

Automation and Autonomy in Air Defence Systems Catalogue (v.1)

Dr Tom Watts, Department of Politics and International Relations, Hertfordshire University
& **Dr Ingvild Bode**, Centre for War Studies, University of Southern Denmark.

February 2021

This catalogue has been created in conjunction with the '*Meaning-Less Human Control: Lessons from Air Defence Systems on Meaningful Human Control for the debate on AWS*' report published in February 2020 as a collaboration between Drone Wars UK and the University of Southern Denmark. It provides information on the system history, maximum system range, target type, system updates/variants and automated/autonomous features of twenty-eight air defence systems which have been operated by at least sixty states.

This catalogue has been constructed using a range of open-source material. This includes: (1) press releases and marketing material from weapons manufacturers; (2) press releases and factsheets published by defence ministries; (3) technical and policy reports authored by researchers based at think tanks; (4) Media reports from reputable international news and defence outlets; and (5) other air defence system databases. All references are provided as URLs and were accessible online as of January 2nd 2021. Please note: when information about a system has been unavailable, we have listed it as NDA (No Data Available).

In constructing this open-source catalogue, we have faced three methodological challenges worth briefly highlighting here:

1. Many of the technical capabilities of air defence systems are not publicly available. Without having physically observed the testing and development of these systems, or been involved in their operation, we cannot be sure of their exact capabilities.
2. Given the political sensitivities concerning the definition of autonomy, some of the open-source information which is available on the autonomous and automated features of air defence systems is vague and, at times, even contradictory.
3. Whilst this catalogue has included information on the technical capabilities of air defence systems, this must be qualified by the uncertainty concerning the Rules of Engagement under which human agents use these systems.

A more detailed explanation of our case selection, catalogue index and research approach and limitations can be found in Section 3 of the accompanying report.

Spotted an error? Contact Us!

We have taken the decision to make this catalogue open-access so that, if any of the information included in this document is incorrect, we can update it accordingly. If you spot an error in this catalogue, and would like to inform us of it, we can be reached at t.watts3@herts.ac.uk.

Funding

Research for this data catalogue was supported by grants from the Joseph Rowntree Charitable Trust and from the European Research Council.

Table of Contents

Table of Contents.....	2
CLOSE IN WEAPONS SYSTEMS.....	3
AK-630M.....	3
Crotale Next Generation	5
Goalkeeper	8
Kashtan-M.....	10
NBS MANTIS.....	12
Pantsir-S1	14
Phalanx.....	17
Rapier FSC.....	20
SeaRAM.....	22
Sea Wolf.....	24
Type 730 (H/PJ12)	26
AREA DEFENCE SYSTEMS.....	28
BAMSE SRSAM	28
Buk-M2.....	30
HQ-9.....	33
KM-SAM (Cheongung)	36
MIM-104 Patriot	38
Sea Ceptor	45
Sky Sabre.....	47
Spada 2000.....	49
S-400 Triumph	51
Tor-M1.....	53
BALLISTIC MISSILE DEFENCE SYSTEMS.....	56
Aegis Combat System BMD	56
Arrow Weapon System.....	59
DRDO Ballistic Missile Defence System.....	61
SAMP/T Air Defense System	63
S-500 Prometey	65
Terminal High Altitude Area Defense (THAAD)	67

CLOSE IN WEAPONS SYSTEMS

AK-630M	
System manufacturer	Tulamashzavod (KBP Instrument Design Bureau, Russia)
System users	Russia, China, Croatia, India, and Vietnam. ¹
System history	<p>Development of the AK-630M began in 1963. It was accepted into service with the Russian military in 1979.² When operated on Russian warships, the AK-630M “form[s] a part of a complete self-defense system called A-213-Vympel-A, which includes gun, radar, optical and TV control systems”.³ This system’s MR-123 radar can simultaneously coordinate two AK-630M batteries. A human operator supervises this system’s operation via a command centre.⁴</p> <p>The AK-630M is one of several CIWS operated by the Russian Navy. It has been compared to the Goalkeeper and Phalanx CIWs discussed later in this catalogue. A variant of the AK-630M known as the H/PJ13 is operated by the Chinese navy.⁵ Although a different casing is used, the H/PJ13 is reported to be “practically identical to the AK-630M”.⁶</p>
Maximum system range	5km ⁷
Target type	Rosoboronexport advertise the AK-630M-2 – a modernised variant of the original AK-630M design – as being designed to “engage anti-ship missiles, aircraft, helicopters and other enemy air threats, destroy small surface targets and floating mines; kill visible open enemy manpower and firing points on the shore”. ⁸
System updates and variants	Since its initial introduction in the late 1970s, the AK-630M has undergone several modernisations including the AK-630M-2 programme which began during the late 2000s. ⁹ The AK-630M-2 has been described as a “radical upgrade” of this air defence system. ¹⁰
Automation and autonomy in critical functions	Whilst human agents can remain ‘in the loop’ when operating this system, the AK-630M is reported to be “completely automatic”: it “does not require human supervision although it can be directed from optical control posts in case of damage or for firing on shore targets”. ¹¹ According to Rosoboronexport, when operated in automatic mode, the AK-630M-2’s “gun mount operation is fully automated, except for the belt filling and loading operations”. ¹² The AK-630M-2’s more advanced fire control system

¹ <https://www.deagel.com/Cannons%20&%20Gear/AK-630/a001892>

² http://www.navweaps.com/Weapons/WNRussian_30mm-54_ak-630.php

³ http://www.navweaps.com/Weapons/WNRussian_30mm-54_ak-630.php

⁴ <https://weaponsystems.net/system/565-30mm+AK-630>

⁵ <https://weaponsystems.net/system/565-30mm+AK-630>

⁶ <https://weaponsystems.net/system/565-30mm+AK-630>

⁷ <http://roe.ru/eng/catalog/naval-systems/shipborne-weapons/ak-630m/>

⁸ <http://roe.ru/eng/catalog/naval-systems/shipborne-weapons/ak-630m-2/>

⁹ <http://roe.ru/eng/catalog/naval-systems/shipborne-weapons/ak-630m-2/>

¹⁰ <https://www.deagel.com/Cannons%20&%20Gear/AK-630/a001892>

¹¹ http://www.navweaps.com/Weapons/WNRussian_30mm-54_ak-630.php

¹² <http://roe.ru/eng/catalog/naval-systems/shipborne-weapons/ak-630m-2/>

	is also reported to enable the “fully automatic tracking and targeting” of targets. ¹³	
Response time and simultaneous tracking capacity	Response time	NDA
	Number of targets which can be simultaneously tracked/engaged	NDA

¹³ http://www.deagel.com/Cannons-and-Gear/AK-630M-2_a001892002.aspx

Crotale Next Generation	
System manufacturer	Thales (France)
System users	France, Finland, Greece, Georgia, Libya, Oman, and Saudi Arabia. ¹⁴
System history	<p>The Crotale Next Generation (NG) is advertised by Thales as being “the first land air defence missile system designed with both radar and infrared sensors to provide the best view of the situation”.¹⁵ Having operated this system since 2003, the Greek Air Force describe it as “provid[ing] anti-aircraft defense capability to tactical and strategic assets by engaging targets in low and very low altitudes”.¹⁶</p> <p>The first Crotale variant – known as the Cactus – was developed during the 1960s as a collaboration between the South African defence company Rockwell International and the French defence company Thomson-Houston. Following the delivery of these systems to the South African military in the early 1970s, the French Air Force ordered an improved variant of the Cactus which it called the Crotale (Rattlesnake). Twenty Crotale systems had been delivered to the French military by 1978.¹⁷ The original Crotale variant – Crotale R440 – was “designed to protect high value targets, such as airfields, military bases, ammunition depots” and defend against “supersonic low-flying aircraft”.¹⁸ On some estimates, over 300 Crotale systems have been exported to fifteen states.¹⁹</p> <p>The Crotale NG, a “deep redesign of the basic Crotale”,²⁰ was introduced in 1990.²¹ The system consists of hyper-velocity VT1 missiles,²² a S-band Pulse Doppler radar, a Ku-band TWT tracking radar and an advanced camera suite.²³</p>
Maximum system range	12km (VT1 missile) ²⁴
Target type	Aircraft, cruise missiles, short-range ballistic missiles, precision guided munitions, and UAV. ²⁵

