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5 Images

Static and towed surface-to-air missile systems, United States

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Jane's Land-Based Air Defence

Patriot PAC-3

Type TOP

Static surface-to-air missile system

Development TOP

The Patriot Advanced Capability-3 (PAC-3 - formerly ERINT) design programme began in 1983, but flight testing was not funded until 1987, when the prime contractor, Lockheed Martin Missiles and Fire Control - Dallas, was awarded a contract worth USD80 million. Originally conceived as a follow-on from the earlier Flexible Lightweight Agile Guided Experiment (FLAGE) for intercepting Tactical Ballistic Missiles (TBMs) at altitudes in excess of 15,000 m, the programme has been extended to provide an intercept capability against both TBMs and air-breathing missiles.

ERINT competed with Patriot MultiMode Seeker (MMS) for the missile to be part of the PAC-3 system. In early 1994, the ERINT was chosen for the PAC-3 programme with the Patriot radar system to be modified accordingly.

PAC-3 Configuration 1: 1995 - a new pulse doppler processor that significantly improved radar performance was added; also, Engagement Control Station (ECS) and Information Coordination Central (ICC) upgrades; improved weapons-control computer throughput, memory and reliability. ECS and ICC upgrades also added optical disk and embedded data recording equipment to decrease computer access times, improve reliability and provide a tactical data recording capability. Patriot Guidance Enhanced Missile (GEM) included a faster warhead fuze to improve kill probability against tactical ballistic missiles and a new low-noise missile seeker section to expand the missile's engagement area.

PAC-3 Configuration 2: 1996 - improved the Communications Processor and added the Joint Tactical Information Distribution System (JTIDS) to improve communications and interfaces with joint forces. Fielded Post Deployment Build (PDB) 4 software which improves multi-function radar performance, detects small radar cross section targets and improves system detection, identification, and engagement of anti-radiation missiles and aircraft carrying those missiles.

PAC-3 Configuration 3 Ground Equipment: 2000 - addition of dual travelling wave tube units and a new radio frequency exciter to the radar to further improve radar multifunction performance and detection of small targets in cluttered environments. A Classification, Discrimination Identification Phase III programme which significantly improves radar range performance to discriminate and identify a tactical ballistic missile warhead from other target debris or objects. Post Deployment Build 5 software improves radar multi-function performance, determines tactical ballistic missile impact and launch points, and provides interfaces with the Theatre High Altitude Area Defence System (THAAD). Remote Launch improvements increased the location of launchers from the ECS from a distance of 10 km to 30 km. This dramatically increased the Patriot-defended area. PDB-5 was deployed to Turkey with the Netherlands Air Defence Group (Patriot PAC-2 GEM missiles) to protect high-value areas in case of attack during the Iraq/Coalition war. PDB-5 also meant that, if necessary, the Dutch systems could be reinforced with PAC-3 missiles with no further changes necessary. A further PDB-6, composed of user-requested improvements, planned performance improvements and

improvements that resulted from lessons learned in operations during the Iraq war, was demonstrated at the White Sands Missile Test Range, New Mexico, from May to July 2006. The successful trials further demonstrated the PDB-6 software upgrade works with all variations of the Patriot system.

The PAC-3 uses hit-to-kill as its prime kill mechanism. It also employs a ring-type warhead of small, explosive-propelled, high-density tungsten pellets, which is considered only as a lethality enhancer against air-breathing targets, such as cruise missiles and aircraft.

PAC-3 is one of the world's most sophisticated technologies. The PAC-3 Missile boasts 12 successes out of 13 flights over the past three years, with nine intercepts in 10 attempts, an overall success rate of 92 per cent for the flight test programme.

