

MIM-104 Patriot

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The **MIM-104 Patriot** is a surface-to-air missile (SAM) system, the primary of its kind used by the United States Army and several allied nations. It is manufactured by the Raytheon Company of the United States. The Patriot System replaced the Nike Hercules system as the U.S. Army's primary High to Medium Air Defense (HIMAD) system, and replaced the MIM-23 Hawk system as the U.S. Army's medium tactical air defense system. In addition to these roles, Patriot has been given the function of the U.S. Army's anti-ballistic missile (ABM) system, which is now Patriot's primary mission.

Patriot uses an advanced aerial interceptor missile and high performance radar systems. Patriot was developed at Redstone Arsenal in Huntsville, Alabama, which had previously developed the Safeguard ABM system and its component Spartan and Sprint missiles. The symbol for Patriot is a drawing of a Revolutionary War-era Minuteman.

Patriot systems have been sold to Taiwan, Egypt, Germany, Greece, Israel, Japan, Kuwait, the Netherlands, Saudi Arabia, United Arab Emirates,^[2] and Spain. The Republic of Korea is also in the process of purchasing several second-hand Patriot systems after North Korea test-launched ballistic missiles to the Sea of Japan and proceeded with underground nuclear testing in 2006.^[3] During August 2008, the United States and Poland signed a Declaration on Strategic Cooperation, in which they agreed to “the deployment of a U.S. Army Patriot air and missile defense battery in Poland. We intend to begin this cooperation next year (note: 2009) and to expand it with the aim of establishing by 2012 a garrison to support the U.S. Army Patriot battery.”^[4]

MIM-104 Patriot



Patriot system of the German Luftwaffe

Type	Mobile Surface-to-air missile system
Place of origin	 United States
In service	1981–present
Used by	See list of operators
	Production history
Designer	Raytheon, Hughes and RCA
Designed	1969
Manufacturer	Raytheon
Produced	1976
Number built	over 172 ^[1]
Variants	Patriot, Patriot PAC-1, Patriot PAC-2, Patriot PAC-3

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Introduction

On 15 October 1964 the Secretary of Defense directed that the Army Air Defense System for the 1970s (AADS-70s) program name be changed to Surface-to-Air Missile, Development (SAM-D).[1] (<http://www.redstone.army.mil/history/systems/PATRIOT.html>) In 1975 the SAM-D missile successfully engaged a drone at the White Sands Missile Range. During 1976, it was renamed the PATRIOT Air Defense Missile System. The MIM-104 Patriot would combine several new technologies, including the phased array radar and track-via-missile guidance. Full-scale development of the system began in 1976 and it was deployed in 1984. Patriot was used initially as an anti-aircraft system, but during 1988 it was upgraded to provide limited capability against tactical ballistic missiles (TBM) as PAC-1 (Patriot Advanced Capability-1). The most recent upgrade, called PAC-3, is a nearly total system redesign, intended from the outset to engage and destroy tactical ballistic missiles.

Patriot equipment

The Patriot system has four major operational functions: communications, command and control, radar surveillance, and missile guidance. The four functions combine to provide a coordinated, secure, integrated, mobile air defense system.

The Patriot system is modular and highly mobile. A battery-sized element can be emplaced in less than 1 hour. All components, consisting of the fire control section (radar set, engagement control section, antenna mast group, electric power plant) and launchers, are truck- or trailer-mounted. The radar set and launchers (with missiles) are mounted on M860 Semi-Trailers, which are towed by M983 HEMTTs.

Missile reload is accomplished using an M985E1 truck with a crane on the back. This crane is bigger than the

standard crane found on most HEMTTs. This crane, called a Guided Missile Transporter (GMT), removes spent missile canisters from the launcher and then replaces them with fresh missiles. Because the crane nearly doubles the height of the HEMMT when not stowed, crews informally refer to it as the "scorpion tail." A standard M983 with a regular-sized crane is referred to as the Large Repair Parts Transporter (LRPT).



German Patriot system with camouflage

The heart of the Patriot battery is the fire control section, consisting of the AN/MPQ-53 or -65 Radar Set, the AN/MSQ-104 Engagement Control Station (ECS), the OE-349 Antenna Mast Group (AMG), and the EPP-III Electric Power Plant. The system's missiles are transported on and launched from the M901 Launching Station, which can carry up to four PAC-2 missiles or up to sixteen PAC-3 missiles. A Patriot battalion is also equipped with the Information Coordination Central (ICC), a command station designed to coordinate the launches of a battalion and uplink Patriot to the JTIDS or MIDS network.

The AN/MPQ-53 and AN/MPQ-65 Radar Set

The AN/MPQ-53/65 Radar Set is a passive electronically scanned array radar equipped with IFF, electronic counter-countermeasure (ECCM), and track-via-missile (TVM) guidance subsystems.

The AN/MPQ-53 Radar Set equips PAC-2 units, while the AN/MPQ-65 Radar Set equips PAC-3 units. The main difference between these two radars is the addition of a second traveling wave tube (TWT), which gives the -65 radar increased search, detection, and tracking capability. The radar's antenna array consists of over 5,000 elements that "flash" the radar's beam many times per second. Additionally, the radar's antenna array contains an IFF interrogator subsystem, a TVM array, and at least one "sidelobe canceller" (SLC), which is a small array designed to decrease interference that might affect the radar. Patriot's radar is somewhat unique in that it is a "detection-to-kill" system, meaning that a single unit performs all search, identification, track, and engagement functions. This is in contrast to most SAM systems, where several different radars are necessary to perform all functions necessary to detect and engage targets.