¹⁴ <https://missiledefenseadvocacy.org/defense-systems/crotale-next-generation-ng/>

¹⁵ <https://www.thalesgroup.com/en/worldwide/defence/magazine/crotale-how-leader-air-defence-missile-systems-keeps-its-edge>

¹⁶ <https://www.haf.gr/en/equipment/crotale/>

¹⁷ <http://www.military-today.com/missiles/crotale.htm>

¹⁸ <http://www.military-today.com/missiles/crotale.htm>

¹⁹ <http://www.ausairpower.net/APA-HQ-7-Crotale.html#mozTocId908954>

²⁰ <http://www.ausairpower.net/APA-HQ-7-Crotale.html#mozTocId908954>

²¹ <https://missiledefenseadvocacy.org/defense-systems/crotale-next-generation-ng/>

²² https://www.thalesgroup.com/sites/default/files/database/d7/asset/document/VT1_brochure.pdf

²³ https://odin.tradoc.army.mil/WEG/Asset/Crotale-NG_French_Short-Range_Air_Defense_System

²⁴ https://www.thalesgroup.com/sites/default/files/database/d7/asset/document/VT1_brochure.pdf

²⁵ <https://missiledefenseadvocacy.org/defense-systems/crotale-next-generation-ng/>;

<https://www.thalesgroup.com/en/worldwide/defence/magazine/crotale-how-leader-air-defence-missile-systems-keeps-its-edge>

<p>System updates and variants</p>	<p>Since its initial development, Thales have “continually upgraded the Crotale [system] with new features including improved connectivity and electronics”.²⁶ According to a 2018 press release published by Thales, a recent upgrade added “a state of the art thermal camera that provides the Finnish Defence Forces with a dependable real-time image in daylight or at night”.²⁷ These upgrades were designed to enable the Crotale NG to better detect and intercept UAV. Pascal L’ebrellec, Air Defence Sales Manager at Thales, has described the benefits of this upgrade:</p> <p style="padding-left: 40px;">The camera gives you much more information than radar... Radar allows you to see something on a screen, but you don’t know what it is. It can only tell you whether something is flying according to the flight plan. But with the infrared camera, you can see whether the object is, a dangerous aircraft, or just a toy drone. It can distinguish between a Finnish aircraft and a Russian, giving you “friend or foe” capacity.²⁸</p> <p>A naval variant of this system – the Crotale Naval – has also been developed and is installed on the French Navy’s La Fayette class frigates.²⁹</p> <p>Saudi Arabia operate a tracked variant of the Crotale system called the Shahine which was developed during the 1970s. This system has been described as “a further developed and more capable version of the widely used Crotale self-propelled SAM system” and was designed to provide mobile local aerial defence.³⁰ It first entered service in the 1980s and has since been upgraded.³¹</p> <p>By reverse engineering Crotale R440 systems provided for evaluation purposes during the 1970s, China has developed the HQ-7 family of air defence systems.³²</p> <p>Beginning testing in 2007, Thales is also developing the Crotale MK3 as a longer-range variant of the Crotale NG. The Crotale MK3 is reportedly being designed to use the Shikra 3D multibeam surveillance radar and an improved missile interceptor.³³</p>
<p>Automation and autonomy in critical functions</p>	<p>When crewing the Crotale NG, the human operator is noted to be ‘on the loop’, but only in the form of a time-restricted veto: “[a]ll functions from target detection to target tracking are automated to achieve reduced reaction times ... The operator has the option of overriding the sensor automatically selected by the operational software”.³⁴ Other analysts have described the</p>

²⁶ <https://www.thalesgroup.com/en/worldwide/defence/magazine/crotale-how-leader-air-defence-missile-systems-keeps-its-edge>

²⁷ <https://www.thalesgroup.com/en/worldwide/defence/magazine/crotale-how-leader-air-defence-missile-systems-keeps-its-edge>

²⁸ <https://www.thalesgroup.com/en/worldwide/defence/magazine/crotale-how-leader-air-defence-missile-systems-keeps-its-edge>

²⁹ <http://www.seaforces.org/wpnsys/SURFACE/Crotale-EDIR-SAM.htm>

³⁰ <https://weaponsystems.net/system/131-Shahine>

³¹ https://www.militaryfactory.com/armor/detail.asp?armor_id=865

³² <http://www.ausairpower.net/APA-HQ-7-Crotale.html#mozTocId908954>

³³ <https://www.army-technology.com/projects/crotale/>

³⁴ <https://www.army-technology.com/projects/crotale/>

	Crotale system's target detection and engagement cycle as being "automatic". ³⁵	
Response time and simultaneous tracking capacity	Response time	6 seconds. ³⁶
	Number of targets which can be simultaneously tracked/engaged	This system can reportedly track up to 8 targets simultaneously. ³⁷

³⁵

<https://en.missilery.info/missile/crotale#:~:text=Crotale%20DNG%20complex%20is%20a,reaction%20time%20of%205%20seconds.>

³⁶ <https://missiledefenseadvocacy.org/defense-systems/crotale-next-generation-ng/>

³⁷ <http://www.seaforces.org/wpnsys/SURFACE/Crotale-EDIR-SAM.htm>

Goalkeeper	
System manufacturer	Thales Group (The Netherlands)
System users	The Netherlands, Belgium, Chile, Portugal, Qatar, South Korea, the UAE, and the UK. ³⁸
System history	<p>Armed with a 30mm Gatling gun, the Goalkeeper is designed to provide a last-line-of defence against anti-ship missiles.³⁹ It operates with two radar subsystems: the first, which detects targets; the second, which tracks and directs fire toward them.⁴⁰ To protect against incoming threats, the Goalkeeper “fires ‘a wall of steel’ at the incoming target at a speed of 4200 shots per minute”.⁴¹</p> <p>Development of the Goalkeeper began in 1975 and the first prototype was tested by the Dutch navy in 1979.⁴² The Dutch Navy ordered ten Goalkeeper systems in 1985 with an additional three systems being ordered the subsequent year.⁴³ Two Dutch warships armed with the Goalkeeper system – <i>Hr.Ms. Witte de With</i> and <i>Hr.Ms. Pieter Florisz</i> – deployed to the Persian Gulf during the first Gulf War.⁴⁴</p> <p>By 2018, a total of 63 Goalkeeper systems had been sold.⁴⁵ Between 1988 and 2015, the Goalkeeper system was operated by the British Royal Navy including on the aircraft carrier <i>HMS Invincible</i> and Type 22 frigates.⁴⁶</p>
Maximum system range	2km ⁴⁷
Target type	Aircraft, anti-ship missiles and fast manoeuvring surface vessels. ⁴⁸
Major system updates	<p>As part of the Upkeep Modifications programme began in 2012, the Netherlands Ministry of Defence contracted Thales to modernise 16 Goalkeeper systems.⁴⁹ Despite suspected cost-over runs,⁵⁰ the programme completed sea trials in 2018. The exact technical details of the Upkeep modifications are unknown. According to Thales, it included “new algorithms and state-of-the-art electro-optic tracking capabilities” to address obsolescence issues.⁵¹ Dutch media reports allude to the possibly greater integration of automation and autonomy into the Goalkeeper’s critical functions. It was noted that the Upkeep Modification programme:</p> <p style="text-align: center;">[...] makes the Goalkeeper easier to operate and the weapon is faster due to the greater computing power and it can calculate more accurately where the shots should be placed. The Goalkeepers are</p>

³⁸ <https://www.thalesgroup.com/en/goalkeeper-close-weapon-system>

³⁹ <https://www.thalesgroup.com/en/goalkeeper-close-weapon-system>

⁴⁰ <http://www.seaforces.org/wpnsys/SURFACE/Goalkeeper-CIWS.htm>

⁴¹ <https://marineschepen.nl/dossiers/goalkeeper.html>

⁴² <https://missiledefenseadvocacy.org/defense-systems/goalkeeper-close-in-weapons-system-ciws/>

⁴³ <https://marineschepen.nl/dossiers/goalkeeper.html>

⁴⁴ <https://marineschepen.nl/dossiers/goalkeeper.html>

⁴⁵ <https://www.thalesgroup.com/en/netherlands/press-release/thales-goalkeeper-scores-again-and-again-sea-acceptance-trials>

