved by the Government of India on July 26, 1983. A feasibility study was conducted by a team comprising members from DRDO, the army, navy, air force, and defence production. The team recommended the development of five missile systems.

1.2.1 Missiles Developed Under IGMDP

- **Prithvi:** Short-range surface-to-surface ballistic missile.
- **Agni:** Intermediate to long-range surface-to-surface ballistic missile. Initially developed as a technology demonstrator for a re-entry vehicle, it was later upgraded to serve as a ballistic missile with varied ranges.
- **Trishul:** Short-range low-level surface-to-air missile.
- **Akash:** Medium-range surface-to-air missile.

- **Nag:** Third-generation anti-tank missile.

Programme Completion

- **Achievement and Announcement:** After accomplishing its goal of making India self-reliant in missile technology, DRDO formally announced the successful completion of IGMDP on January 8, 2008.

1.3 About some recent Agni missiles

1.3.1 Agni-IV Specifications

- **Series and Naming:** Fourth in the Agni series, formerly known as Agni II prime.
- **Test History:** First tested in 2011 and again in 2012 from Wheeler Island, off the coast of Orissa.
- **Technical Details:**
 - A two-stage missile powered by solid propellant.
 - Length: 20 meters
 - Launch weight: 17 tonnes
 - Range: Up to 4,000 km
 - Warhead capacity: 1 tonne
- **Advanced Technologies:** Equipped with indigenously developed ring laser gyro and composite rocket motor.
- **Launch Capabilities:** Can be fired from a road-mobile launcher.

1.3.2 Agni-V Specifications

- **Development Timeframe:** Developed indigenously in a span of just three years.
- **Technical Details:**
 - A three-stage missile
 - All stages based on solid fuel
 - Nuclear-capable
 - Payload capacity: 1.5 tonnes
 - Range: 5,000+ km
 - Total weight: 50 tonnes
- **Advanced Technologies:** Equipped with composite rocket motors, advanced navigation systems, onboard computers, and re-entry vehicles. Capable of MIRV (Multiple Independently Targetable Re-entry Vehicle) for anti-satellite systems.
- **Launch Capabilities:** Can be fired from a road-mobile launcher.

Strategic Significance of Agni-V

- **Global Context:** Considered a game changer for India, placing it among the elite group of countries with the capability to launch intercontinental ballistic missiles, including the US, Russia, France, and China.
- **Geopolitical Implications:** Provides almost complete coverage of China, enhancing India's deterrence capabilities.

1.3.3 Agni-VI: In Development

- **Status:** Reported to be in early stages of development, intended to be the most advanced version in the Agni missile programme.
- **Technical Expectations:**
 - Capable of being launched from both submarines and land.
 - Projected strike range of 11,000–12,000 km.
 - Expected to be equipped with MIRVed warheads.

1.4 BrahMos Missile Programme

1.4.1 Origins and Development

- The BrahMos missile is a joint venture between India's Defence Research and Development Organisation (DRDO) and Russia's NPO Mashinostroyeniya, who together have formed BrahMos Aerospace.
- The missile is based on the P-800 Oniks from Russia.
- The name BrahMos is a portmanteau formed from the names of two rivers, the Brahmaputra of India and the Moskva of Russia.

1.4.2 Technical aspects

The **BrahMos missile** is a medium-range ramjet supersonic cruise missile that can be launched from various platforms including submarines, ships, fighter aircraft, or land-based platforms.

Range

- The initial version of the **BrahMos missile** had a range capped at **290 km** due to obligations of the Missile Technology Control Regime (MTCR).
- After India became a member of MTCR in 2016, the range of the **BrahMos missile** was extended.
- The missile's range varies depending on the launch platform used, with ranges of **300-500 km**.
- The range has been extended to about **900 km** as of 2024.

1.4.3 Capabilities

- The **BrahMos missile** is capable of carrying a **200–300 kg warhead**.
- It can fly at a maximum speed of **Mach 3**.
- The missile has an accuracy of **1 m CEP** (Circular Error Probable).
- It can fly as low as **3–4 meters** in sea-skimming mode.

1.4.4 Variants

- The **BrahMos missile** has several variants including ship-launched, land-launched, submarine-launched, air-launched, BrahMos-ER, BrahMos-NG, and BrahMos-II.
- The land-launched and ship-launched versions are already in service.
- An air-launched variant of BrahMos, which can be fired from the **Su-30MKI**, entered service in 2019.
- The **BrahMos-II**, a future hypersonic missile, is likely to be developed from and have similar characteristics to the **3M22 Zircon**.