The beam created by the Patriot's flat phased array radar is comparatively narrow and highly agile compared to a moving dish. This gives the radar an unmatched ability to detect small, fast targets like ballistic missiles, or low radar cross section targets such as stealth aircraft or cruise missiles. Additionally, the power and agility of Patriot's radar is highly resistant to countermeasures, including electronic countermeasures (ECM) radar jamming and radar warning receiver (RWR) equipment. Patriot is capable of quickly jumping between frequencies to resist jamming.

The AN/MSQ-104 Engagement Control Station



A detailed view of an AN/MPQ-53 radar set. The circular pattern on the front of the vertical component is the system's main phased array, consisting of over 5,000 individual elements, each about 39 millimeters (1.535 in) diameter.^[*citation needed*]

The AN/MSQ-104 Engagement Control Station (ECS) is the nerve center of the Patriot firing battery. The ECS consists of a shelter mounted on the bed of an M927 5-Ton Cargo Truck or on the bed of a Light Medium Tactical Vehicle (LMTV) cargo truck. The main sub-components of the ECS are the Weapons Control Computer (WCC), the Data Link Terminal (DLT), the UHF communications array, the Routing Logic Radio Interface Unit (RLRIU), and the two manstations that serve as the system's man-to-machine interface. The ECS is air conditioned, pressurized (to resist chemical/biological attack), and shielded against Electromagnetic pulse (EMP) or other such electromagnetic interference. The ECS also contains several SINCGARS radios to facilitate voice communications.

The WCC is the main computer within the Patriot system. It is a 24-bit parallel militarized computer with fixed and floating point capability. It is organized in a multiprocessor configuration that operates at a maximum clock rate of 6 megahertz. This computer controls the operator interface, calculates missile intercept algorithms, and provides limited fault diagnostics. Compared to modern personal computers, it has somewhat limited processing power, although it has been upgraded several times during Patriot's service life.

The DLT connects the ECS to Patriot's Launching Stations. It uses either a SINCGARS radio or fiber optic cables to transmit encrypted data between the ECS and the launchers. Through the DLT, the system operators can remotely emplace, slew or stow launchers, perform diagnostics on launchers or missiles, and fire missiles.

The UHF communications array consists of three UHF radio "stacks" and their associated patching and encrypting equipment. These radios are connected to the antennas of the OE-349 Antenna Mast Group, which are used to create UHF "shots" between sister Patriot batteries and their associated ICC. This creates a secure, real-time data network (known as PADIL, Patriot Data Information Link) that allows the ICC to centralize control of its subordinate firing batteries.

The RLRIU functions as the primary router for all data coming into the ECS. The RLRIU gives a firing battery an address on the battalion data network, and sends/receives data from across the battalion. It also "translates" data coming from the WCC to the DLT, facilitating communication with the launchers.

Patriot's crew stations are referred to as Manstation 1 and 3 (MS1 and MS3). These are the stations where Patriot operators interface with the system. The manstations consist of a monochrome (green and black) screen surrounded by various Switch Indicators. Each manstation also has a traditional QWERTY keyboard and isometric stick, a tiny joystick that functions much like a PC mouse. It is through these switch indicators and the Patriot user interface software that the system is operated.

The OE-349 Antenna Mast Group



AN/MSQ-104 vehicle of a Dutch Patriot unit.

The OE-349 Antenna Mast Group (AMG) is mounted on an M927 5-Ton Cargo Truck. It includes four 4 kW antennas in two pairs on remotely controlled masts. The antennas can be controlled in azimuth, and the masts can be elevated up to 100 feet 11 inches (30.76 m) above ground level. Mounted at the base of each pair of antennas are two high-power amplifiers associated with the antennas and the radios in the collocated shelter. It is through these antennas that the ECS and ICC send their respective UHF "shots" to create the PADIL network.



Antenna Mast Group

The EPP-III Electric Power Plant

The EPP-III Electric Power Plant is the prime power source for the ECS and Radar. The EPP consists of two 150 kilowatt, 400 hertz diesel engines that are interconnected through the power distribution unit. These generators are mounted on a modified M977 HEMTT. Each EPP contains two interconnected 75-gallon (280 L) fuel tanks and a fuel distribution assembly with grounding equipment. Each diesel engine can operate more than 8 hours with a full fuel tank. The EPP delivers its power to the Radar and ECS through massive cables stored in reels alongside the generators.

The M901 Launching Station

The M901 Launching Stations are remotely-operated, self-contained units. The ECS controls operation of the launchers through each launcher's DLT, via fiber optic or VHF (SINCGARS) data link.

Integral leveling equipment permits emplacement on slopes of up to 10 degrees. Each launcher is trainable in azimuth and elevates to a fixed, elevated launch position. Precise aiming of the launcher before launch is not necessary; thus, no extra lags are introduced into system reaction time. Each launcher is also capable of providing detailed diagnostics to the ECS via the data link.