⁴⁶ <https://www.savetheroyalnavy.org/last-ditch-defence-the-phalanx-close-in-weapon-system-in-focus/>

⁴⁷ <https://missiledefenseadvocacy.org/defense-systems/goalkeeper-close-in-weapons-system-ciws/>

⁴⁸ <https://www.naval-technology.com/news/newsthales-upgrade-goalkeeper-weapon-system-dutch-navy/>

⁴⁹ <https://www.naval-technology.com/news/newsthales-upgrade-goalkeeper-weapon-system-dutch-navy/>

⁵⁰ <https://www.tubantia.nl/hengelo/thales-lijdt-miljoenenstrop-ad629fc2/>

⁵¹ <https://www.thalesgroup.com/en/netherlands/press-release/thales-goalkeeper-scores-again-and-again-sea-acceptance-trials>

	<p>also able to detect targets faster, time shots better and change targets faster, partly due to new algorithms.⁵²</p> <p>The Upkeep Modification programme also reportedly included upgrades to the Goalkeeper’s display console to enable the operator to manually track and engage fast surface targets.⁵³</p>	
<p>Automation and autonomy in critical functions</p>	<p>According to Thales, this system “automatically performs the entire process from surveillance and detection to destruction, including selection of the next priority target”.⁵⁴ The Missile Defence Advocacy Alliance have described the Goalkeeper as being “fully autonomous”: a functionality which helps it defend against threats “that would be difficult to detect and follow by a human-operated system”.⁵⁵ Others have described the Goalkeeper as being a “completely automatic weapon system for short-range defence”⁵⁶ and as being a “fully automatic system”.⁵⁷</p>	
<p>Response time and simultaneous tracking capacity</p>	<p>Response time</p>	<p>5-6 seconds.⁵⁸</p>
	<p>Number of targets which can be simultaneously tracked/engaged</p>	<p>The Goalkeeper system can reportedly track up to 30 targets simultaneously. It can also reportedly prioritise the engagement of up to 4 targets simultaneously.⁵⁹</p>

⁵² <https://marineschepen.nl/nieuws/Gemoderniseerde-Goalkeeper-klaar-voor-tests-220716.html>

⁵³ <https://marineschepen.nl/nieuws/Gemoderniseerde-Goalkeeper-klaar-voor-tests-220716.html>

⁵⁴ <https://www.thalesgroup.com/en/goalkeeper-close-weapon-system>

⁵⁵ <https://missiledefenseadvocacy.org/defense-systems/goalkeeper-close-in-weapons-system-ciws/>

⁵⁶ <http://www.seaforces.org/wpnsys/SURFACE/Goalkeeper-CIWS.htm>

⁵⁷ <https://www.naval-technology.com/news/newsthales-upgrade-goalkeeper-weapon-system-dutch-navy/>

⁵⁸ <http://www.seaforces.org/wpnsys/SURFACE/Goalkeeper-CIWS.htm>

⁵⁹ http://www.navweaps.com/Weapons/WNNeth_30mm_Goalkeeper.php

Kashtan-M		
System manufacturer	KBP Instrument Design Bureau (Russia)	
System users	Russia, China, and India. ⁶⁰	
System history	<p>The Kashtan-M is a naval CIWS used on several different classes of Russian warship. Variants of this system are also operated by the Chinese and Indian navies.⁶¹</p> <p>Development of this system began in the 1980s and it first achieved Initial Operational Capability in 1992.⁶² The Kashtan-M system is equipped with eight surface to air missiles and two 30mm automatic guns. The system also consists of a command module, an optical guidance system and “target and missile tracking equipment”.⁶³ Up to 6 Kashtan-M complexes can be installed on a single warship.⁶⁴ This system is set to be phased out and replaced by the Pantsir-SM system currently in development.⁶⁵</p>	
Maximum system range	10km (missile) and 4km (guns) ⁶⁶	
Target type	KBP Instrument Design Bureau advertise this system as being “designed for self-defense of ships and ground-based stationary objects against various air threats, including anti-ship missiles flying at extremely low altitudes, as well as for engagement of small-size seaborne and ground targets”. ⁶⁷	
System updates and variants	The Kashtan-M is an updated variant of the Kashtan system. Amongst other upgrades, it has a faster response time, a dedicated targeting station and improved armament. ⁶⁸	
Automation and autonomy in critical functions	KBP Instrument Design Bureau advertise the Kashtan-M as having “automatic operation”. ⁶⁹ According to the Rosoboroneexport, this system is “[f]ully automated...from target acquisition till engagement”. ⁷⁰ The Kashtan-M’s command module can detect, identify and track targets. It is also reportedly capable of generating target designation data and assigning targets among its combat modules. ⁷¹ Others have described this system as being capable of the “full automation of combat operations”. ⁷²	
Response time and simultaneous tracking capacity	Response time	3-6 seconds. ⁷³
	Number of targets which can be	This system can reportedly engage up to 6 targets simultaneously. ⁷⁴

⁶⁰ <https://www.deagel.com/Protection%20Systems/Kashtan/a001460>

⁶¹ <https://www.deagel.com/Protection%20Systems/Kashtan/a001460>

⁶² <https://www.deagel.com/Protection%20Systems/Kashtan/a001460>

⁶³ <http://www.kbptula.ru/en/productions/air-defense-weapon-systems/kashtan-m>

⁶⁴ <http://roe.ru/eng/catalog/naval-systems/shipborne-weapons/kashtan-m/>

⁶⁵ <https://www.thedrive.com/the-war-zone/17233/russia-to-begin-testing-its-fearsome-new-pantsir-me-naval-close-in-defensive-system>

⁶⁶ <http://www.kbptula.ru/en/productions/air-defense-weapon-systems/kashtan-m>

⁶⁷ <http://www.kbptula.ru/en/productions/air-defense-weapon-systems/kashtan-m>

⁶⁸ <http://www.navyrecognition.com/index.php/east-european-navies-vessels-ships-equipment/russian-navy-vessels-ships-equipment/weapons-a-systems/123-kashtan-kashtan-m-kashtan-lr-cads-n-1-close-in-weapon-system-ciws-.html>

⁶⁹ <http://www.kbptula.ru/en/productions/air-defense-weapon-systems/kashtan-m>

⁷⁰ <http://roe.ru/eng/catalog/naval-systems/shipborne-weapons/kashtan-m/>

⁷¹ <http://kbptula.ru/en/productions/air-defense-weapon-systems/kashtan-m>

⁷² <http://www.navyrecognition.com/index.php/east-european-navies-vessels-ships-equipment/russian-navy-vessels-ships-equipment/weapons-a-systems/123-kashtan-kashtan-m-kashtan-lr-cads-n-1-close-in-weapon-system-ciws->

⁷³ <http://www.kbptula.ru/en/productions/air-defense-weapon-systems/kashtan-m>

⁷⁴ <https://www.deagel.com/Protection%20Systems/Kashtan/a001460>

	simultaneously tracked/engaged	
--	-----------------------------------	--

NBS MANTIS	
System manufacturer	Rheinmetall Air Defence (Germany)
System users	Germany
System history	<p>The NBS (Nächstbereichschutzsystem) MANTIS (Modular, Automatic and Network-capable Targeting and Interception System) is a CIWS designed for the German military.⁷⁵ The NBS MANTIS appears to also be known as the Oerlikon Skyshield MOOTW/C-RAM (counter-rocket, artillery and mortar) because it was originally developed from this existing technology.⁷⁶ An NBS MANTIS is “equipped with [up to] six 35mm automatic [Oerlikon Millennium Guns], two sensor units and a central command ground-control unit”.⁷⁷ It uses AHEAD ammunition which “contains 152 tungsten sub-projectiles capable of neutralizing small and even very small targets, much the way a shotgun shell destroys a clay pigeon”.⁷⁸</p> <p>NBS MANTIS’s development began in 2007 as part of the German Army’s <i>SysFla</i> air-defence programme. It was designed to defend German military bases in Afghanistan from insurgent attacks, and “to protect military installations and critical civilian infrastructure from aerial threats coming in at low altitude, including manned and unmanned aircraft”.⁷⁹ Development of the NBS MANTIS was completed in twelve months and field tests were conducted in the summer of 2008.⁸⁰</p> <p>The German government ordered 2 NBS MANTIS systems in an initial contract worth €110.8 million agreed in May 2009.⁸¹ The German Air Force accepted delivery of a MANTIS air defence system in November 2012 “provid[ing] the Bundeswehr with a high performance, automated air defence system for asset protection that is second to none”.⁸²</p>
Maximum system range	3km ⁸³
Target type	Aircraft, cruise missiles, rocket, artillery and mortar attacks, and UAV. ⁸⁴
System updates and variants	NDA