1.4.5 Recent Developments

- On January 24, 2024, the Indian Navy successfully engaged a land-based target at an enhanced range using the BrahMos supersonic cruise missile.
- This test indicated that the missile is now capable of reaching ranges of up to 900 km.

1.4.6 Usage

- The BrahMos missile is the preferred offensive missile used by the Indian Navy.
- Its various versions are tested often.
- The range extension can be applied to all variants of the missile, including the air-launched variant.

1.5 Missiles of Collaborative Development

| Missile Name | Type | Origin/Collaboration |
|---------------------------------|--------------------------------|---------------------------------------|
| BrahMos Cruise Missile | Medium-range supersonic cruise | Jointly developed by India and Russia |
| Barak-8 | Medium-range Surface-to-Air | Jointly developed by India and Israel |
| Exocet Anti-Ship Cruise Missile | Anti-ship | Imported from France |
| Harpoon Anti-Ship Missiles | Anti-ship | Imported from the United States |

1.5.1 Barak 8 Missile System

- **Type:** Medium to long-range surface-to-air missile.

- **Place of Origin:** India and Israel.
- **In Service:** 2016–present.
- **Launch Platform:** Includes an 8 cell VLS module and an 8 cell, double-stacked land launcher.
- **Operational Range:**
 - Barak-8 MRSAM (single-stage rocket): 0.5 km - 70 km.
 - Barak-8 LRSAM (single-stage rocket): 0.5 km - 100 km.
 - Barak ER (2-stage rocket): 0.5 km - 150 km.
- **Maximum Speed:** Mach 2 for the LRSAM variant.
- **Guidance System:** Features a 2-way datalink with WCS and active radar homing.

Development and Production

The Barak 8 missile defence system is a collaboration involving Israel's Directorate of Research and Development (DDR&D), Elta Systems, Rafael Advanced Defense Systems, and India's Bharat Dynamics Limited (BDL). It is tailored to counter a wide range of airborne threats including aircraft, helicopters, anti-ship missiles, UAVs, ballistic missiles, cruise missiles, and combat jets. The system has both maritime and land-based variants.

Long-Range Surface-to-Air Missile (LRSAM) Defence System

India is developing a three-layered long-range surface-to-air missile defence system capable of engaging enemy aircraft and missiles up to 400 km away.

LRSAM and MRSAM: Variants of Barak 8

- **LRSAM (Long Range Surface-to-Air Missile):** This variant, designed for naval vessels, boasts an operational range of up to 100 km.
- **MRSAM (Medium Range Surface-to-Air Missile):** This land-based variant has an operational range of up to 70 km.

Both LRSAM and MRSAM are engineered to defend against diverse airborne threats and share the same missile configuration, differing primarily in their operational range and deployment platforms.

1.6 India's Nuclear Triad: Components and Strategic Importance

India's nuclear triad refers to its capability to deliver **nuclear weapons** through three distinct platforms: **land, air, and sea**. This diversified approach ensures the effectiveness of India's nuclear deterrence by making it challenging for any adversary to neutralise all of the country's nuclear forces in a first strike.

1.6.1 Components of the Nuclear Triad

- **Land-Based Missiles:** Includes missiles like the **Agni 2, Agni 4, and Agni 5**. These provide India with a robust land-based delivery system for nuclear weapons.
- **Air-Based Delivery:** Aircraft such as **Sukhoi Su-30MKIs, Mirage 2000s, and Jaguars** serve as airborne platforms capable of launching nuclear payloads.
- **Sea-Based Capability:** The **INS Arihant**, a 6,000-tonne indigenous Ship Submersible Ballistic Nuclear (SSBN), represents the maritime component. Additionally, the **K-4 Sagarika** is an Indian 3500 km-range **submarine-launched nuclear warhead capable ballistic missile (SLBM)**. It is designed to be launched from India's **indigenous nuclear submarines**.

1.6.2 Strategic Importance

The operationalisation of this triad contributes to maintaining a **credible nuclear deterrent**. It supports India's **No First Use policy**, making it highly difficult for an adversary to incapacitate India's nuclear arsenal through a first strike. This forms a cornerstone of India's **Nuclear Doctrine**.