The launching station contains four major equipment subsystems: the launcher generator set, the launcher electronics module (LEM), the launcher mechanics assembly (LMA), and the launcher interconnection group (LIG). The generator set consists of a 15 kW, 400 Hz generator that powers the launcher. The LEM is used for the real-time implementation of launcher operations requested via data link from the ECS. The LMA physically erects and rotates the launcher's platform and its missiles. The LIG connects the missiles themselves to the launcher via the Launcher Missile Round Distributor (LMRD).

Patriot Guided Missile

The first fielded variant was the round MIM-104A, "Standard." It was optimized solely for engagements against aircraft and had very limited capability against ballistic missiles. It had a range of 70 km (44 miles), and a speed in excess of Mach 3.^[5] The MIM-104B "anti-standoff jammer" (ASOJ) is a missile designed to seek out and destroy ECM emitters.

The MIM-104C PAC-2 missile was the first Patriot missile that was optimized for ballistic missile engagements. The GEM series of missiles (MIM-104D/E) are further refinements of the PAC-2 missile. The PAC-3 missile is a

Patriot missile

new interceptor, featuring a Ka band active radar seeker, employing "hit-to-kill" interception (in contrast to previous interceptors' method of exploding in the vicinity of the target, destroying it with shrapnel), and several other enhancements which dramatically increase its lethality against ballistic missiles. It has a substantially lower range of 15 km.^[5] The specific information for these different kinds of missiles are discussed in the "Upgrades" section.

The first seven of these are in the larger PAC-2 configuration of a single missile per canister, of which four can be placed on a launcher. PAC-3 missile canisters contain four missiles, so that sixteen rounds can be placed on a launcher. The missile canister serves as both the shipping and storage container and the launch tube. Patriot missiles are referred to as "certified rounds" as they leave the factory, and additional maintenance is not necessary on the missile prior to its being launched.

The PAC-2 missile is 5.8 meters (19 ft 0 in) long, weighs about 900 kg (2000 lb), and is propelled by a solid-fueled rocket motor at speeds in excess of Mach 5.0.

Patriot missile design

The PAC-2 family of missiles all have a fairly standard design, the only differences between the variants being certain internal components. They consist of (from front to rear) the radome, guidance section, warhead section, propulsion section, and control actuator section.

The radome is made of slip-cast fused silica approximately 16.5 millimeters (0.64 inch) thick, with nickel alloy tip, and a composite base attachment ring bonded to the slip cast fused silica and protected by a molded silicone rubber ring. The radome provides an aerodynamic shape for the missile and microwave window and thermal protection for the RF seeker and electronic components.

The Patriot guidance section consists primarily of the modular digital airborne guidance system (MDAGS). The MDAGS consists of a modular midcourse package that performs all of the required guidance functions from launch through midcourse and a terminal guidance section. The TVM seeker is mounted on the guidance section, extending into the radome. The seeker consists of an antenna mounted on an inertial platform, antenna control electronics, a receiver, and a transmitter. The Modular Midcourse Package (MMP), which is located in the forward portion of the warhead section, consists of the navigational electronics and



Four Patriot missiles can be fired from the highly mobile

TEL

Type	Surface-to-air missile
Place of origin	 United States
Production history	
Designer	Raytheon
Unit cost	US\$ 1 to 3 million
Number built	over 8,600 ^[1]
Variants	Standard, ASOJ/SOJC, PAC-2, PAC-2 GEM, GEM/C, GEM/T (or GEM+) and PAC-3
Specifications (PAC-1^[1])	
Weight	700 kg
Length	5,800 mm
Diameter	410 mm
Warhead	M248 Composition B HE blast/fragmentation with two layers of pre-formed fragments and Octol 75/25 HE blast/fragmentation
Warhead weight	200 lb (90 kg)
Detonation mechanism	Proximity fuze
Wingspan	920 mm (3 ft 0 in)

a missile-borne computer that computes the guidance and autopilot algorithms and provides steering commands according to a resident computer program.

The warhead section, just aft of the guidance section, contains the proximity fused warhead, safety-and-arming device, fuzing circuits and antennas, link antenna switching circuits, auxiliary electronics, inertial sensor assembly, and signal data converter.

The propulsion section consists of the rocket motor, external heat shield, and two external conduits. The rocket motor includes the case, nozzle assembly, propellant, liner and insulation, pyrogen igniter, and propulsion arming and firing unit. The casing of the motor is an integral structural element of the missile airframe. It contains a conventional, casebonded solid rocket propellant.

The Control Actuator Section (CAS) is at the aft end of the missile. It receives commands from the missile autopilot and positions the fins. The missile fins steer and stabilize the missile in flight. A fin servo system positions the fins. The fin servo system consists of hydraulic actuators and valves and an electrohydraulic power supply. The electrohydraulic power consists of battery, motor pump, oil reservoir, gas pressure bottle, and accumulator.

Patriot upgrades

The modular nature of the Patriot system has made both hardware and software upgrades a relatively simple and continuous process throughout the system's service. The most common upgrades have been to the software and to the missiles themselves, though almost every major sub-component of the system has seen at least one upgrade at some point.

Patriot was first introduced with a single missile type: the MIM-104A. This was the initial "Standard" missile (still known as "Standard" today). In Patriot's early days, the system was used exclusively as an anti-aircraft weapon, with no capability against ballistic missiles. This was remedied during the late 1980s when Patriot received its first major system overhaul with the introduction of the Patriot Advanced Capability missile and concurrent system upgrades.