⁷⁵ https://www.rheinmetall-defence.com/en/rheinmetall_defence/public_relations/news/archiv/archive2012/aktuellesdetailansicht_4_2560.php

⁷⁶ https://www.rheinmetall-defence.com/media/editor_media/rm_defence/publicrelations/pressemitteilungen/2014_1/aad/2014_09_17_AAD_04_Air_Defence.pdf

⁷⁷ <https://www.army-technology.com/projects/mantis/>

⁷⁸ https://www.rheinmetall-defence.com/media/editor_media/rm_defence/publicrelations/pressemitteilungen/2015/cansec/2015-05-27_Rheinmetall_Cansec_Millennium_Gun_en.pdf

⁷⁹ https://www.rheinmetall-defence.com/en/rheinmetall_defence/public_relations/news/archiv/archive2012/aktuellesdetailansicht_4_2560.php

⁸⁰ <https://www.army-technology.com/projects/mantis/>

⁸¹ <https://www.army-technology.com/projects/mantis/>

⁸² https://www.rheinmetall-defence.com/en/rheinmetall_defence/public_relations/news/archiv/archive2012/aktuellesdetailansicht_4_2560.php

⁸³ https://www.rheinmetall-defence.com/en/rheinmetall_defence/public_relations/news/detail_1426.php

⁸⁴ <https://www.army-technology.com/projects/mantis/>; https://www.rheinmetall-defence.com/en/rheinmetall_defence/public_relations/news/archiv/archive2012/aktuellesdetailansicht_4_2560.php

<p>Automation and autonomy in critical functions</p>	<p>Rheinmetall describe the MANTIS as being “a high performance, automated air defence system”.⁸⁵ Analysts have similarly described it as a “fully automated air defence system”.⁸⁶ Human operators assess and classify the current air situation via the MANTIS’ command unit and decide whether to activate the system.⁸⁷ Once activated, MANTIS operates in automatic mode without further human involvement.⁸⁸ Early media reporting on the MANTIS described it as operating with “[a] very high degree of automation, including automatic target detection and engagement processes which the operator only has to monitor”.⁸⁹ Human operators can, however, initiate “rapid shutdown in cases of targeting errors, change of situation or change in status of targets”.⁹⁰</p>	
<p>Response time and simultaneous tracking capacity</p>	<p>Response time</p>	<p>4-5 seconds.⁹¹</p>
	<p>Number of targets which can be simultaneously tracked/engaged</p>	<p>NDA</p>

⁸⁵ https://www.rheinmetall-defence.com/en/rheinmetall_defence/public_relations/news/archiv/archive2012/aktuellesdetailansicht_4_2560.php

⁸⁶ <https://www.army-technology.com/projects/mantis/>

⁸⁷ <https://www.bundeswehr.de/de/organisation/luftwaffe/aktuelles/blitzschnell-entscheiden-leben-retten-139222>

⁸⁸ <https://www.boell.de/en/2018/05/17/autonomy-weapon-systems>

⁸⁹ <https://www.defenseindustrydaily.com/Germany-Orders-Skyshield-C-RAM-Base-Defense-Systems-05418/>

⁹⁰ <https://www.boell.de/en/2018/05/17/autonomy-weapon-systems>, p.21.

⁹¹ <https://militaryleak.com/2018/11/03/nbs-mantis-air-defence-system/>

Pantsir-S1	
System manufacturer	KBP Instrument Design Bureau (Russia)
System users	Russia, Algeria, Brazil, Iran, Iraq, Jordan, Libya, Oman, Russia, Saudi Arabia, Slovenia, Syria, UAE, and Vietnam. ⁹²
System history	<p>The Pantsir-S1 – NATO code name SA-22 Greyhound – is a self-propelled, air defence system used to provide “short-range defense for Russian ground forces and longer range air defense systems like the S-300, S-400, and S-500”.⁹³ The baseline Pantsir-S1 variant is equipped with two 30mm 2A38M cannons and 12 57E6 missiles.⁹⁴ Its target acquisition radar, tracking radar and its launchers can be mounted onto a single combat vehicle.⁹⁵ The Pantsir-S1 system is advertised as being capable of engaging targets on the move and having an “all-weather and round-the-clock application”.⁹⁶</p> <p>Development of the Pantsir-S1 system began in 1989. It was designed to replace the 2K22 Tunguska air defence system. Although a prototype Pantsir model was built by 1995, the Russian military lost interest in the project. It was revived following an export order from the UAE and led to a major redesign of the system.⁹⁷ The Pantsir-S1 entered service with the Russian military in 2003.⁹⁸</p> <p>According to media reports, Russian Pantsir-S1 batteries have been deployed at Khmeimim airbase in Syria since 2015.⁹⁹ In 2018, Israel released video footage of what it claims showed a successful cruise-missile attack against a Syrian operated Pantsir-S1 system.¹⁰⁰ Pantsir-S1’s systems have also reportedly been deployed by Russia to support pro-Russian forces in Ukraine and its preferred party in the Libya Civil War: the Libyan National Army.¹⁰¹ The operational effectiveness of the Pantsir-S1 system against slow-flying and small unmanned aerial systems has been subject to considerable scrutiny.¹⁰² According to some media reports, up to nine Pantsir-S1 export variants operated by the Russian-backed Libyan National Army were destroyed by drone attacks in May 2020 alone. A further system is also reported to have been captured by the Turkish backed Government of National Accord fighters in June 2020.¹⁰³</p>
Maximum system range	20km (57E6 missiles) and 4km (gun) ¹⁰⁴

⁹² <https://missilethreat.csis.org/defsyst/pantsir-s-1/>

⁹³ <https://missilethreat.csis.org/defsyst/pantsir-s-1/>

⁹⁴ <https://missilethreat.csis.org/defsyst/pantsir-s-1/>

⁹⁵ <https://www.youtube.com/watch?v=50TmAd6AxfE>

⁹⁶ <http://www.kbptula.ru/en/productions/air-defense-weapon-systems/pantsir-s1>

⁹⁷ https://www.defenseworld.net/feature/42/Russian_Pantsir_Air_Defense_System__Sitting_duck_or_Top_Dog_#.X93J5tj7Tcd

⁹⁸ <https://missilethreat.csis.org/defsyst/pantsir-s-1/#easy-footnote-bottom-1-1917/>

⁹⁹ <https://www.bbc.co.uk/news/world-middle-east-42207172>

¹⁰⁰ <https://www.businessinsider.com/israel-releases-video-of-missile-strike-on-a-pantsir-s1-in-syria-2018-5?r=US&IR=T>

¹⁰¹ <https://missilethreat.csis.org/defsyst/pantsir-s-1/>;

https://www.realcleardefense.com/articles/2020/06/19/libya_a_catastrophe_for_russias_pantsir_s1_air_defense_system_115394.html

¹⁰² <https://dimdex.com/News/new-and-improved-russias-pantsir-sm-air-defence-system/>; https://defense-update.com/20190625_pantsir-2.html

¹⁰³ https://www.realcleardefense.com/articles/2020/06/19/libya_a_catastrophe_for_russias_pantsir_s1_air_defense_system_115394.html

