How Patriot Missiles Work

By: Marshall Brain & Sarah Gleim | Updated: Mar 10, 2022

The Patriot missile has been in development by the U.S. army since the early 1960s. The Army activated its first Patriot missile battalion in May 1982. JOHN HAMILTON, ARMY

The MIM-104 Patriot (Phased Array Tracking Radar to Intercept On Target) missile system is the U.S. Army's main air and missile defense system. It was originally designed as an anti-aircraft system, but the newest iterations of the Patriot can detect, target and track ballistic and cruise missiles, munitions as well as aircraft.

It was first developed in the early '60s to replace both the Nike Hercules and Hawk air defense missile systems. The Army named the program Surface-to-Air Missile, Development (SAM-D) and the first tests occurred in 1969 and 1970.

In the '70s, the Department of Defense overhauled the SAM-D to include a Track-Via-Missile (TVM) guidance system. The updated SAM-D was renamed Patriot and entered full production in 1980. The Army activated its first Patriot missile battalion in May 1982.

According to Raytheon Missiles and Defense, the company that designs and makes the Patriot, the missile system has been used by five nations in more than 250 combat engagements since it was first activated in the field in 1982, though Raytheon has built and delivered more than 240 Patriot systems to 17 nations.

Patriot missiles are launched from Patriot missile batteries based on the ground. A typical battery has five components:

- the missiles themselves
- the missile launcher, which holds, transports, aims and launches the missiles
- a radar antenna to detect incoming missiles
- an equipment truck known as the engagement control station (ECS) housing computers and consoles to control the battery
- a power plant truck equipped with two 150-kilowatt generators that provide power for the radar antenna and the ECS

In the following sections we will look at each of the different components and then how the system operates as a whole.

The Patriot Missile

The MIM-104 Patriot PAC-3 missile has a range of about 25 miles (40 kilometers). WIKIMEDIA/(CC BY-SA 3.0)

Like the Stinger missile, the Patriot is a guided missile, though the Patriot is more sophisticated. The Stinger uses an infrared seeker that locks on to the heat of an airplane's engine exhaust. Stingers are launched by a person who holds it on their shoulder after aiming and then firing the missile at the target.

A Patriot missile, instead, uses ground-based radar to surveil, track and engage targets. An incoming missile could be as far away as 50 miles (80.5 kilometers) and the Patriot system's radar can lock onto it. At that distance, the missile would not be visible from the ground, much less identifiable.

The Patriot missile has been through several significant upgrades since its initial development, including:

- Software changes in the mid-1980s allowed the missile to engage tactical ballistic missiles, known as the PAC-1 (Patriot Advanced Capability).
- The first major missile upgrade in the late 1980s introduced the MIM-104C

missile, also known as the PAC-2 missile.

- In 1993, more upgrades were made to allow remote launch capabilities of the PAC-2 missile.
- In 1997, the Army deployed the PAC-3 missile — or MIM-104F missile — with an onboard radar detection and tracking system for improved capabilities against ballistic missiles. The first PAC-3 missiles used in combat were during Operation Iraqi Freedom in 2003.

More improvements have been made to the PAC-3 missile since its first use during Operation Iraqi Freedom. The PAC-3 Missile Segment Enhancement (MSE) now includes a bigger motor that nearly doubles the PAC-3's range. It was fully approved by the U.S. Army in 2018.

The Patriot currently supports the PAC-2 and PAC-3 missiles.

PAC-2 Missile Specs

- AKA MIM-104C and MIM-104D missile
- range of about 99 miles (160 kilometers)
- HE-FRAG warhead
- 17 feet long (5.2 meters)
- 16 inches (41 centimeters) in diameter
- has fins that extend out another 16 inches (41 centimeters)
- weighs almost 2,000 pounds (900 kilograms)
- carries a 200-pound (90-kilogram) fragmentation bomb with a proximity fuse
- flies at Mach 5 and is supersonic within a second after launch

The PAC-2 flies straight toward incoming missiles and then explodes at the point of nearest approach. The explosion will either destroy the incoming missile with the fragments from the fragmentation bomb, or knock the incoming missile off course so it misses its target.