The PAC-3 Missile intercept successes are:

- 15 March 1999 - successful intercept of TBM
- 16 September 1999 - successful intercept of TBM
- 5 February 2000 - successful intercept of TBM
- 22 July 2000 - successful intercept of low-flying cruise missile
- 28 July 2000 - successful intercept of low-flying cruise missile
- 14 October 2000 - successful intercept of TBM
- In 2000, Lockheed Martin won the contract to include the Patriot PAC-3 missile in the Medium Extended Air Defence System (MEADS). After winning the contract, Lockheed replaced the blast fragmentation warhead in PAC-3 with a hit-to-kill millimetre wave seeker as part of the Missile Segment Enhancement (MSE) upgrade programme.
- 31 March 2001 - first tactical ripple mode test (successful intercept of TBM by first PAC-3 Missile and successful tactical self-destruct of second PAC-3 Missile
- 9 July 2001 - successful intercept of an F-4 remotely piloted aircraft by PAC-3 Missile
- 19 October 2001 - successful intercept of advanced cruise missile
- Early 2003 - deployed to Middle East to support Gulf War II
- July 2003 - start of 51 month software update by Lockheed Martin. Flight trials expected September 2006
- 4 March 2004 - ripple fired testing at White Sands, against a PAAT (Patriot-As-A-Target) simulating a Scud type missile
- 15 September 2005 - software changes to the system and other improvements lead to a successful test firing at White Sands, against a full-body aerodynamic TBM target
- May 2006 - Lockheed Martin Missiles and Fire Control was contracted to a PAC-3 Missile Segment Enhancement (MSE) upgrade; this comprises the PAC-3 Missile - a highly agile hit-to-kill interceptor, the PAC-3 Missile canisters (in four packs), a Fire Solution Computer and an Enhanced Launcher Electronics System. The PAC-3 MSE programme also includes flight software, flight-testing, modification and qualification of subsystems, production planning and tooling, and support for full Patriot system integration. The MSE programme will span 57 months, with flight testing scheduled to begin in September 2006. Flight test programmes include one controlled test flight and two guided intercept tests against threat-representative tactical ballistic missiles (TBMs). All testing will be conducted at White Sands Missile Range. In January 2008, Lockheed Martin received a contract worth USD66 million to incorporate the PAC-3 MSE missile into the MEADS programme. The MSE missile includes a more powerful warhead with hit-to-kill capability, new motor for longer-range and more responsive control surfaces.

In addition to the 12 successful PAC-3 Missile flight tests, the PAC-3's predecessor, the Extended-Range Interceptor, hit three times in a row during the demonstration/validation programme in 1994. Two of those tests involved TBM targets and one air-breathing target (simulating a cruise missile or aircraft).

First low-rate initial production began in late 1999. This was followed by further testing in February and July 2000. Selection for the MEADS programme also took place in May 2000. Customer acceptance flights and trials started in 2001 and culminated in the 4th low-rate production in December 2002. Elements of the command and control were then shipped to Israel in late 2002 with the complete system being sent to the Gulf to protect US troops during the Gulf War II in early 2003.

The programme requirement was for 1,500 missiles, 180 modified Patriot launchers and 74 modified radars. Total cost at 1994 prices was USD3 billion, with Lockheed Martin Missiles and Fire Control - Dallas receiving a contract for the missiles and Raytheon for PAC-3 integration into the Patriot launchers and the associated fire-control equipment. The final totals may well be short of this.

The Lockheed Martin Corporation, Grand Prairie, Texas, was awarded a modification to a cost-plus-incentive-fee contract of USD7,500,000 in September 2003 for initial production facility additional tools and equipment for the PAC-3 missile programme. Work on this contract is currently being carried out at Grand Prairie and is to be completed by September 2004.

An additional contract in February 2004, for USD214,277,004 for 133 PAC-3 missile four packs and ground support equipment has also been allocated. This contract is to be completed by April 2006. As with the September 2003 contract, all work is to be carried out at Grand Prairie, Texas.

Further development contracts associated with the Patriot PAC-3 issued 13 April 2006 to Lockheed Martin were for:

- Missiles
- Launcher mod kits
- Parts library
- Storage and ageing
- Missile mid-section audits
- Interim contractor depot support
- PALS FSC
- Shorting plugs
- Test set cables
- Concurrent spares
- Replenishment parts

The work on these contracts is expected to be completed by July 2008.

Patriot PAC-3 has been chosen as the weapon for the Medium Extended Air Defence System (MEADS) development programme being undertaken by Lockheed Martin, Alenia Marconi Systems and Daimler Chrysler Aerospace. In 2004, the Combined Aggregate Programme (CAP) was first identified with the start of the development of the first fire unit. The CAP is the process by which the Patriot PAC-3 system transitions to the MEADS. The MEADS mission is to provide low-to-medium altitude air and missile defence with the capability to counter, defeat, or destroy tactical ballistic missiles, air-breathing threats (including cruise missiles), Unmanned Aerial Vehicles (UAVs), tactical air-to-surface missiles and anti-radiation missiles. MEADS will be interoperable with other airborne, ground-based and sea-based sensors, early trials for which, using the Patriot system, have been completed. The CAP programme plans call for a system design review in 2009 and the start of production in the first quarter of fiscal year 2013. The US Army expect MEADS to achieve initial operating capability in 2017 with four units.