¹⁰⁴ <http://www.kbptula.ru/en/productions/air-defense-weapon-systems/pantsir-s1>

Target type	Aircraft, cruise missiles, helicopters, precision guided munitions, and UAV. ¹⁰⁵
System updates and variants	<p>The Pantsir-M is a naval variant of the Pantsir system designed for the Russian Navy and the export market. It reportedly has a “response time of 3-5 seconds and can engage and destroy simultaneously up to four targets at ranges of up to 20 kilometers”.¹⁰⁶ In December 2020, it was reported that six Pantsir-M combat modules would be installed on the Russian aircraft carrier Admiral Kuznetsov.¹⁰⁷</p> <p>Prompted by concerns about the military performance of the baseline Pantsir-S1, the Pantsir-SM variant is currently in development.¹⁰⁸ According to Alexander Khomyakov, the KBP Instrument Design Bureaus chief designer, the Pantsir-SM will have double the range of the Pantsir-S1.¹⁰⁹ It will also reportedly be better optimised for operations in the Arctic, be more capable of engaging slow flying UAV, and will be operated from a more capable combat vehicle which includes an improved radar system.¹¹⁰ Speaking to the Russian media, a spokesperson with knowledge of the programme has noted that “[i]t is very important that the range of hittable targets has been greatly expanded on the basis of the results we obtained in Syria. Corresponding amendments have been introduced. The system can now hit any type of drones effectively”.¹¹¹ In 2020, the chief designer for air defense systems at Shipunov Design Bureau of Instrument-Making claimed that a hypersonic missile was also being developed for the Pantsir-SM variant.¹¹²</p>
Automation and autonomy in critical functions	<p>Rosoboronexport describe the Pantsir-S1 as having an “automatic target engagement mode” and as being capable of “autonomous operation with an automatic target engagement cycle, from target acquisition to engagement”.¹¹³ KBP Instrument Design Bureau, the system’s manufacturer, advertise the Pantsir-S1’s command module as having been “designed for automated control over combat operations”.¹¹⁴ The Pantir-S1 system is noted by others to be capable of “operat[ing] in a fully automatic mode”.¹¹⁵</p> <p>In 2018, it was reported that Russia’s Aerospace Forces had “tested the country’s first automated air defense control system with elements of Artificial Intelligence” for use by the Pantsir-S1 and S-400 air defence systems.¹¹⁶ Whilst a full technical breakdown of this upgrade are</p>

¹⁰⁵ <http://www.kbptula.ru/en/productions/air-defense-weapon-systems/pantsir-s1>

¹⁰⁶ <https://www.deagel.com/Artillery%20Systems/Pantsir/a000019>

¹⁰⁷ <https://www.navalnews.com/naval-news/2020/12/russian-aircraft-carrier-admiral-kuznetsov-to-get-pantsir-m-ciws/>

¹⁰⁸ <https://www.ibtimes.sg/pantsir-s1m-russia-feature-advanced-version-anti-aircraft-gun-missile-moscow-parade-46665>;

https://www.defenseworld.net/feature/42/Russian_Pantsir_Air_Defense_System__Sitting_duck_or_Top_Dog_#.X93J5tj7Td

¹⁰⁹ <https://tass.com/defense/904503>

¹¹⁰ <https://www.deagel.com/Artillery%20Systems/Pantsir/a000019>; <https://www.ibtimes.sg/pantsir-s1m-russia-feature-advanced-version-anti-aircraft-gun-missile-moscow-parade-46665> ; <https://www.edrmagazine.eu/russia-showcases-upgraded-pantsir-s1m-spaagm>

¹¹¹ <https://tass.com/defense/1058576>

¹¹² <https://dsm.forecastinternational.com/wordpress/2020/01/29/russian-pantsir-system-receiving-hypersonic-missile/>

¹¹³ http://roe.ru/pdfs/pdf_1978.pdf

¹¹⁴ <http://www.kbptula.ru/en/productions/air-defense-weapon-systems/pantsir-s1>

¹¹⁵ <https://odin.tradoc.army.mil/Search/All/Pantsir>

¹¹⁶ <https://defaiya.com/news/2018/05/04/russia-s-s-400-pantsir-s-air-defense-systems-to-get-ai-boost>

	<p>unavailable, Russian media reports speak to the increased complexity of machine-human interactions:</p> <p>With the new system in place, the Russian air-defense forces will be able to respond to all situational changes in real time, bypassing the stage of analysis at command posts. Currently, each anti-aircraft missile and radar installation has its own control which is absolutely vital given the high speed of modern aircraft and high density of air attacks. The automated air defense system will reduce the decision-making time and will facilitate the distribution of targets among air defense batteries.¹¹⁷</p> <p>In 2020, it was reported that frontline Pantsir systems had received these upgrades with unnamed Russia military sources telling the Russian media that:</p> <p>Documents hint at automated control system being Artificial Intelligence (AI)-enabled. Software takes into account the tactical situation, location of targets, degree of their danger and other parameters. Based on this, it selects the best tactic to repel the attack.¹¹⁸</p>	
<p>Response time and simultaneous tracking capacity</p>	<p>Response time</p>	<p>4-6 seconds.¹¹⁹</p>
	<p>Number of targets which can be simultaneously tracked/engaged</p>	<p>The Pantsir-S1's radar is reportedly capable of tracking up to 20 targets simultaneously.¹²⁰ The system is advertised by its manufacturer as being capable of engaging up to 4 targets simultaneously.¹²¹</p>

¹¹⁷ <https://defaiya.com/news/2018/05/04/russia-s-s-400-pantsir-s-air-defense-systems-to-get-ai-boost>

¹¹⁸

https://www.defenseworld.net/news/27519/Russian_Pantsir_Air_Defence_System_Gets_Artificial_Intelligence_Upgrade#.X93Y39j7Tcc

¹¹⁹ <http://www.military-today.com/missiles/pantsyr.htm>

¹²⁰ <https://missilethreat.csis.org/defsyst/pantsir-s-1/>

¹²¹ <http://www.kbptula.ru/en/productions/aair-defense-weapon-systems/pantsir-s1>

Phalanx	
System manufacturer	Raytheon (US)
System users	The US, Australia, Bahrain, Canada, Egypt, Greece, India, Israel, Japan, New Zealand, Pakistan, Poland, Portugal, Saudi Arabia, South Korea, Taiwan, Turkey, and the UK. ¹²²
System history	<p>The Phalanx system has been described as “a fast-reaction, rapid-fire 20-millimeter gun system that provides US Navy ships with a terminal defense against anti-ship missiles that have penetrated other fleet defences”.¹²³ Its Block 1B variant consists of a 20mm M-61A1 cannon, a search radar and a tracking radar.¹²⁴</p> <p>Development of the Phalanx system began in the 1970s, with production beginning in 1978.¹²⁵ It was first deployed on a US Navy warship – <i>USS Coral Sea</i> – in 1980. As with other CIWS, the Phalanx’s development was prompted by growing concerns about the threat which fast, low flying anti-ship missiles posed to warships. These concerns were given greater impetus by the sinking of the Israeli destroyer <i>INS Eilat</i> by Egyptian Komar-class missile craft during the Six Day War. Until that point, air defence systems had been primarily designed to defend against attack from fighter aircraft.¹²⁶</p> <p>The Phalanx system is used on every class of US Navy warship, being described as the “mainstay” CIWS system.¹²⁷ By 2017, 850 systems were produced for a total of 24 states.¹²⁸ During the first Gulf War, when operating in automatic mode, the frigate <i>USS Jarrett</i>’s Phalanx system malfunctioned when attempting to defend the battleship <i>USS Missouri</i> from an attack from Iraqi Silkworm anti-ship missiles.¹²⁹ In 1996, a Phalanx system operated on the Japanese Navy destroyer <i>Yugiri</i> was involved in an accident which destroyed a US Navy A-6E Intruder airplane.¹³⁰ The Phalanx system had locked onto the A-6E Intruder rather than the aerial target it was towing: “[a] post-accident review board concluded that YUGIRI’s Phalanx was in manual control and the YUGIRI’s gunnery officer gave the order to fire before the A-6 was out of the CIWS engagement envelope”.¹³¹</p>
Maximum system range	5km ¹³²
Target type	Anti-ship missiles, aircraft, helicopters, “small high-speed surface craft”, and surface mines. ¹³³
System updates and variants	Since its first development, the capabilities of the Phalanx system have been improved through at least 2 major ‘block’ upgrades: Block 1 (1988) and

¹²² <https://www.deagel.com/Protection%20Systems/Mk%2015%20Phalanx/a001641>

¹²³ <https://fas.org/man/dod-101/sys/ship/weaps/mk-15.htm>

¹²⁴ http://www.navweaps.com/index_tech/tech-103.php

¹²⁵ <https://fas.org/man/dod-101/sys/ship/weaps/mk-15.htm>

¹²⁶ http://www.navweaps.com/index_tech/tech-103.php

¹²⁷ <https://fas.org/man/dod-101/sys/ship/weaps/mk-15.htm>

¹²⁸ <https://www.gd-ots.com/wp-content/uploads/2017/11/Phalanx.pdf>

¹²⁹ http://www.navweaps.com/index_tech/tech-103.php

¹³⁰ <https://www.nytimes.com/1996/06/05/world/japanese-down-navy-plane-in-an-accident-crew-is-safe.html>