Patriot Advanced Capability (PAC)

Patriot Advanced Capability, known today as the PAC-1 upgrade, was a software-only upgrade. The most significant aspects of this upgrade was changing the way the radar searched and the way the system defended its assets. Instead of searching low to the horizon, the top of the radar's search angle was lifted to near vertical (89 degrees) from the previous angle of 25 degrees. This was done as a counter to the steep parabolic trajectory of inbound ballistic missiles. The search beams of the radar were tightened, and while in "TBM search mode" the "flash", or the speed at which these beams were shot out, was increased significantly. While this increased the radar's detection capability against the ballistic missile threat set, it decreased the system's effectiveness against traditional atmospheric targets, as it reduced the detection range of the radar as well as the number of "flashes" at the horizon. Because of this, it was necessary to retain the search functions for traditional atmospheric threats in a separate search program, which could be easily toggled by the operator based on the expected threat. Additionally, the ballistic missile defense capability changed the way Patriot defended targets. Instead of being used as a system to defend a significant area against enemy air attack, it was now used to defend much smaller "point" targets, which needed to lie within the system's TBM "footprint." The footprint is the area on the ground

Propellant	Solid-fuel rocket
Operational range	160 kilometers (100 mi)
Flight altitude	79,500 feet (24,200 m)
Speed	Mach 5.0
Guidance system	Radio command with Track Via Missile semi-active homing
Launch platform	mobile trainable four-round semi-trailer

that Patriot can defend against inbound ballistic missiles.

During the 1980s, Patriot was upgraded in relatively minor ways, mostly to its software. Most significant of these was a special upgrade to discriminate and intercept artillery rockets in the vein of the Multiple Launch Rocket System, which was seen as a significant threat from North Korea. This feature has not been used in combat and has since been deleted from U.S. Army Patriot systems, though it remains in South Korean systems. Another upgrade the system saw was the introduction of another missile type, designated MIM-104B and called "anti stand-off jammer" (ASOJ) by the Army. This variant is designed to help Patriot engage and destroy ECM aircraft at standoff ranges. It works similar to an anti-radiation missile in that it flies a highly lofted trajectory and then locates, homes in on, and destroys the most significant emitter in an area designated by the operator.

PAC-2

During the late 1980s, tests began to indicate that, although Patriot was certainly capable of intercepting inbound ballistic missiles, it was questionable whether or not the MIM-104A/B missile was capable of destroying them reliably. This necessitated the introduction of the PAC-2 missile and system upgrade.

For the system, the PAC-2 upgrade was similar to the PAC-1 upgrade. Radar search algorithms were further optimized, and the beam protocol while in "TBM search" was further modified. PAC-2 also saw Patriot's first major missile upgrade, with the introduction of the MIM-104C, or PAC-2 missile. This missile was optimized for ballistic missile engagements. Major changes to the PAC-2 missile were the size of the projectiles in its blast-fragmentation warhead (changed from around 2 grams to around 45 grams), and the timing of the pulse-doppler fuse, which was optimized for high-speed engagements (though it retained its old algorithm for aircraft engagements if necessary). Engagement procedures were also optimized, changing the method of fire the system used to engage ballistic missiles. Instead of launching two missiles in an almost simultaneous salvo, a brief delay (between 3 and 4 second) was added in order to allow the second missile launched to discriminate a ballistic missile warhead in the aftermath of the explosion of the first.

PAC-2 was first tested in 1987 and reached Army units in 1990, just in time for deployment to the Middle East for the Persian Gulf War. Although no evidence of actual hits was ever recorded,^[6] it was here that Patriot was first regarded as a successful ABM system and proof that ballistic missile defense was indeed possible. The complete study on its effectiveness remains classified.

There have been many more upgrades to PAC-2 systems throughout the 1990s and into the 21st century, again mostly centering on software. However, the PAC-2 missiles have been modified significantly into four separate variants known collectively as guidance enhanced missiles (GEM).

The main upgrade to the original GEM missile was a new, faster proximity fused warhead. Tests had indicated that the fuse on the original PAC-2 missiles were detonating their warheads too late when engaging ballistic missiles with an extremely steep ingress, and as such it was necessary to shorten this fuse delay. The GEM missile was also given a new "low noise" seeker head designed to reduce interference in front of the missiles radar seeker, and a higher performance seeker designed to better detect low radar cross section targets, such as stealth aircraft. The GEM was used extensively in Operation Iraqi Freedom (OIF), with a perfect success rate.

Just prior to OIF, it was decided to further upgrade the GEM and PAC-2 missiles. This upgrade program produced missiles known as the GEM/T and the GEM/C, the "T" designator referring to "TBM", and the "C" designator referring to cruise missiles. These missiles were both given a totally new nose section, which was designed specifically to be more effective against low altitude, low RCS targets like cruise missiles. Additionally, the GEM/T was given a new fuse which was further optimized against ballistic missiles. The GEM/C is the upgraded version of the GEM, and the GEM/T is the upgraded version of the PAC-2. The GEM+ entered

service in 2002, and the Army is currently upgrading its PAC-2 and GEM missiles to the GEM/C or GEM/T standard.