2 India's Missile Defence Programme

2.1 Indian Ballistic Missile Defence (BMD) Programme

Historical Context

- **Initiation:** Commenced in 1999 post-Kargil War and as a counter to China and Pakistan's missile capabilities.

System Architecture

- **Two-Tiered System:** Comprises Prithvi Air Defense (PAD)/Pradyumna and Advanced Air Defence (AAD).
 - **First Layer (Exo-atmospheric):** PAD/Pradyumna and Prithvi Defense Vehicle (PDV) intercept missiles at altitudes of 50-180 km.
 - **Second Layer (Endo-atmospheric):** AAD/Ashwin intercepts missiles at altitudes of 15-40 km.
- **Target Range:** Capable of intercepting missiles launched from up to 5,000 km away.

Components

- **Radars and Control Posts:** Overlapping network of early warning and tracking radars, along with command and control posts.

Testing and Status

- **Initial Tests:** Started in 2006; multiple successful tests, including one in August 2018.
- **Completion:** First phase completed as of January 2020; awaiting government approval for deployment around the national capital.

2.2 Iron Dome System

Overview

- **Purpose:** Developed by Israel to intercept and destroy short-range rockets and artillery shells.
- **Detection Range:** Identifies rockets at a distance of 4 to 70 km.

Milestones

- **Final Testing:** Completed in July 2010.
- **Operational Status:** Declared operational in 2011; used in conflicts against Hamas in 2012 and 2014.

Deployment and Collaboration

- **Operators:** Israel and Singapore.
- **India-Israel Deal:** A \$2 billion deal signed in 2017 for India to acquire the Iron Dome system.

2.3 Comparative Analysis

Common Objectives

- Both Indian BMD and Iron Dome aim to protect against incoming missile threats but differ significantly in the types of threats they are designed to counteract.

Technical Capabilities

- Indian BMD is designed for longer ranges and higher altitudes, whereas Iron Dome targets short-range threats.

International Collaboration

- While Indian BMD is an indigenous programme, the Iron Dome system represents international defence collaboration, particularly between India and Israel.

Status and Future Developments

- Indian BMD is waiting for government approval for further deployment, whereas the Iron Dome is already operational and has been combat-tested.

2.4 S-400 Triumph

The **S-400 Triumph** is a **mobile surface-to-air missile system (SAM)** designed by Russia. It holds the distinction of being the most advanced operationally deployed **modern long-range SAM**, surpassing the United States' **Terminal High Altitude Area Defense system (THAAD)**. The S-400 Triumph is equipped to engage a wide array of aerial threats. These include **aircraft, unmanned aerial vehicles (UAVs)**, and **ballistic and cruise missiles**.

The system has a range of **400 km** and can operate at altitudes up to **30 km**. Furthermore, it can track **100 airborne targets** and engage up to **six of them simultaneously**.

India's Acquisition of S-400 Triumph

India entered into a **\$5.43 billion USD agreement** with Russia in October 2018 for the acquisition of the S-400 Triumph missile system. The deliveries have already begun and are expected to conclude by **late 2023 / 2024**. This acquisition is going to substantially enhance India's ability to neutralise **enemy fighter aircraft and cruise missiles at long range**.

Geopolitical Implications

While the deal significantly boosts India's defensive capabilities, it has faced diplomatic challenges. The United States has expressed objections and has threatened to impose sanctions under the **Countering America's Adversaries Through Sanctions Act (CAATSA)**. Despite such international pressure, India has opted to proceed with the acquisition, underscoring the strategic importance it attributes to the S-400 system for its defence infrastructure.

Design and Capabilities

- **Origin:** Designed by Russia, the **S-400 Triumph** is a mobile surface-to-air missile system (SAM).
- **NATO Designation:** Also known as **SA-21 Growler** by NATO.
- **Operational Superiority:** Considered the most advanced **Modern Long-Range SAM (MLR SAM)**, surpassing the US-developed **Terminal High Altitude Area Defense system (THAAD)**.
- **Aerial Engagement:** Capable of targeting a variety of aerial objects including **aircraft, Unmanned Aerial Vehicles (UAVs)**, and **ballistic and cruise missiles** within a range of **400 km** and up to an altitude of **30 km**.