¹³¹ http://www.navweaps.com/index_tech/tech-103.php

¹³² <https://missiledefenseadvocacy.org/defense-systems/mk-15-phalanx/>

¹³³ <http://www.seaforces.org/wpnsys/SURFACE/Goalkeeper-CIWS.htm>

	<p>Block 1B (1999).¹³⁴ Block 0, the system’s first variant, was principally designed to detect and intercept anti-ship missiles at low altitudes.¹³⁵</p> <p>The Phalanx’s Block 1A upgrades were designed to improve the system’s rate of fire, ammunition holding capacity, and radar.¹³⁶ Improvements were also made to the system’s fire control algorithms, and “were intended to increase the system’s capability against emerging Russian supersonic anti-ship missiles”.¹³⁷</p> <p>The first Block 1B Phalanx system was installed aboard the <i>USS Underwood</i> in 1999.¹³⁸ The Block 1B capability upgrade improved the Phalanx’s defense against small surface targets, slow-moving air targets, and helicopters whilst “add[ing] control stations that allow operators to visually track and identify targets before engagement”.¹³⁹ Improvements to the system’s gun barrel, sensors and armament were also made.¹⁴⁰ This upgrade aimed to better protect American warships against asymmetric threats. Whilst the “[t]he Block 1B version adds control stations that allow operators to visually track and identify targets before engagement”, as Raytheon note, this is for use at “sea against helicopters and high-speed surface craft and on land to help identify and confirm incoming threats”.¹⁴¹</p> <p>A land-based variant of the Phalanx – the Centurion – has also been developed to “protect ground forces and high-value sites against rocket, artillery and mortar (RAM) threats”.¹⁴² Development of this variant began in 2004.¹⁴³ Centurion systems were deployed to Iraq as early as 2005, and were used to defend high priority areas such as the Green Zone.¹⁴⁴ In January 2019, Raytheon was awarded a \$205 million contract to provide additional Centurion systems to the American Army.¹⁴⁵</p>
<p>Automation and autonomy in critical functions</p>	<p>The Phalanx system is reportedly capable of “automatically engag[ing] incoming anti-ship missiles and high-speed, low-level aircraft that have penetrated the ship’s primary defense envelope... while providing for manual override”.¹⁴⁶ A US Navy Fact File presents the Phalanx as being a system which “automatically detects, evaluates, tracks, engages, and performs kill assessment against [Anti-Ship Missiles] and high speed aircraft threats”.¹⁴⁷</p> <p>As with other CIWS, the Phalanx system can operate in both manual and automatic modes. It operates in the latter when human operators are perceived to lack sufficient time to deliberate on incoming threats.¹⁴⁸</p>

¹³⁴ <https://www.public.navy.mil/surfor/pages/phalanx-ciws.aspx>

¹³⁵ <https://fas.org/man/dod-101/sys/ship/weaps/mk-15.htm>

¹³⁶ <https://www.deagel.com/Protection%20Systems/Mk%2015%20Phalanx/a001641>

¹³⁷ <http://www.seaforces.org/wpnsys/SURFACE/Mk-15-close-in-weapon-system.htm>

¹³⁸ <https://missiledefenseadvocacy.org/defense-systems/mk-15-phalanx/>

¹³⁹ <https://fas.org/man/dod-101/sys/ship/weaps/mk-15.htm>

¹⁴⁰ <https://www.gd-ots.com/armaments/naval-platforms-system/phalanx/>

¹⁴¹ <https://www.raytheonmissilesanddefense.com/capabilities/products/phalanx-close-in-weapon-system>

¹⁴² <https://www.deagel.com/Protection%20Systems/Mk%2015%20Phalanx/a001641>

¹⁴³ https://www.armyrecognition.com/united_states_us_army_artillery_vehicles_system_uk/centurion_c-ram_land-based_weapon_system_phalanx_technical_data_sheet_specifications_pictures_video.html

¹⁴⁴ http://www.navweaps.com/index_tech/tech-103.php

¹⁴⁵

https://www.armyrecognition.com/january_2019_global_defense_security_army_news_industry/raytheon_to_supply_phalanx_air_defense_system_to_u.s._army.html

¹⁴⁶ <https://fas.org/man/dod-101/sys/ship/weaps/mk-15.htm>

¹⁴⁷ <https://www.public.navy.mil/surfor/pages/phalanx-ciws.aspx>

¹⁴⁸ <https://www.jstor.org/stable/pdf/resrep24525.10.pdf?refreqid=excelsior%3A7e456d11b047287bdc89d8d44eef9b48>, p.34.

	<p>Against slower threats such as small surface targets however, early variants of the Block 1B Phalanx reportedly “required human intervention via optical sensors to point the gun at small surface targets”.¹⁴⁹ When operating in automatic mode, the systems engagement cycle is explained works in the following way:</p> <ol style="list-style-type: none"> 1. “... [s]earch radar acquires inbound threat at 10 miles; Phalanx software starts track, assigns priority. 2. Search radar continues track; software confirms threat; fire control radar locks onto target at 5 miles. 3. About 2 miles (or at optimal range assigned by software) gun opens fire on Threat 1 and continues until a hard or soft kill is achieved. 4. Phalanx switches to engage Threat 2 or ceases fire. 5. Phalanx continues to search for threats. 6. Phalanx drum is reloaded at first opportunity”.¹⁵⁰ 	
<p>Response time and simultaneous tracking capacity</p>	<p>Response time</p>	<p>NDA</p>
	<p>Number of targets which can be simultaneously tracked/engaged</p>	<p>The Phalanx system is reportedly capable of “processing” up to six threats simultaneously.¹⁵¹</p>

¹⁴⁹ <https://core.ac.uk/download/pdf/36732163.pdf>, p.3.
¹⁵⁰ http://www.navweaps.com/index_tech/tech-103.php
¹⁵¹ http://www.navweaps.com/index_tech/tech-103.php

Rapier FSC	
System manufacturer	MBDA (Europe/UK)
System users	The UK, Iran, Kenya, Malaysia, Oman, Singapore, Switzerland, Turkey, UAE and Zambia. ¹⁵²
System history	<p>The Rapier is described by the British Ministry of Defense as “a technologically advanced short-range air defence system”.¹⁵³ Development of the Rapier began in the 1960s, and was designed to replace the L/70 Bofors Air Defense System.¹⁵⁴ The Rapier achieved initial operational status in 1973, and saw service as part of the Falkland War, the Gulf War and the Iraq War.¹⁵⁵ An updated version of the Rapier - Field Standard C - entered service with the British Army, its principal user, in 1996.¹⁵⁶</p> <p>Rapier systems were deployed to provide air defense for the 2012 London Olympics.¹⁵⁷ More commonly, this system has been used to provide short area defense for divisional headquarters and airfields.¹⁵⁸ Given its lack of armored protection and limited mobility, the Rapier has been described as being “best suited to providing protection to less mobile, more static assets”.¹⁵⁹ As part of the Future Local Area Air Defense System programme, the Rapier is scheduled to be replaced by the Sky Sabre system also examined in this catalogue.</p>
Maximum system range	8km ¹⁶⁰
Target type	Aircraft, cruise missiles, helicopters and UAV. ¹⁶¹
System updates and variants	<p>Development of the Rapier FSC began in 1992, with the first systems entering service with the Royal Air Force and the Royal Artillery in 1996.¹⁶² The FSC variant of the Rapier system included more sophisticated radar and improved missiles.¹⁶³</p> <p>The earlier Field Standard B1 upgrades which were completed in the early 1980s incorporated an improved DN181 radar which “gave the operator a choice of either manually using the Optical Tracker or [an] automatic Blind Fire capability”.¹⁶⁴</p>
Automation and autonomy in critical functions	In describing how soldiers are taught to operate the Rapier FSC, a member of the Royal Artillery has described elements of this system as being “automatic”: its surveillance radar detects whether an incoming target is a friendly force or an enemy. If the radar identifies an incoming target as an enemy, the system is switched to manual mode where the operator can then

¹⁵² <https://missiledefenseadvocacy.org/defense-systems/rapier-field-standard-c-fsc/>

¹⁵³ <https://www.army.mod.uk/equipment/artillery-and-air-defence/>

¹⁵⁴ <https://missiledefenseadvocacy.org/defense-systems/rapier-field-standard-c-fsc/>

¹⁵⁵ https://mraths.org.uk/?page_id=2860

¹⁵⁶ <https://missiledefenseadvocacy.org/defense-systems/rapier-field-standard-c-fsc/>

¹⁵⁷ <https://www.theguardian.com/sport/2012/jul/10/residents-tower-government-olympic-missiles>

¹⁵⁸ https://www.youtube.com/watch?time_continue=11&v=xSa5oeLO5OE&feature=emb_title

¹⁵⁹

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/784305/archive_doctrine_uk_joint_air_defence_jwp_3_63.pdf, p.2-8.