PAC-3

The PAC-3 upgrade is the most significant upgrade Patriot has received thus far, and is one of the most comprehensive upgrade programs ever undertaken on an American weapon system. Nearly every aspect of the system received a significant upgrade. The PAC-3 upgrade took place in three stages, and units were designated Configuration 1, 2, or 3 based on the stage of upgrade they were in.

The system itself saw another upgrade of its WCC and its software, and the communication setup was given a complete overhaul. Due to this upgrade, PAC-3 operators can now see tracks on the Joint Tactical Information Distribution System (JTIDS), which greatly increases the situational awareness of Patriot crews. The software can now conduct a tailored TBM search, optimizing radar resources for search in a particular sector known to have ballistic missile activity, and can also support a "keepout altitude" to ensure ballistic missiles with chemical warheads or early release submunitions (ERS) are destroyed at a certain altitude. For Configuration 3 units, the Patriot radar was completely redesigned, adding an additional traveling wave tube (TWT) that increased the radar's search, detection, tracking, and discrimination abilities. The PAC-3 radar is capable, among other things, of discriminating whether or not an aircraft is manned and which of multiple reentering ballistic objects are carrying ordnance.

The PAC-3 upgrade carried with it a new missile design, nominally known as MIM-104F^[*citation needed*] and called PAC-3 by the Army. The PAC-3 missile is dedicated almost entirely to the anti-ballistic missile mission. Due to miniaturization, a single canister can hold four PAC-3 missiles (as opposed to one PAC-2 missile per canister). The PAC-3 missile is also more maneuverable than previous variants, due to dozens of tiny rocket motors mounted in the forebody of the missile (called Attitude Control Motors, or ACMs). However, the most significant upgrade to the PAC-3 missile is the addition of a K_a band active radar seeker. This allows the missile to drop its uplink to the system and acquire its target itself in the terminal phase of its intercept, which improves the reaction time of the missile against a fast-moving ballistic missile target. The PAC-3 missile is accurate enough to select, target, and home in on the warhead portion of an inbound ballistic missile. The active radar also gives the warhead a "hit-to-kill" capability that completely eliminates the need for a traditional proximity-fused warhead. This greatly increases the lethality against ballistic missiles of all types.

The PAC-3 upgrade has effectively quintupled the "footprint" that a Patriot unit can defend against ballistic missiles of all types, and has considerably increased the system's lethality and effectiveness against ballistic missiles. It has also increased the scope of ballistic missiles that Patriot can engage, which now includes several intermediate range. However, despite its increases in ballistic missile defense capabilities, the PAC-3 missile is a less capable interceptor of atmospheric aircraft and air-to-surface missiles. It is slower, has a shorter range, and has a smaller explosive warhead compared to older Patriot missiles.

Patriot's PAC-3 interceptor will be the primary interceptor for the new MEADS system, which is scheduled to enter service alongside Patriot in 2012.

Lockheed Martin Missiles and Fire Control is the prime contractor on the PAC-3 Missile Segment upgrade to the Patriot air defense system. The PAC-3 Missile Segment upgrade consists of the PAC-3 missile, a very agile hit-to-kill interceptor, the PAC-3 missile canisters (in four packs), a fire solution computer, and an Enhanced



PAC-3 missile launcher, note four missiles in each canister

Launcher Electronics System (ELES).

The future

Patriot upgrades continue, with the most recent being new software known as PDB-6 (PDB standing for "Post Deployment Build"). This software will allow Configuration 3 units to discriminate targets of all types, to include anti-radiation missile carriers, helicopters, unmanned aerial vehicles, and cruise missiles.

The PAC-3 missile is currently being tested for a significant new upgrade, currently referred to as Missile Segment Enhancement (MSE). The MSE upgrade includes a new fin design and a more powerful rocket engine. The modification is alleged to increase the operational capability of the current PAC-3 missile up to 50 percent.

Lockheed Martin has proposed an air-launched variant of the PAC-3 missile for use on the F-15C. Other aircraft, such as the F-22 and P-8A Poseidon, have also been proposed.^[7]

In the long term, it is expected that existing Patriot batteries will be gradually upgraded with MEADS technology.^[8]

Raytheon has developed the Patriot guidance enhanced missile (GEM-T), an upgrade to the PAC-2 missile. The upgrade involves a new fuse and the insertion of a new low noise oscillator which increases the seeker's sensitivity to low radar cross-section targets.

The Patriot Battalion

In the U.S. Army, the Patriot System is designed around the battalion echelon. A Patriot battalion consists of a headquarters battery (which includes the Patriot ICC and its operators), a maintenance company, and between four and six "line batteries," which are the actual launching batteries that employ the Patriot systems. Each line battery consists of three or four platoons: Fire Control platoon, Launcher platoon, and Headquarters/Maintenance platoon (either a single platoon or separated into two separate units, at the battery commander's discretion). The Fire Control platoon is responsible for operating and maintaining the "big 4." Launcher platoon operates and maintains the launchers, and Headquarters/Maintenance platoon(s) provides the battery with maintenance support and a headquarters section. The Patriot line battery is commanded by a captain and usually consists of between 70 and 90 soldiers. The Patriot battalion is commanded by a lieutenant colonel and can include as many as 600 soldiers.