Patriot PAC-3 Cost Reduction Initiative (CRI) missiles will probably be sold to Germany to supplement the existing fielded Patriot systems.

Lockheed Martin confirmed in January 2007 that it received a contract from the US Missile Defence Agency to continue studies into a possible air-launched variant of the Patriot PAC-3 known as the Air-Launched Hit-to-Kill (ALHTK) initiative. The AAM is expected to engage ballistic missiles and cruise type targets during their boost phase (ballistic missile) and early part of flight. The system is further expected to draw target data information gathered by systems such as the JLENS or satellite.

This contract follows the Risk Assessment (RA) contract that concluded in April 2006 that it had studied and identified the feasibility for such a system.

During March 2007, the 500th PAC-3 missile seeker was handed over to the US Army in Huntsville, Alabama. Additionally, at this time Lockheed received a further contract for the production of 112 Patriot PAC-3 missiles.

In May 2008, the US Army conducted a controlled flight test of the Patriot PAC-3 MSE (Missile Segment Enhancement) interceptor at the White Sands Missile Test Range in New Mexico. This test demonstrated launch canister hardware, missile functionality, interfaces and integration with the system and missile fly-out functions.

Description TOP

The PAC-3 is designed to utilise the Patriot launcher unit. It is 5 m long, has a maximum body diameter of 0.255 m and weighs 312.4 kg at launch. A PAC-3 launch canister is compatible with the Patriot launcher, but will hold four PAC-3 missiles instead of one Patriot missile thus effectively quadrupling the ready missile inventory per launcher without increasing the force structure.

The missile has four fixed fins and four aerodynamic control surfaces located just aft of its centre and 180 mini solid-propellant altitude-control thruster motors mounted in a special attitude control section located in its fore body section, to effect flight-control manoeuvres. A high-performance HTPB solid propellant rocket motor with lightweight composite case is used as the propulsion system.

The missile uses an inertial guidance package for the fly-out guidance phase to fly to the predicted intercept point. Initial target data are acquired by the system's fire-control radar, which pre-programmes the onboard guidance package before the launch.

If required, the weapon's trajectory can be updated during the flight using the fire-control radar system. In the last few seconds of the flight, a Boeing Company Electronic Systems and Missile Defence radome-covered, nose-mounted, gimballed Ka-band pulse Doppler range gated radar seeker antenna assembly is activated to terminally guide the missile to the target. The high-power coherent radar also doubles as the proximity fuzing system to detonate the lethality enhancer, which uses rings of tungsten high density pellets to enhance its effectiveness against air-breathing targets such as aircraft or cruise missiles.

The export model of the Patriot PAC-3 consists of:

- M901 launchers
- AN/MPQ-53 fire-control radars
- AN/MSQ-104 engagement control stations
- OA-9054(V) 41G antennae mast groups
- MIM-104D or GEM missiles

The PAC-3 is designed to intercept short-range TBMs over a wide range of closing velocities. At impact, the PAC-3 weighs 142 kg.

Under the Patriot PAC-3 MSE programme (the most up-to-date addition to the Patriot family of PAC-3 missiles - May 08), the company (Lockheed Martin Missiles and Fire Control) will incorporate a larger, more powerful motor into the missile for added thrust, along with larger fins and other structural modifications for more agility. The modifications will extend the missile's reach by up to 50 per cent. The larger fins, which will collapse to allow the missile to fit into the current PAC-3 launcher, will provide the interceptor increased capability and manoeuvrability against faster and more sophisticated ballistic, cruise missiles and air-breathing threats.

These enhancements are the natural, pre-planned evolution of a system that was baselined in 1994.