¹⁶⁰ <https://www.army.mod.uk/equipment/artillery-and-air-defence/>; <https://fas.org/man/dod-101/sys/land/row/rapier.htm>

¹⁶¹ <https://www.army.mod.uk/equipment/artillery-and-air-defence/>

¹⁶² <https://www.army-technology.com/projects/jernas>

¹⁶³ <http://www.armedforces.co.uk/army/listings/10120.html>

¹⁶⁴ https://mraths.org.uk/?page_id=2860

	<p>“engage” the missile and track its launch toward the target. In this way, the Rapier is described as operating with a “man in the loop”.¹⁶⁵</p> <p>Consistent with this explanation, others have described the Rapier’s engagement process in greater detail:</p> <p>Upon detection of a target, the optical tracking system would be slewed to target azimuth and the operator would then search for the target in elevation. The operator's field of view would depend on the target range: "wide" at about 20 degrees or "track" at about 4.8 degrees. When the target was found the operator switches to "track" and uses a joystick to keep the target centred in the telescope. Once a steady track was established the missile was fired. The TV camera on the tracker was tuned to track the four flares on the missile's tail. Like the operator's telescope, the TV system had two views, one about 11 degrees wide for the initial "capture", and another at 0.55 degrees for midcourse tracking. The difference between the line-of-sight of the operator's telescope and the missile's flare was calculated by the computer in the base of the launcher. Guidance updates were sent to the missile through the transmitter on the launcher platform, and received on small antennas on the rear of the mid-body fins. The operator simply kept the telescope's crosshairs on the target using the joystick, and the missile would automatically fly into the line-of-sight, a system of operation known as SACLOS. The basic concept is very similar to the one used by most anti-tank missiles, with the exception that those systems normally use small wires to send guidance information to the missile, rather than a radio link.¹⁶⁶</p>	
<p>Response time and simultaneous tracking capacity</p>	<p>Response time</p>	<p>6 seconds.¹⁶⁷</p>
	<p>Number of targets which can be simultaneously tracked/engaged</p>	<p>The system’s Dagger target acquisition and surveillance radar reportedly “has the processing capacity to detect more than 75 threats a second”.¹⁶⁸ According to the Ministry of Defence, the Rapier FCS “has the capability of engaging two targets at once”.¹⁶⁹</p>

¹⁶⁵ <https://www.youtube.com/watch?v=xSa5oeLO5OE>

¹⁶⁶ <https://odin.tradoc.army.mil/Search/WEG/Rapier>

¹⁶⁷ https://www.sipri.org/sites/default/files/2017-11/siprireport_mapping_the_development_of_autonomy_in_weapon_systems_1117_1.pdf, p.37.

¹⁶⁸ <https://www.army-technology.com/projects/jernas>

¹⁶⁹ <https://www.army.mod.uk/equipment/artillery-and-air-defence/>

SeaRAM	
System manufacturer	Raytheon (US)
System users	US and Japan. ¹⁷⁰
System history	<p>The SeaRAM is a longer-range variant of the Block 1B Phalanx CIWS whose principal design innovation is that the 20mm M61A1 Vulcan Gatlin gun is replaced with eleven supersonic Rolling Airframe Missiles (RAM). Raytheon advertises this system as “combin[ing] the accuracy, extended range and agility of the RAM missile with the high resolution search-and-track sensor and reliable, quick-response of the Phalanx Block 1B system”.¹⁷¹ The SeaRAM is estimated to have a eight five per cent commonality with the Phalanx Block 1B.¹⁷² The use of RAM gives this system greater range supporting the “layered defense” of American warships: the use of different ranged air defence systems to intercept different aerial threats at different distances.¹⁷³</p> <p>Development of the SeaRam began in the 2000s and was first trialled on the Royal Navy destroyer <i>HMS York</i> in 2001.¹⁷⁴ The first SeaRam system was integrated onto the US Navy’s Littoral Combat ships in 2008 and onto US Navy destroyers in 2014.¹⁷⁵ In the latter case, the SeaRam was integrated onto Arleigh Burke-class destroyers based in the Spanish port of Rota to provide greater protection against the Russian cruise missile threat in the Mediterranean.¹⁷⁶</p> <p>In what one Raytheon employee described as “a major milestone”, the SeaRam completed its first live-fire exercise in August 2015.¹⁷⁷ The development and testing of the SeaRam has been connected to the American Navy’s strategy of “distributed lethality” which aims to better equip warships to fight “near-peer” naval adversaries by improving their defensive and offensive weapon capabilities.¹⁷⁸</p>
Maximum system range	Whilst the SeaRAM’s range is classified, it has been estimated at 9km. ¹⁷⁹
Target type	Raytheon, the lead contractor on the SeaRAM, markets this system as being designed to defend against “supersonic and subsonic threats including cruise missiles, drones and helicopters”. ¹⁸⁰ According to the MBDA, which manufactures the missile, the RAM provides “self-defence against Anti-Ship Missiles (ASM), helicopters, aircraft and surface targets”. ¹⁸¹
System updates and variants	NDA

¹⁷⁰ <https://www.navyrecognition.com/index.php/news/defence-news/2020/september/9048-japanese-navy-to-get-u-s-rolling-airframe-missiles-ram-block-2-tactical-missiles.html>

¹⁷¹ <https://www.raytheonmissilesanddefense.com/capabilities/products/searam-ship-defense-system>

¹⁷² <https://news.usni.org/2016/08/17/navy-studying-installing-searam-destroyers-ship-classes#more-21188>

¹⁷³ <https://nationalinterest.org/blog/the-buzz/the-us-navys-supersonic-searam-missile-system-could-be-game-18199>

¹⁷⁴ [http://www.defense-aerospace.com/article-view/release/2956/royal-navy-to-test-sea-ram-ship-defense-\(sept.-13\).html](http://www.defense-aerospace.com/article-view/release/2956/royal-navy-to-test-sea-ram-ship-defense-(sept.-13).html)

¹⁷⁵ https://missiledefenseadvocacy.org/defense-systems/searam-anti-ship-missile-defense-system/#_edn2

¹⁷⁶ <https://news.usni.org/2016/08/17/navy-studying-installing-searam-destroyers-ship-classes#more-21188>

¹⁷⁷ <http://investor.raytheon.com/node/24081/pdf>

¹⁷⁸ <https://nationalinterest.org/blog/the-buzz/the-us-navys-supersonic-searam-missile-system-could-be-game-18199>

¹⁷⁹ <https://missiledefenseadvocacy.org/defense-systems/searam-anti-ship-missile-defense-system/>

¹⁸⁰ <https://www.raytheonmissilesanddefense.com/capabilities/products/searam-ship-defense-system>

¹⁸¹ mbda-deutschland.de/wp-content/uploads/2018/03/RAM-e-18.pdf

<p>Automation and autonomy in critical functions</p>	<p>The US Navy Fact File on the system notes that the SeaRam “automatically detects, evaluates, tracks, engages, and performs kill assessment against [anti-ship missiles] and high speed aircraft threats in an extended self-defense battle space envelope around the ship”.¹⁸² Other analysts have described the SeaRam as having the capacity to “autonomously” detect and intercept aerial targets.¹⁸³</p>	
<p>Response time and simultaneous tracking capacity</p>	<p>Response time</p>	<p>Whilst an exact response time is unavailable from the existing open source data, the US Navy has described the SeaRam as a “[f]ast-reaction, detect-through-engage, missile weapon system”.¹⁸⁴</p>
	<p>Number of targets which can be simultaneously tracked/engaged</p>	<p>The RAM missile used as part of the SeaRam system is advertised as being designed to provide “high firepower to engage multiple threats simultaneously”.¹⁸⁵ In a May 2016 test, the SeaRam destroyed 2 supersonic missiles simultaneously.¹⁸⁶ The SeaRam’s ability to engage several targets simultaneously is noted by analysts to be a “key advantage”.¹⁸⁷</p>

¹⁸² https://www.navy.mil/navydata/fact_display.asp?cid=2100&tid=456&ct=2

¹⁸³ <https://www.paxforpeace.nl/publications/all-publications/where-to-draw-the-line#:~:text=Where%20to%20draw%20the%20line.with%20automated%20critical%20functions>, p.12.