PAC-3 Missile Specs

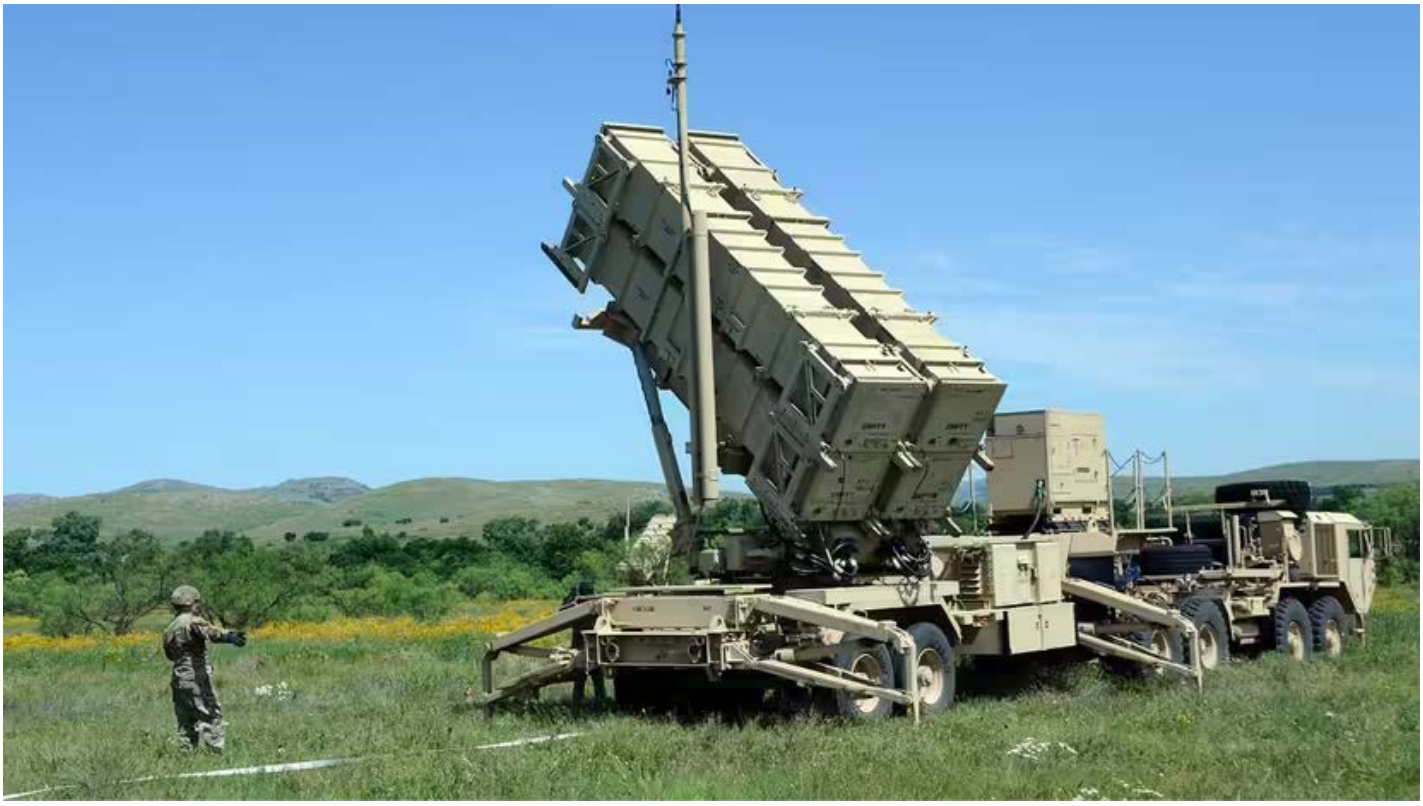
- AKA MIM-104F missile
- range of about 25 miles (40 kilometers)
- HE-FRAG warhead
- 17 feet long (5.2 meters)
- 10 inches (25 centimeters)
- weighs almost 688 pounds (312 kilograms)
- carries a 160 pounds (73 kilograms) fragmentation bomb with a proximity fuse
- flies at Mach 5 and is supersonic within a second after launch

The PAC-3 missile is the same length as the PAC-2 but weighs only a third as much. The smaller size means that 16 PAC-3 missiles can fit on a launcher, compared to just four PAC-2 missiles.

