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Missile Defence Systems: Layers, Logic, and India's Own Shield

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WHY IN NEWS

The US-Israel-Iran military confrontation in March 2026 brought multiple advanced missile defence systems into live combat operation simultaneously — Iron Dome, Arrow-3, THAAD, and Patriot. Iran's retaliatory missile barrage and Israel's and the US's interception responses have made understanding missile defence architecture directly relevant for UPSC Science & Technology and Security & Defence sections.

Every time a major conflict erupts involving advanced militaries, it forces a global audience to grapple with the sophisticated technology of modern warfare. The US-Israel-Iran confrontation has brought missile defence systems — their capabilities, limitations, and strategic logic — into sharp relief. For India, a country surrounded by nuclear-armed neighbours and investing heavily in its own air defence architecture, understanding these systems is not merely academic.

THE STRATEGIC LOGIC OF LAYERED DEFENCE

No single missile defence system can guarantee 100% interception. The philosophy behind modern air defence is therefore **layering**: deploying multiple systems capable of engaging threats at different altitudes, ranges, and speeds. A threat that bypasses the outermost layer faces a second, then a third. This “defence in depth” approach dramatically increases the probability of neutralising incoming missiles before they reach critical targets.

Think of it as concentric rings of protection:

Outer ring (exo-atmospheric): Intercepts ballistic missiles in space, during their mid-course phase

Middle ring (endo-atmospheric, high altitude): Engages missiles as they re-enter the atmosphere

Inner ring (low altitude, terminal phase): Last-ditch interception of missiles already in their final descent

HOW INTERCEPTION ACTUALLY WORKS

The physics and engineering of missile interception is remarkably complex. Here is the complete sequence:

1. Detection Detection is the foundation. Two primary sensor types are used:

Ground-based radar: Long-range phased-array radars (like the AN/TPY-2 used with THAAD) can detect launches hundreds of kilometres away within seconds

Space-based early warning satellites: Infrared sensors in geosynchronous orbit detect the heat plume of a missile launch almost instantly; the US Space-Based Infrared System (SBIRS) is the world's most advanced such network

2. Tracking and Classification Once a launch is detected, the system must determine: Is it a ballistic missile or a cruise missile? Is it a short-range, medium-range, or ICBM? What is its trajectory and projected impact point? This classification determines which interceptor system responds.

3. Engagement Decision Engagement authority can be pre-delegated (automatic mode) or require human approval. The time window can be as short as 30–90 seconds for short-range threats, demanding near-instantaneous decisions.

4. Interceptor Launch The right interceptor is launched to create a future intercept point — a calculated location in space where both the incoming missile and the interceptor will arrive simultaneously.

5. Terminal Destruction: Two Mechanisms

Hit-to-Kill (HTK): The interceptor physically collides with the incoming missile at closing speeds of several kilometres per second. The kinetic energy of impact destroys both. Arrow-3 and SM-3 use this mechanism. It leaves no unexploded warhead — the target is vaporised by the collision

Proximity Fuse Detonation: The interceptor detonates near the incoming missile, destroying it with shrapnel. Iron Dome primarily uses this approach. A risk: the warhead of the incoming missile may survive in fragments and still cause damage on the ground

KEY SYSTEMS: A COMPREHENSIVE COMPARISON

United States Systems:

System	Type	Range	Altitude	Key Feature
THAAD	Terminal defence	200 km	40–150 km	Hit-to-kill; mobile and deployable
Patriot PAC-3	Terminal defence	35 km	Low altitude	Widely deployed; proven in Gulf Wars
SM-3 (Aegis)	Midcourse defence	700+ km	Exo-atmospheric	Naval-based; intercepts outside atmosphere
SM-6	Terminal/midcourse	240 km	High altitude	Dual role: air defence + missile defence
Ground-Based Midcourse Defense (GMD)	Midcourse	5,000+ km	Space	ICBM defence for continental US

THAAD (Terminal High Altitude Area Defense) is particularly significant: it uses no explosive warhead at all — pure kinetic interception. The decision to deploy THAAD to South Korea was announced in **July 2016** and declared operational on **April 26, 2017**, during the height of the North Korean missile crisis, triggering a major diplomatic dispute with China, which objected to the powerful AN/TPY-2 radar’s ability to peer deep into Chinese territory.