Specifications TOP

	Patriot PAC-3	Patriot PAC-3 MSE
Type:	short-range, high-performance, single-stage theatre defence	short-range, high-performance with improved capability against ballistic and cruise missiles
Length:	5.205 m	5.205 m
Diameter:	0.255 m	0.255 m
Weight:	315 kg	312 kg
Warhead:	kinetic energy hit-to-kill with a back-up high-explosive fragmentation enhanced warhead	A more powerful warhead with hit-to-kill capability
Guidance:	inertial with update capability and Ka-band active radar terminal homing	probably inertial with update and Ka-band active radar terminal homing or dual mode seeker. The missile also has more responsive control surfaces.
Propulsion:	Atlantic Research solid propellant composite rocket motor with special attitude control section for in-flight manoeuvring	a larger more powerful solid propellant motor is planned for added thrust
Velocity:	1,700 m/s	n/a but increased velocity
Max altitude:	unknown	n/a
Min altitude:	unknown	n/a

Max range:	15 km	extended range by up to 50% = 22 km

JLENS TOP

The Joint Land Attack Cruise Missile Defence Elevated Netted Sensor System (JLENS) consists of the aerostat, mobile mooring station, power and fibre optic data transfer tethers, and ground support equipment and will in the future provide surveillance and engagement support to the PAC-3 and MEADS programmes. The aerostat has undergone an increase in size from 71 metres to 74 metres in order to accommodate the necessary lift increase to 7,000 pounds of total payload. JLENS is primarily an integration effort based on relatively mature technologies from other programmes and is designed to provide over-the-horizon detection and tracking of land-attack cruise missiles. In addition to providing a significant cruise missile defence capability, the JLENS system will also be capable of tracking surface moving targets and tactical ballistic missiles during their boost phase, and passing target data to various weapon systems and platforms across the military service. JLENS will provide a long-duration, wide-area cruise missile defence capability while also providing elevated communications capabilities. Each JLENS consists of a long-range surveillance radar and a high-performance fire control radar, each integrated onto a large aerostat connected via tether to a ground-based processing station. System testing is scheduled to begin late 2009 through 2010 with programme completion in 2012, however, a full design review is expected in September 2008, until then the programme faces risk of redesign until technologies demonstrate full maturity and weight issues are resolved.

As of April 2008, JLENS passed its Orbit PDR (Preliminary Design Review), this took four days and involved a comprehensive assessment of the design maturity.

Variants TOP

Air-launched variant from the F-16, F-22 and F-35 has been in development since at least 2006. A risk assessment contract concluded in April 2006 and was followed by a Feasibility Study that was completed in January 2007. Since then, a Risk Reduction/Concept Definition Programme has been underway and will be probably completed during 2008. Lockheed has received a USD3 million contract from the Missile Defence Agency (MDA) to continue the Air-Launched Hit-to-Kill (ALHTK) initiative, that would enable fighter aircraft to carry and launch Patriot PAC-3 missiles to intercept hostile ballistic and cruise missiles.

Status TOP

The US Army announced, in November 2001, that it was considering a surface-to-surface Patriot. Modifications of the original MIM-104 missile began in September 2003.

In February 2006, Lockheed Martin delivered the first PAC-3 Stockpile Reliability Test (SRT) Missiles to the US Army in Camden, AR.

The Netherlands received their first system during early 2007. On 30th March 2007, the first anti-missile PAC-3 missiles were transferred to the Guided Missiles Group in a short ceremony at De Peel air force base in the Netherlands.

On 7 September 2006, PAC-3 Cost Reduction Initiative (CRI) missiles as well as associated equipment and services, were requested by Germany with notification to Congress as a Foreign Military Sale. Up to 72 PAC-3 CRI missiles, 12 each Missile Round Trainers, support equipment, modification kits, publications, spare and repair parts, US Government and contractor technical assistance and other related elements of logistics support.

Raytheon announced, in December 2001, that it proposed adding a new front end to older Patriots in order to give them a hit-to-kill capability, similar to the PAC-3.

The Patriot PAC-3 missile system was first deployed in small numbers only to Suwon Air Base in South Korea during 2003. The Suwon deployment consists of six firing units attached to the 1st Battalion 43rd Air Defence Artillery organisation.

Japan received the Patriot PAC-3 during 2005. License production of the system by Mitsubishi Heavy Industries has been agreed between the US and Japanese governments. Domestically produced missiles are not, however, expected to be deployed with Japanese forces before 2008.