When a PAC-3 missile is launched, it actually hits the incoming target and explodes so the enemy missile is completely destroyed. This feature makes it more effective against chemical and biological warheads because they are destroyed well away from the target.

The biggest difference between the PAC-2 and the PAC-3 — and what allows the PAC-3 to actually hit its target — is the PAC-3's built-in radar transmitter and guidance computer.

The Patriot Missile Launcher and Other Systems



Patriot missile launchers can hold between four and 16 missiles, depending on the type. U.S. ARMY

The Patriot system launches missiles from the M901 launching station. The stations include up to four launch canisters that can hold four different PAC-3 missiles, depending on the type. The launchers are about the size of a tractor-trailer rig. Each get its power from the electric power plant (EPP) vehicle.

Each launching station is pulled by an M983 truck. Typically, a Patriot battery will include six to eight launching stations, a radar set, engagement control station (ECS), power generation and other support vehicles.

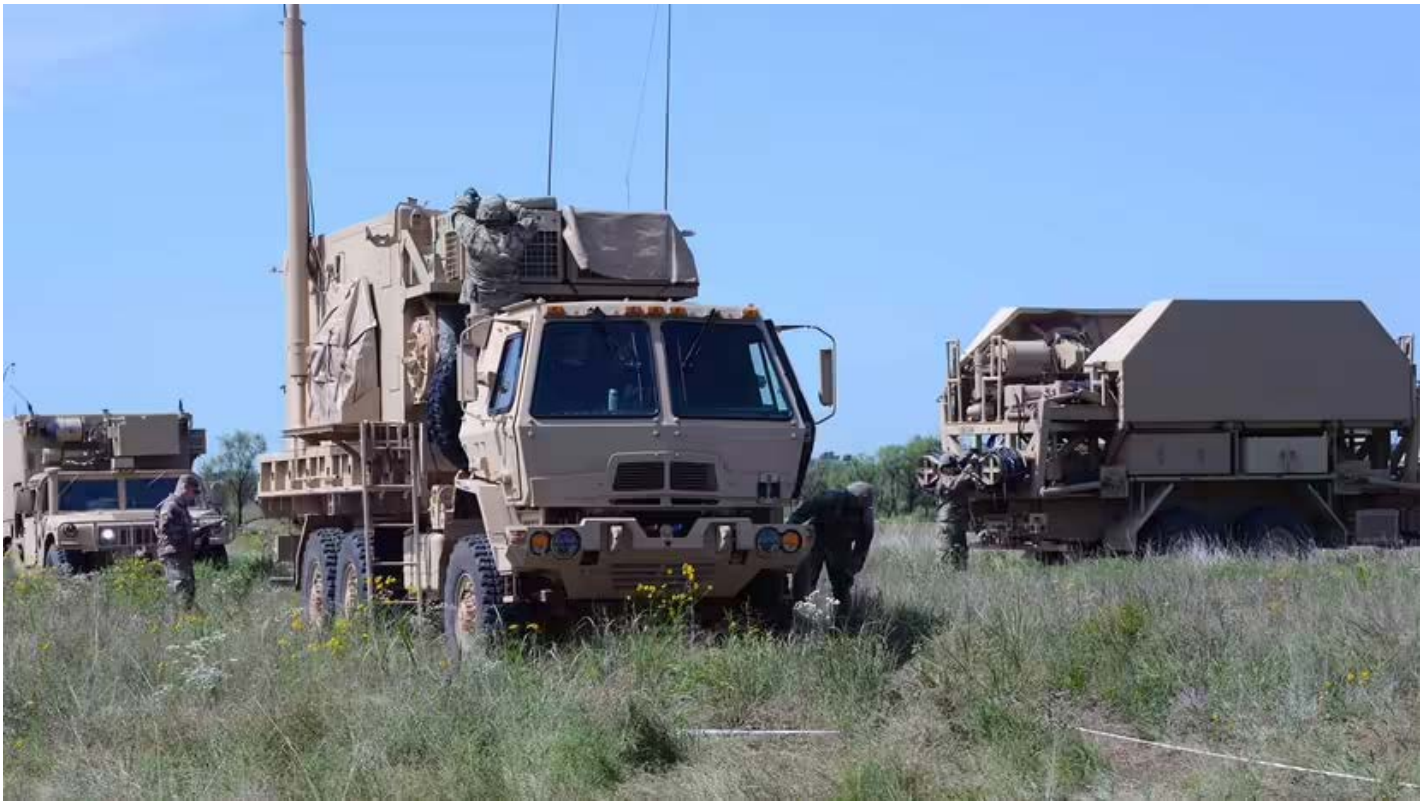
While there are about 90 soldiers assigned to a Patriot battery, the ECS vehicle — which is based on a military cargo truck — is the only one manned. The ECS has two computers and room for a tactical control officer, tactical control assistant and communications operator. Operators can see the status of all of the targets that the system is currently tracking. Operators can let the system run in fully automatic mode, or they can intervene to select or deselect targets. There is also a communication station