Israeli Layered Defence — The World’s Most Battle-Tested System:

System	Designed For	Range	Success Rate
Iron Dome	Short-range rockets, mortars, artillery (4–70 km)	70 km	80–97%
David’s Sling	Medium-range missiles, cruise missiles, aircraft	300 km	Not fully public
Arrow-2	Short-to-medium range ballistic missiles	90 km	Classified
Arrow-3	Long-range ballistic missiles (exo-atmospheric)	2,400 km	Classified
Iron Beam	Short-range rockets, drones (laser)	7 km	Developmental

Iron Dome deserves special attention. Developed by Rafael Advanced Defense Systems (Israel), it was declared **operational on March 27, 2011**, and achieved its **first combat interception on April 7, 2011**, intercepting a Grad rocket fired from Gaza at the city of Beersheba. Since then, it has intercepted over 2,500 rockets in actual combat. Its genius lies in its **selective engagement algorithm** — it calculates which incoming rockets will hit populated areas and ignores those that will land harmlessly in open ground, conserving expensive interceptor missiles. Each Iron Dome interceptor costs approximately \$50,000–80,000, while the rockets it defends against cost a few hundred dollars — a cost asymmetry that is strategically significant.

Iron Beam represents the next frontier: a directed-energy (laser) weapon that can destroy small drones and rockets at virtually zero marginal cost per shot (just electricity). Israel is deploying it at scale to complement Iron Dome.

Iranian Systems:

Bavar-373: Iran’s domestically developed long-range air defence system, designed as an S-300 equivalent after Russia delayed/cancelled the S-300 deal. Has limited combat testing

Sevom-e-Khordad: Medium-range system; famously claimed the shoot-down of a US Global Hawk drone in 2019

Tor-M1: Russian-supplied short-range mobile system (tragically, Iran mistakenly shot down Ukraine International Airlines Flight PS752 in 2020 using a Tor-M1 in an alert-state error)

Iran’s offensive missile capability — the Shahab series, Fateh-110, and the Fattah hypersonic missile — is arguably more advanced than its defensive systems.

HYPERSONIC MISSILES: THE NEW CHALLENGE

The current conflict has also showcased the emerging threat of **hypersonic missiles** — weapons travelling at Mach 5 or faster, often with manoeuvrable warheads. Unlike traditional ballistic missiles that follow predictable parabolic trajectories, hypersonic glide vehicles fly at lower altitudes and can change course, making interception extremely difficult. No existing missile defence system has a proven ability to consistently intercept hypersonic missiles in combat conditions.

Iran’s **Fattah missile** (claimed Mach 13–15) represents this category. The US, China, Russia, North Korea, and India (BrahMos-II development) are all racing in this space.

INDIA’S AIR DEFENCE ARCHITECTURE

India is building its own layered missile defence — directly analogous to the Israeli model — under the **Defence Research and Development Organisation (DRDO)**:

Layer	System	Status
Exo-atmospheric	Prithvi Defence Vehicle (PDV) Mk-II	Under development (DRDO)
Endo-atmospheric, high	Advanced Air Defence (AAD) interceptor	Tested successfully
Long-range area defence	S-400 Triumpf (5 squadrons from Russia)	Partially inducted
Medium range	Barak-8 / MR-SAM (India-Israel joint)	Operational with Army and Navy
Short range	Akash missile system	Operational
Very short range	Quick Reaction Surface-to-Air Missile (QRSAM)	Under induction

The **S-400 Triumph acquisition** — India signed the deal with Russia on **October 5, 2018** for **five squadrons at a cost of \$5.43 billion** — drew threats of US sanctions under CAATSA. India was granted a waiver, reflecting the US’s recognition that India needed advanced air defence given its threat environment (Pakistan and China both possess ballistic missiles and cruise missiles). The **Indian Air Force (IAF) inducted the first S-400 squadron in 2021-22**, deploying it in the **Punjab sector** (facing Pakistan) to provide cover to the sensitive northern border region.

The **Barak-8 (Medium Range Surface-to-Air Missile / MR-SAM)** is jointly developed by **DRDO (India)** and **Israel Aerospace Industries (IAI) of Israel**; the naval variant (LR-SAM) was first test-fired from INS Kolkata in **December 2015** and inducted into the Indian Navy in **2016**, while the land-based variant (MR-SAM) was inducted into the Indian Army and IAF from **2019 onwards**, providing a proven medium-range air defence capability.