Technical Specifications

- **Target Tracking:** Can monitor **100 airborne targets** and engage up to **six of them simultaneously**.
- **Generational Advancement:** Represents the **fourth generation** of long-range Russian SAMs, succeeding the S-200 and S-300.
- **Integrated Systems:** Comprises a **multifunction radar, autonomous detection and targeting systems, anti-aircraft missile systems, launchers, and a command and control centre**.
- **Missile Variants:** Capable of launching **three types of missiles** for layered defence.

Efficiency and Deployment

- **Effectiveness:** Two times more effective than previous Russian air defence systems.
- **Rapid Deployment:** Can be operational within **five minutes**.
- **Operational Status:** First became operational in **2007** and is tasked with defending Russia.
- **Interoperability:** Can be integrated with **Air Force, Army, and Navy** air defence units.

Strategic Deployment

- **Location:** Systems are already deployed to counter threats from **China in the northern sector** and along the **frontier with Pakistan**.

3 LCA Tejas

3.1 Overview of HAL Tejas

- **HAL Tejas**, also known as **Light Combat Aircraft (LCA) Tejas**, is an Indian **single-engine, delta wing, multirole light fighter**.
- Designed by the **Aeronautical Development Agency (ADA)** in collaboration with the **Aircraft Research and Design Centre (ARDC)** of **Hindustan Aeronautics Limited (HAL)**.
- Developed for the **Indian Air Force (IAF)** and **Indian Navy**.

3.2 Origin and Development

- The LCA programme began in the **1980s**.
- Aims:
 - **Replacement** for India's ageing **MiG-21** fighters.
 - Boost **domestic aviation capability**.
 - Achieve **aerospace self-reliance**.
 - Build a local industry for **state-of-the-art products with commercial spin-offs**.

3.3 Organisational Structure

- **Aeronautical Development Agency (ADA)** was established in **1984** by the Government of India.
- Principal partner: **Hindustan Aeronautics Limited (HAL)**.
- Collaboration with **DRDO & CSIR Laboratories, public and private sector industries, and academic institutions.**

3.4 Technical Features

- **Aerodynamically unstable tailless compound delta-wing configuration** optimised primarily for **manoeuvrability and agility**.
- **Maximum speed: Mach 1.8.**
- **Range: 3,200 km.**
- **Combat range: 500 km.**
- **Ferry range: 1,850 km.**
- Constructed of **aluminium-lithium alloys, carbon-fibre composites, and titanium alloys.**
- **Composite materials** make up **45% of the airframe by weight and 95% by surface area.**

3.5 Avionics and Systems

- **Night Vision Goggles (NVG)-compatible "glass cockpit".**
- **Domestically-developed head-up display (HUD) by Central Scientific Instruments Organization (CSIO).**
- **Multi-function displays, Smart Standby Display Units (SSDU), and a "get-you-home" panel.**

3.6 Variants and Orders

- **Mark 1, Mark 1A, and a trainer version.**
- IAF has ordered **32 Mark 1s, 73 Mark 1As, and 18 Mark 1 trainers.**
- Planned procurement: **324 aircraft in all variants** including **Tejas Mark 2** under development.
- **43 improvements** in the Mark-1A jets including **AESA radar, long-range beyond visual range missiles, air-to-air refuelling, and advanced electronic warfare.**

3.7 Deployment

- First Tejas squadron became operational in **2016**. (IAF fighter squadrons typically have 18 operationally deployed aircraft, with three crafts kept as a reserve.)

- Participated in military exercises like **Gagan Shakti 2018 and Vayu Shakti 2019**.
- **83 single-engine Tejas Mark-1A** aircrafts by the Indian Air Force were finalised in **January 2020**.
- **Argentina and Egypt have shown interest in Tejas**, the Light Combat Aircraft (LCA) manufactured by Hindustan Aeronautics Limited (HAL).

3.8 Comparative Advantages and Significance

- Lightest in its category at **nine tons**.
- Cost-effective at **Rs.180 crore apiece**.
- Comparable to **French Mirage 2000, U.S. F-16, and Swedish Gripen**.
- No accidents during trials.
- Contributes to **indigenisation of military hardware** and provides valuable experience for future aircraft development.

3.9 Challenges and Future Prospects

- **Long development period** costing **Rs.172.69 billion**.
- **Limited payload and agility** due to the current **GE F404 engine**.
- **Tejas Mark II with GE 414 engine** is awaited but may require re-engineering.