Once emplaced, the system requires a crew of only three individuals to operate. The Tactical Control Officer (TCO), usually a lieutenant, is responsible for the operation of the system. The TCO is assisted by the Tactical Control Assistant (TCA). Communications are handled by the third crewmember, the communications system specialist. A 'Hot-crew' composed of an NCOIC (usually a Sergeant) and 1 or more additional launcher crew members is on-hand to repair/refuel launching stations, and a reload crew is on standby to replace spent canisters after missiles are launched. The ICC crew is similar to the ECS crew at the battery level, except its operators are designated as the Tactical Director (TD) and the Tactical Director Assistant (TDA).

Patriot battalions prefer to operate in a centralized fashion, with the ICC controlling the launches of all of its subordinate launching batteries through the secure UHF PADIL communications network.

The U.S. Army operates 14 Patriot battalions:

- 1-1 ADA, assigned to the 94th AAMDC, PACOM (Kadena Air Base, Okinawa Japan)
- 1-44 ADA, 69th ADA Brigade, Fort Hood, Texas (assigned to 32d AAMDC)

- 4-5 ADA, 69th ADA Brigade, Fort Hood, Texas (assigned to 32d AAMDC)
- 3-2 ADA, 31st ADA Brigade (assigned to the 32d AAMDC), Fort Sill, Oklahoma
- 1-7 ADA, 108th ADA Brigade, assigned to 32d AAMDC
- 3-4 ADA, 108th ADA Brigade, assigned to 32d AAMDC
- 5-7 ADA, 357th ADA Detachment (Germany)[2] (<http://www.tioh.hqda.pentagon.mil/ADA/357AirMissileDefenseDetachment.htm>)
- 2-1, 35th ADA Brigade (Korea)
- 6-52 ADA, 35th ADA Brigade (Korea)
- 1-43 ADA, 11th ADA Brigade (assigned to the 32d AAMDC)
- 2-43 ADA, 11th ADA Brigade (assigned to the 32d AAMDC)
- 3-43 ADA, 11th ADA Brigade (assigned to the 32d AAMDC)
- 5-52 ADA, 11th ADA Brigade (assigned to the 32d AAMDC)
- 3rd Battalion, 6th ADA Brigade, U.S. Army Air Defense Artillery School, Fort Sill

Operation

Following is the process a PAC-2 firing battery uses to engage a single target (an aircraft) with a single missile:

1. A hostile aircraft is detected by the AN/MPQ-53 Radar. The radar examines the track's size, speed, altitude, and heading, and decides whether or not it is a legitimate track or "clutter" created by RF interference.
2. If the track is classified by the radar as an aircraft, in the AN/MSQ-104 Engagement Control Station, an unidentified track appears on the screen of the Patriot operators. The operators examine the speed, altitude and heading of the track. Additionally, the IFF subsystem "pings" the track to determine if it has any IFF response.
3. Based on many factors, including the track's speed, altitude, heading, IFF response, or its presence in "safe passage corridors" or "missile engagement zones", the ECS operator, the TCO (tactical control officer), makes an ID recommendation to the ICC operator, the TD (tactical director).
4. The TD examines the track and decides to certify that it is hostile. Typically, the engagement authority for Patriot units rests with the Regional or Sector Air Defense Commander (RADC/SADC), who will be located either on a US Navy guided missile cruiser or on a USAF AWACS aircraft. A Patriot operator (called the "ADAFCO" or Air Defense Artillery Fire Control Officer) is colocated with the RADC/SADC to facilitate communication to the Patriot battalions.
5. The TD contacts the ADAFCO and correlates the track, ensuring that it is not a friendly aircraft.
6. The ADAFCO obtains the engagement command from RADC/SADC, and delegates the engagement back down to the Patriot battalion.
7. Once the engagement command is received, the TD selects a firing battery to take the shot and orders them to engage.
8. The TCO instructs the TCA to engage the track. The TCA brings the system's launchers from "standby" into "operate".
9. The TCA presses the "engage" switch indicator. This sends a signal to the selected launcher and fires a missile selected automatically by the system.
10. The AN/MPQ-53 Radar, which has been continuously tracking the hostile aircraft, "acquires" the just-fired missile and begins feeding it interception data. The Radar also "illuminates" the target for the missile's semi-active radar seeker.
11. The monopulse receiver in the missile's nose receives the reflection of illumination energy from the target. The track-via-missile uplink sends this data through an antenna in the missile's tail back to the AN/MPQ-53 set. In the ECS, computers calculate the maneuvers that the missile should perform in order to maintain a trajectory to the target and the TVM uplink sends these to the missile.
12. Once in the vicinity of the target, the missile detonates its proximity fused warhead.