The Japanese government had requested (7 September 2004), from the US, a possible sale of 20 × PAC-3 systems including:

- 120 Guided missiles
- Support equipment
- Modification kits
- Fire-control computer
- Publications
- Personnel training
- Spare parts and repair kits
- Logistics support

The whole deal is worth approximately USD79 million. Additional to this, as of June 2006, up to three or four extra PAC-3 batteries were to be immediately purchased and deployed to the Island of Okinawa with up to 600 US troops. This was in direct response to the threat from North Korea and an imminent Taepodong-2 MRBM launch. As of 30 March 2007, the first of the PAC-3 launchers were installed at an air base to the north of Tokyo. US forces are already using the PAC-3 system on the southern island of Okinawa. The Japanese Self Defence Forces have set up a ring of Patriot PAC-3 defences around the city of Tokyo. By January 2008, trials had begun in order to tune and test these systems while the third site was activated in February 2008 at the Takeyama base in Yokosuka, near the US seventh fleet naval base. A fourth site has now (April 2008) been completed at Kasumigaura in Ibaraki to the northeast of Tokyo. The Tokyo defence ring with this last installation is now considered complete.

Saudi Arabia is also likely to upgrade their missile systems to the PAC-3 standard. Both Saudi Arabia and Kuwait have been fully briefed on the PAC-3 system and contracts were originally expected late 2005 or early 2006. However, as of July 2008, Kuwait has issued a contract to Raytheon to upgrade their PAC-2's to the Config 3 status which includes upgrades and support consistent with the US Army's Pure Fleet initiative. The PAC-3 has already been sold to Israel, Germany, the Netherlands, Belgium, Japan and Spain and has also been offered to India in July 2008.

Lockheed Martin has received a USD532 million contract for 156 PAC-3 missiles for the US Army, Netherlands and Japan.

During a visit to the US by the Indian Defence Minister, Shri Pranab Mukherjee, the US Department of Defense made a verbal offer to provide technical briefings on the PAC-3 anti-missile system.

In January 2007, Lockheed Martin confirmed preliminary talks for a potential sale of the Patriot PAC-3 to Turkey.

In August 2007, it was announced from Jerusalem that the Israeli Air Force is to buy the Patriot PAC-3 to replace the PAC-2 variant currently in use. No date has yet been set for the first delivery.

In December 2007, the United Arab Emirates placed an order with the US for the following:

288 x Patriot PAC-3 missiles216 x Patriot GEM-T missiles9 x Launching Stations (4 per fire unit)8 x Antenna Mast Groups on trailers8 x Antenna Mast Groups for Tower MountsAN/GRC-245 RadiosSingle Channel Ground and Airborne Radio Systems (SINCGARS, Export)Multi-functional Information Distribution System/Low Volume TerminalsGeneratorsElectrical Power UnitsTrailersCommunication and support equipmentPublicationsSpare and repair partsRepair and return partsUS government and contractor technical assistanceOther related elements of logistics supportBy late 2008, it became apparent that the PAC-3 for use in the UAE would have to be capable of interfacing with the THAAD system, that is also being purchased by the UAE.

On 2nd Sept 2008, Germany announced the IOC of their Patriot PAC-3 Config 3 missiles system having completed trials and other upgrades. Firing trials of the system were carried out in October 2008 at the White Sands Missile Test Range in the US.

The upgrades to the system include:

PAC-3 Missile Segment Launcher ElectronicsFire Solution Computer upgradePAC-3 missilesInterface with other Patriot systems

In May 2009, a new contract set with Lockheed Martin was awarded for the PAC-3 Guidance Processor Unit Redesign. The estimated date for completion of the redesign is Sept 2011.

Contractor TOP

Lockheed Martin Missiles and Fire Control, (prime contractor)

Raytheon , (JLENS programme and prime contractor for Systems Integration)

Atlantic Research , (solid propellant composite motors)

Mitsubishi Heavy Industries , (Japanese PAC-3)

Moog Components Group , (Electro-mechanical and fibre optic products including slip rings).

PAC-3 being launched from Patriot launcher during trials

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PAC-3 intercept of a high-level target

0100708

PAC-3 intercept of a low-level target

0100706

Outline drawing of the PAC-3 showing position of main components

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Patriot PAC-3 at Kadens AFB in Okinawa (Itsuo Inouye)

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