that allows the battery to communicate with other batteries or with the command center for the region.

Every Patriot missile battery has a radar set. Today it uses a single AN/MPQ-53, AN/MPQ-65, or AN/MPQ-65A radar set to detect targets. But the radar also is used for several other roles, including:

- scanning the skies for incoming targets
- detecting potential targets
- determining the trajectory, speed and heading of incoming targets
- providing information to identify incoming targets, including whether the target is friend or foe
- tracking Patriot missiles once they are launched to help aim them at the target
- illuminating the target, which is important to the Track-via-Missile guidance system used by the PAC-2 missiles

Putting It All Together



One Patriot missile battery requires about 90 soldiers to be fully operational. U.S. ARMY

A Patriot missile battery operates slightly differently depending on whether it is firing PAC-2 or PAC-3 missiles. We will look at the operation of the PAC-2 missile first.

The radar antenna scans the sky looking for incoming targets. Once it finds a target, it scans it more intensely and communicates with the ECS. The goal of the scan is to determine the speed and heading of the target and also to identify it as a friend or a foe. When the operator or computer decides that it has an incoming foe, the ECS calculates an initial heading for the Patriot missile. It chooses the Patriot missile it will launch, downloads the initial guidance information to that missile and launches it.

Within three seconds, the missile is traveling at Mach 5 and is headed in the general direction of the target. The radar antenna on the ground has three roles at this point:

- It continues to track the incoming missile.
- It acquires and tracks the outbound Patriot missile to provide the ECS with information on its heading and speed.
- It illuminates the incoming target.

The illumination signal reflects off the target and is received by an antenna in the nose of the PAC-2 missile that is heading its way. The PAC-2 missile then relays this signal back to the ECS. The ECS uses the illumination signal information along with the radar's information on the track of the incoming target and outbound Patriot to steer the missile. The ECS sends guidance commands to the Patriot missile to adjust its course. When the missile is at the point of closest approach to the target, its fragmentation bomb explodes.

Unlike the PAC-2, the PAC-3 missile contains its own radar transmitter and computer, allowing it to guide itself. Once launched, it turns on its radar, finds the target and aims for a direct hit. This has been compared to hitting a bullet with a bullet. The difference is that both the incoming target missile and the outbound Patriot missile are traveling up to

five times faster than a typical bullet and are closing in on one another at up to Mach 10, or 2 miles (3.2 kilometers) per second. At that speed there is no room for error — if the missile miscalculates by even 1/100th of a second, it will be off by more than 100 feet (30.5 meters).

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