Following is the process a PAC-3 firing battery uses to engage a single tactical ballistic missile with two PAC-3 missiles:

1. A missile is detected by the AN/MPQ-65 radar. The radar reviews the speed, altitude, behavior, and radar cross section of the target. If this data lines up with the discrimination parameters set into the system, the missile is presented on the screen of the operator as a ballistic missile target.
2. In the AN/MSQ-104 Engagement Control Station, the TCO reviews the speed, altitude, and trajectory of the track and then authorizes engagement. Upon authorizing engagement, the TCO instructs his TCA to bring the system's launchers into "operate" mode from "standby" mode. The engagement will take place automatically at the moment the computer determines will provide the highest probability of kill.
3. The system computer determines which of the battery's launchers have the highest probability of kill and selects them to fire. Two missiles are launched 4.2 seconds apart in a "ripple".
4. The AN/MPQ-65 radar continues tracking the target and uploads intercept information to the PAC-3 missiles which are now outbound to intercept.
5. Upon reaching its terminal homing phase, the Ka band active radar seeker in the nose of the PAC-3 missile acquires the inbound ballistic missile. This radar selects the radar return most likely to be the warhead of the incoming missile and directs the interceptor towards it.
6. The ACMs (attitude control motors) of the PAC-3 missile fire to precisely align the missile on the interception trajectory.
7. The interceptor flies straight through the warhead of the inbound ballistic missile, detonating it and destroying the missile.
8. The second missile locates any debris which may be a warhead and attacks in a similar manner.

Patriot in the Persian Gulf War/Operation Desert Storm (January-February 1991)

Trial by fire

Prior to the Persian Gulf War, ballistic missile defense was an unproven concept in war. During Operation Desert Storm, in addition to its anti-aircraft mission, Patriot was assigned to shoot down incoming Iraqi Scud or Al Hussein short range ballistic missiles launched at Israel and Saudi Arabia. The first combat use of Patriot occurred 18 January 1991 when it engaged what was later found to be a computer glitch.^[9] There were actually no Scuds fired at Saudi Arabia on 18 January^[10] This incident was widely misreported as the first successful interception of an enemy ballistic missile in history.

Throughout the war, Patriot missiles attempted engagement of over 40 hostile ballistic missiles. The success of these engagements, and in particular how many of them were real targets is still controversial. Postwar video analysis of presumed interceptions by Prof. Postol suggests that no Scud was actually hit;^[6]^[11] this analysis is contested by Dr. Zimmerman.^[12]

Failure at Dhahran

On February 25, 1991, an Iraqi Scud hit the barracks in Dhahran, Saudi Arabia, killing 28 soldiers from the US Army's 14th Quartermaster Detachment.



The AN/MPQ-53 radar system used by the Patriot for target detection, tracking and missile guidance

A government investigation revealed that the failed intercept at Dhahran had been caused by a software error in the system's clock.^{[13][14]} The Patriot missile battery at Dhahran had been in operation for 100 hours, by which time the system's internal clock had drifted by one third of a second. Due to the closure speed of the interceptor and the target, this resulted in a miss distance of 600 meters.

The radar system had successfully detected the Scud and predicted where to look for it next, but because of the time error, looked in the wrong part of the sky and found no missile. With no missile, the initial detection was assumed to be a spurious track and the missile was removed from the system. No interception was attempted, and the missile impacted on a barracks killing 28 soldiers.

At the time, the Israelis had already identified the problem and informed the US Army and the PATRIOT Project Office (the software manufacturer) on February 11, 1991, but no upgrade was present at the time. As a stopgap measure, the Israelis recommended rebooting the system's computers regularly, however, Army officials did not understand how often they needed to do so. The manufacturer supplied updated software to the Army on February 26, the day after the Scud struck the Army barracks.

Preceding failures in the MIM-104 system were failures at Joint Defense Facility Nurrungar in Australia, which was charged with processing signals from satellite-based early launch detection systems.^[15]

Success rate vs. accuracy

The U.S. Army claimed an initial success rate of 80% in Saudi Arabia and 50% in Israel. Those claims were eventually scaled back to 70% and 40%. However, when President George H. W. Bush traveled to Raytheon's Patriot manufacturing plant in Andover, Massachusetts during the Gulf War, he declared, the "Patriot is 41 for 42: 42 Scuds engaged, 41 intercepted!"^[16] The President's claimed success rate was thus over 97% during the war.

On April 7, 1992 Theodore Postol of the Massachusetts Institute of Technology, and Reuven Pedatzur of Tel Aviv University testified before a House Committee stating that, according to their independent analysis of video tapes, the Patriot system had a success rate of below 10%, and perhaps even a zero success rate.^{[17][18]} Also on April 7, 1992 Charles A. Zraket of the Kennedy School of Government, Harvard University and Peter D. Zimmerman of the Center for Strategic and International Studies testified about the calculation of success rates and accuracy in Israel and Saudi Arabia and discounted many of the statements and methodologies in Postol's report.^{[19][20]}

According to Zimmerman, it is important to note the difference in terms when analyzing the performance of the system during the war:

- Success Rate – the percentage of Scuds destroyed or deflected to non-populated areas
- Accuracy – the percentage of hits out of all the Patriots fired

In accordance with the standard firing doctrine on average four Patriots were launched at each incoming Scud – in Saudi Arabia an average of three Patriots were fired. If every Scud were deflected or destroyed the success rate would be 100% but the Accuracy would only be 25% and 33% respectively.

The Iraqi redesign of the Scuds also played a role. Iraq had redesigned its Soviet-style Scuds to be faster and longer ranged, but the changes weakened the missile and it was more likely to break up upon re-entering the atmosphere. This presented a larger number of targets as it was unclear which piece contained the warhead.

What all these factors mean, according to Zimmerman, is that the calculation of "Kills" becomes more difficult. Is a kill the hitting of a warhead or the hitting of a missile? If the warhead falls into the desert because a PATRIOT hit its Scud, is it a success? What if it hits a populated suburb? What if all four of the engaging PATRIOT missiles hit, but the warhead falls anyway because the Scud broke up?

