The Indian EXPRESS
JOURNALISM OF COURAGE

Explained: How Air Defence Systems work

Key to India's thwarting of Pakistani aerial attacks along the western border has been the success of Indian air defences.

Written by Arjun Sengupta
New Delhi | Updated: May 9, 2025 07:14 IST

8 min read

Security personnel inspect metal debris found in an open field at Makhan Windi village in Amritsar, Thursday. (PTI)

After thwarting Pakistani attacks on several Indian targets overnight, India on Thursday morning [targeted air defence systems] in a number of locations in Pakistan.

"It has been reliably learnt that an Air Defence system at Lahore has been neutralised," the Army said in a press release. "[The] Indian response has been in the same domain, [and of the] same intensity as Pakistan," the release said.

Controlling the skies is of paramount importance in modern warfare. As such, air defence systems are a vital cog in any nation's defensive infrastructure.

A capable and operational air defence system protects against enemy air strikes, as was evident from the fact that Pakistan failed to inflict damage on India during Wednesday-Thursday night. And taking down the enemy's air defences leaves it vulnerable to aerial attacks in its territory.

HOW THEY WORK

The primary objective of an air defence system is to take out threats from the skies — be it enemy fighter aircraft, unmanned drones, or missiles.

This is done with the help of a complex system of radar, control centres, defensive fighter aircraft, and ground-based air defence missile, artillery, and electronic warfare systems.

An air defence system can be sub-categorised into three interlinked operations.

Also Read | Operation Sindoor and a look at India's past military operations against Pakistan

DETECTION: Key to the success of any air defence system is its ability to detect threats in the first place. This is typically done by radar, although satellites may be used in certain circumstances — such as an enemy launching an Intercontinental Ballistic Missile (ICBM).

Radar send out beams of electromagnetic radio waves through a transmitter. These waves are reflected by the objects that they hit — such as an enemy aircraft. A receiver then collects the returning radio waves — based on which it makes inferences such as the distance of the threat, its speed, and its specific nature (what kind of aircraft/ missile).

Explained | Air defence system in Lahore 'neutralised' by Indian Armed Forces: What does this mean?

TRACKING: The efficiency of an air defence system is also determined by its ability to constantly and accurately track — and not merely detect — an aerial threat. This is typically done using a combination of radar and other sensors such as infrared cameras or laser rangefinders.

More often than not, an air defence system is not just dealing with a single threat — it has to identify and track multiple, fast-moving threats in complex and cluttered environments, which may also include friendly aircraft.

The accuracy of tracking is crucial for effectively neutralising the enemy without targeting false threats.

Read | From HAMMER to BrahMos, the precision guided long range weapons in Indian military's arsenal

---

INTERCEPTION: Once the threat has been detected and tracked, it must be neutralised. Here, the specifics of the threat — its range, type (what kind of missile/ aircraft), speed, etc. — determine the ways in which air defences work.

All these three aspects of an air defence system have to work together as a cogent whole. This requires what in military parlance is called "C3" or a "command, control and communication" system.

Beyond the technical capabilities of detecting, tracking, and intercepting aerial threats, superior communication and decision-making capabilities are crucial for an effective air defence.

HOW THEY INTERCEPT

Depending on the challenges they foresee, nations utilise a wide assortment of weapons to neutralise aerial threats. These include the following.

FIGHTER AIRCRAFT: Interceptors are fighters that take on attacking enemy aircraft, especially bombers. These agile aircraft can be scrambled at a moment's notice, and they climb quickly to altitude and neutralise an enemy aircraft before it deploys its weapons.

Interceptors are equipped for air-to-air combat with cannon, rockets, a suite of visual-range and beyond-visual-range missiles, and electronic warfare systems.

Aircraft such as the MiG-21 — an upgraded variant of which is still in service with the Indian Air Force — were dedicated interceptors; latest fighter aircraft have "multirole capabilities". India can deploy any of its Sukhoi Su-35s, MiG-29s, HAL Tejas, Mig-21 Bisons, and Dassault Rafales for interceptor missions.

SURFACE-TO-AIR MISSILES (SAMS): Today, SAMs are the bread-and-butter of most air defence systems. This is because they are more effective than anti-aircraft artillery (AAA), and do not put pilots in danger like interceptors.

SAMs can be used to target enemy fighters, helicopters, and missiles. They are generally radar-, infrared-, or laser-guided. In addition to being operated from the ground, SAMs can also be launched from ships.

The three, oft-used but unofficial classes of SAMs are:

* Heavy long-range systems which are fixed or semi-mobile;

* Medium-range vehicle-mounted systems that can fire on the move;

* Short-range man-portable air-defense systems (or MANPADS).

Each SAM class has a different function.

The heaviest SAMs, such as the Russian-made S-400 system used by India, take on enemy ballistic missiles or aircraft at long range, as much as a few hundred kilometres. Medium range SAMs have the capability to hit targets in the 50-100 km range but are more mobile, and can be launched in next-to-no time.

MANPADS are used for low-lying targets such as hovering helicopters or drones, or fixed-wing aircraft engaged in ground attack roles. These are far more cost-effective than the other classes, and have been used extensively not only by militaries but also non-state actors in unconventional warfare.

India's arsenal of SAMs include the indigenously-developed medium-range Akash missiles, the medium-to-long range Barak missiles, and the long-range S-400 missiles.

ANTI-AIRCRAFT ARTILLERY (AAA): Once the cornerstone of ground-based air defence systems, the development of SAMs and capabilities of modern fighter jets have greatly reduced the salience of AAA. But augmented with automated fire-control systems, they remain crucial last-ditch defences, and are also used for specialised anti-unmanned aerial vehicle (UAV) roles.

AAA fire shells rapidly, at rates of over 1,000 rounds per minute. AAA shells are designed to explode at predetermined altitudes so as to disperse shrapnel over a wide area. This makes an AAA battery effective even if it does not achieve a direct hit.

ELECTRONIC WARFARE (EW): It is not necessary to actually shoot down an enemy aerial threat in order to neutralise it. EW systems are designed to disrupt, deceive, or destroy threats using the power of the electromagnetic spectrum.

In the context of air defence, EW is most often used to jam enemy radar and targeting systems, so as to impede its ability to accurately and effectively deploy its weapon. EW can confuse attack drones or prevent enemy air-to-surface missiles from homing in on targets.

Several highly sophisticated EW systems are in use today. These can operate from both land and air, including from specialised EW aircraft, such as the US Navy's Boeing EA-18G Growler, the EW version of the F/A-18 Super Hornet.

TAKING DOWN ADs

Establishing air superiority allows an Air Force to operate with a degree of impunity, and without fear of attrition in bombing, tactical air support, paratroop insertion, or supply-drop missions.

To establish air superiority over enemy territory, the enemy's air defence systems have to be neutralised. Suppression of Enemy Air Defences (SEAD) operations target enemy air defences with missiles, EW, bombs, UAVs or even ground attacks. An analysis published in 2005 found that a quarter of American combat sorties in (then) recent conflicts had been SEAD missions (Christopher Bolkcom, 'Military Suppression of Enemy Air Defenses (SEAD): Assessing Future Needs').

Given the role of air superiority in providing a protective umbrella for ground forces, taking down enemy air defences also lays the ground for deeper ground attacks into enemy territory.

This article went live on May ninth, twenty twenty-five, at four minutes past one at night.

TAGS: Express Explained Express Premium Operation Sindoor