India’s **Ballistic Missile Defence (BMD) programme** — run by DRDO — has achieved significant milestones. The **Prithvi Defence Vehicle (PDV)** successfully conducted an exo-atmospheric interception test on **February 11, 2017**, destroying a simulated ballistic missile target outside the atmosphere. On **March 27, 2019**, India demonstrated its exo-atmospheric interception capability via **Mission Shakti** — an anti-satellite (ASAT) test using a modified PDV Mk-II interceptor that destroyed a live satellite at 283 km altitude in low Earth orbit. India is now working toward Phase II, which would defend against longer-range missiles. If fully operational, India would join a very small club of nations with credible BMD capability: US, Russia, Israel, and (arguably) China.

UPSC RELEVANCE

Iron Dome, THAAD, Arrow-3 systems; hit-to-kill mechanism; S-400 system; Barak-8; Akash; DRDO’s PDV; CAATSA.

MAINS GS-3:

Role of technology in defence; India’s defence indigenisation (Atmanirbhar Bharat in defence); missile defence architecture; space-based surveillance.

SCIENCE & TECH:

Hypersonic missiles; directed energy weapons; radar technologies.

★ FACTS CORNER — KNOWLEDGE PEDIA

US SYSTEMS:

THAAD — Terminal High Altitude Area Defense; intercepts ballistic missiles at 40–150 km altitude; uses hit-to-kill (no warhead); range ~200 km; deployed to South Korea July 2016 (announcement), operational April 26, 2017

Patriot PAC-3 — low-to-mid altitude terminal defence; range ~35 km

SM-3 (Aegis) — sea-based; intercepts outside atmosphere; range 700+ km; used on destroyers/cruisers

GMD — Ground-Based Midcourse Defense; defends continental US against ICBMs; range 5,000+ km

ISRAELI SYSTEMS:

Iron Dome — short-range rockets/mortars (4–70 km); success rate **80–97%**; developed by Rafael Advanced Defense Systems; declared operational **March 27, 2011**; first combat interception **April 7, 2011**

David's Sling — medium-range missiles and cruise missiles; range ~300 km

Arrow-2 — short-to-medium range ballistic missiles; endo-atmospheric

Arrow-3 — long-range ballistic missiles; **exo-atmospheric** (intercepts in space); range ~2,400 km

Iron Beam — laser (directed energy) weapon; designed for drones and short-range rockets; ~7 km range; near-zero cost per shot

IRANIAN SYSTEMS:

Bavar-373 — long-range air defence (S-300 class); domestically developed

Sevom-e-Khordad — medium-range; shot down US Global Hawk drone in 2019

Tor-M1 — Russian-supplied short-range mobile SAM; accidentally shot down Ukraine Airlines Flight PS752 in January 2020

INDIA'S SYSTEMS:

S-400 Triumph — deal signed October 5, 2018; 5 squadrons; cost \$5.43 billion; first squadron inducted 2021-22 in Punjab sector by IAF

Barak-8 / MR-SAM — jointly developed by DRDO (India) and IAI (Israel); naval variant (LR-SAM) test-fired Dec 2015, inducted Navy 2016; land variant (MR-SAM) inducted Army/IAF from 2019

Akash — medium-range SAM; fully indigenous (DRDO); operational

QRSAM — Quick Reaction Surface-to-Air Missile; under induction

PDV (Prithvi Defence Vehicle) — DRDO's exo-atmospheric interceptor; successfully tested February 11, 2017 (first test); modified PDV Mk-II used in Mission Shakti ASAT test on March 27, 2019

DRDO full form: Defence Research and Development Organisation

KEY CONCEPTS:

Hit-to-Kill (HTK): Interceptor destroys target by direct physical collision — no explosive warhead

Proximity Fuse: Interceptor detonates near the target; destroys it with shrapnel

Hypersonic missile: Speed > Mach 5; manoeuvrable; flies at lower altitude — harder to intercept than ballistic missiles

Iron Dome cost: Each interceptor ~\$50,000–80,000; rockets it intercepts cost a few hundred dollars (cost asymmetry problem)

OTHER RELEVANT FACTS:

India's BMD programme (DRDO): Phase I — exo-atmospheric interception ✓; Phase II — longer-range intercepts (under development)

SBIRS — Space-Based Infrared System (US); detects missile launches via infrared from geosynchronous orbit

India's **BrahMos-II** (in development): hypersonic cruise missile; target speed Mach 7–8

Fattah missile (Iran): Claimed hypersonic at Mach 13–15; Iran's most advanced ballistic missile

Nations with credible BMD: USA, Russia, Israel, China (partial), India (developing)

THAAD controversy: Deployment announced July 2016, operational April 26, 2017 in South Korea; China objected citing radar range

Sources: [The Hindu](#), [DRDO](#), [PIB](#), [The Wire](#), [Missile Defense Advocacy Alliance](#)

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