According to the Zraket testimony there was a lack of high quality photographic equipment necessary to record the interceptions of targets. Therefore, PATRIOT crews recorded each launch on videotape, and damage assessment teams recorded the Scud debris that was found on the ground. Crater analysis was then used to determine if the warhead was destroyed before the debris crashed or not. Furthermore, part of the reason for the 30% improvement in success rate in Saudi Arabia compared to Israel is that the PATRIOT merely had to push the incoming Scud missiles away from military targets in the desert or disable the Scud's warhead in order to avoid casualties, while in Israel the Scuds were aimed directly at cities and civilian populations. The Saudi Government also censored any reporting of Scud damage by the Saudi press. The Israeli Government did not institute the same type of censorship. Furthermore, PATRIOT's success rate in Israel was examined by the IDF (Israel Defense Forces) who did not have a political reason to play up PATRIOT's success rate. The IDF counted any Scud that exploded on the ground (regardless of whether or not it was diverted) as a failure for the Patriot. Meanwhile, the U.S. Army who had many reasons to support a high success rate for PATRIOT, examined the performance of PATRIOT in Saudi Arabia.

Both testimonies state that part of the problems stem from its original design as an anti-aircraft system. PATRIOT was designed with proximity fused warheads, which are designed to explode immediately prior to hitting a target spraying shrapnel out in a fan in front of the missile, either destroying or disabling the target. These missiles were fired at the target's center of mass. With aircraft this was fine, but considering the much higher speeds of TBMs, as well as the location of the warhead (usually in the nose), PATRIOT would most often hit closer to the tail of the Scud due to the delay present in the proximity fused warhead, thus not destroying the TBM's warhead and allowing it to fall to earth.

In response to the testimonies and other evidence, the staff of the House Government Operations Subcommittee on Legislation and National Security reported, "The Patriot missile system was not the spectacular success in the Persian Gulf War that the American public was led to believe. There is little evidence to prove that the Patriot hit more than a few Scud missiles launched by Iraq during the Gulf War, and there are some doubts about even these engagements. The public and the United States Congress were misled by definitive statements of success issued by administration and Raytheon representatives during and after the war."^[21]

A *Fifth Estate* documentary, quotes the former Israeli Defense Minister as saying the Israeli government was so dissatisfied with the performance of the missile defense, that they were preparing their own military retaliation on Iraq regardless of US objections.^[22] That response was cancelled only with the cease fire with Iraq.

Psychological effects of the system



Patriot Antenna Mast Group (AMG), a 4 kW UHF communications array.

Saddam Hussein had vowed to rain down missiles on Israel with hopes of provoking Israel to attack, thus aligning Iraq with a common cause of many Arab nations and possibly causing those who were members of the coalition to withdraw. If this occurred the United States and its allies would lose crucial support and, in Hussein's mind, would not be able to continue the war.

Israel was concerned over the use of biological or chemical agents in the Scuds. The Patriot gave the Israeli government a way to calm its people in the early days of the war.^[*citation needed*]

Patriot in Operation Iraqi Freedom (2003)

Patriot was deployed to Iraq a second time in 2003, this time to provide air and missile defence for the forces conducting Operation Iraqi Freedom (OIF). Patriot PAC-3, GEM, and GEM+ missiles both had a very high success rate intercepting Al Samoud-2 and Ababil-100 tactical ballistic missiles.^[8] However, no longer-range ballistic missiles were fired during that conflict. The systems were stationed in Kuwait and successfully destroyed a number of hostile surface-to-surface missiles using the new PAC-3 and guidance enhanced missiles. Patriot missile batteries were involved in three friendly fire incidents, resulting in the downing of a Royal Air Force Tornado and the death of both crew members on 23 March 2003. On 24 March 2003, a USAF F-16CJ fired a HARM at a Patriot Missile Battery after being locked on. No one was injured but the Patriot Missile Battery was damaged.^[23] On 3 April 2003, 2 PAC-3 missiles shot down a USN FA-18 killing US Navy Lieutenant Nathan D. White of VFA-195, Carrier Air Wing Five.

Operators

NATO Operators:

-  United States

United States Army Air Defense Artillery

-  Germany

Luftwaffe

-  Netherlands

Royal Netherlands Air Force

-  Greece

Hellenic Air Force

-  Poland

Polish Army

-  Spain

Spanish Army

-  Turkey

Turkish Air Force

Other Operators^[24]:

-  Bahrain

Royal Bahraini Air Force

-  Egypt

Egyptian Air Defense Command

-  Israel

Israeli Air Force

-  Japan

Japan Air Self-Defense Force

-  Republic of China (Taiwan)

Republic of China Air Force

-  Kuwait

Kuwait Air Force

-  Saudi Arabia

Royal Saudi Air Defense

-  South Korea

Republic of Korea Air Force

-  Qatar

Qatar Air Force

-  United Arab Emirates

United Arab Emirates Air Force

See also

- List of missiles
- MEADS
- U.S. Army Aviation and Missile Command

- Anti-ballistic missile
- National Missile Defense
- U.S. Army Air Defense Units
- M-numbers

Comparable SAMs:

- Akash missile
- S-300
- KS-1
- HQ-9
- NASAMS

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