¹⁸⁴ <https://www.navy.mil/Resources/Fact-Files/Display-FactFiles/Article/2167555/searam-close-in-weapon-system-ciws-anti-ship-missile-defense-system/>

¹⁸⁵ <https://www.raytheonmissilesanddefense.com/capabilities/products/ram-missile>

¹⁸⁶ <http://raytheon.mediaroom.com/2016-05-17-US-Navy-uses-Raytheons-SeaRAM-to-knock-out-complex-targets-in-at-sea-test>

¹⁸⁷ <https://nationalinterest.org/blog/the-buzz/the-us-navys-supersonic-searam-missile-system-could-be-game-18199>

Sea Wolf	
System manufacturer	BAE Systems (UK)
System users	The UK, Brazil, Chile, and Malaysia. ¹⁸⁸
System history	<p>The Sea Wolf is a short-range missile defence system which shares some technologies and “similar operating parameters” with the Rapier system also included in this catalogue.¹⁸⁹ It was the principal short-range air defence system used by the Royal Navy’s Type 22 and Type 23 frigates, some of which were later sold to the Chilean Navy.¹⁹⁰ The Sea Wolf has been described as “offering an all-weather, day and night point defence capability against a wide variety of air threats such as fast sea-skimming and high-angle supersonic missiles and strike aircraft”.¹⁹¹</p> <p>The Sea Wolf’s development began in the 1960s and its initial Operational Capability was achieved in 1979. The Sea Wolf system is described as having “dramatically higher performance” than the Sea Cat which it replaced with greater range, greater speed and “a fully automated guidance system”.¹⁹² The Sea Wolf was combat tested during the Falklands War, a conflict in which it is suspected to have destroyed several Argentine aircraft.¹⁹³ It has been replaced in service by the Royal Navy with the Sea Ceptor system also included in this catalogue.¹⁹⁴</p>
Maximum system range	10km (GWS-26 missile) ¹⁹⁵
Target type	The system is listed as capable of defending ships against “aircraft and anti-ship missiles”. ¹⁹⁶
System updates and variants	Two variants of the Sea Wolf system were developed: the original GWS-25 conventionally launched variant and the longer range GWS-26 Mod 1 Vertical Launch Seawolf variant. ¹⁹⁷ Over the Sea Wolf’s service history, improvements were made to the missiles used in both variants of the system. In 2003, Block 2 missiles developed by MBDA were tested “led[ing] to significant improvements in the Seawolf missile’s performance”. ¹⁹⁸ Improvements were also made to the system’s availability and reliability, including the £300 million Seawolf In Service Support contract awarded to BAE Insite and MBDA in 2008. ¹⁹⁹

¹⁸⁸ <https://missiledefenseadvocacy.org/defense-systems/sea-wolf/>

¹⁸⁹

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/784305/archive_doctrine_uk_joint_air_defence_jwp_3_63.pdf, p.2-9.

¹⁹⁰ <http://www.defense-aerospace.com/articles-view/release/3/71069/chilean-navy-orders-seawolf%2C-exocet-missiles.html>

¹⁹¹ <http://www.defense-aerospace.com/articles-view/release/3/96394/uk-mod-details-%C2%A3300m-contracts-for-seawolf-support.html>

¹⁹² <http://www.seaforces.org/wpnsys/SURFACE/Sea-Wolf-SAM.htm>

¹⁹³ <https://www.airspacemag.com/military-aviation/air-war-in-the-falklands-32214512/>

¹⁹⁴ <https://www.mbda-systems.com/press-releases/royal-navy-complete-first-class-firings-sea-ceptor-air-defence-system/>

¹⁹⁵ <https://missiledefenseadvocacy.org/defense-systems/sea-wolf/>

¹⁹⁶ <https://webarchive.nationalarchives.gov.uk/+/http://www.royalnavy.mod.uk/operations-and-support/surface-fleet/weapon-systems/sea-wolf/>

¹⁹⁷ <https://missiledefenseadvocacy.org/defense-systems/sea-wolf/>

¹⁹⁸ [http://www.defense-aerospace.com/article-view/release/26549/successful-test-firing-of-mbda-seawolf-2-\(oct.-2\).html](http://www.defense-aerospace.com/article-view/release/26549/successful-test-firing-of-mbda-seawolf-2-(oct.-2).html)

¹⁹⁹ <http://www.defense-aerospace.com/articles-view/release/3/96394/uk-mod-details-%C2%A3300m-contracts-for-seawolf-support.html>

<p>Automation and autonomy in critical functions</p>	<p>In a now archived Royal Navy factsheet, it is noted that “[t]he complete weapon system, including tracking radars and fire control computers, is entirely automatic in operation”.²⁰⁰ The Missile Defence Advocacy Alliance have described this system as being capable of “target[ing] and track[ing] enemy missiles automatically” thus “help[ing] the ship react faster and more accurately than a human operated system”.²⁰¹ Following an 2006 export order from Chile, MBDA described the Seawolf as a “fully automatic, fast reaction, high speed, warship point defence system”.²⁰²</p> <p>The Sea Wolf used the host ships existing radars for target detection. Once a target was identified, the “[t]arget data [was] processed by the ship's computers and when the system is live, targets are automatically assigned and engaged automatically”. The Missile Director based in the Operations Room could, however, overturn missile launch.²⁰³</p>	
<p>Response time and simultaneous tracking capacity</p>	<p>Response time</p>	<p>NDA</p>
	<p>Number of targets which can be simultaneously tracked/engaged</p>	<p>NDA</p>

²⁰⁰ <https://webarchive.nationalarchives.gov.uk/+/http://www.royalnavy.mod.uk/operations-and-support/surface-fleet/weapon-systems/sea-wolf/>

²⁰¹ <https://missiledefenseadvocacy.org/defense-systems/sea-wolf/>

²⁰² <http://www.defense-aerospace.com/articles-view/release/3/71069/chilean-navy-orders-seawolf%2C-exocet-missiles.html>

²⁰³ <http://www.seaforces.org/wpnsys/SURFACE/Sea-Wolf-SAM.htm>

Type 730 (H/PJ12)	
System manufacturer	713th Research Institute (China). ²⁰⁴
System users	China and Pakistan.
System history	<p>The Type 730 (H/PJ12) is a CIWS which entered service with the People's Liberation Army Navy (PLN) in 2003. Development of this system began in the 1990s, and some have speculated that its design was derived from the Samos CIWs which was tested by the French Navy but never entered service.²⁰⁵ Others have speculated that the Type 370s design was reverse-engineered from the Goalkeeper CIWS discussed elsewhere in this catalogue.²⁰⁶</p> <p>The Type 730 is armed with a 30mm gatling gun and operates with a dedicated fire-control radar and optronic sensor.²⁰⁷ It is “currently fitted on most front line Chinese Navy surface combatants: Type 052, Type 052B, Type 052C, Type 052D, Type 051C destroyers and Type 054A frigates”.²⁰⁸ An export variant of this system will also be installed on the 4 Type 054 A/P Frigates ordered by the Pakistani Navy.²⁰⁹</p>
Maximum system range	3km ²¹⁰
Target type	Anti-ship missiles, aircraft.
System updates and variants	<p>The LuDun-2000 is a ground variant of the naval Type-730 CIWS designed to protect the People's Liberation Army of China from low-altitude threats including cruise missiles and UAV.²¹¹ Both gun and missiles variants of the LuDun-2000 have been developed.²¹² This variant was first showcased in 2005 and has been compared by some analysts to the land variant of the Phalanx CIWS, the Centurion.²¹³</p> <p>A missile equipped variant of the Type 730 – the Type 730C – was advertised by the China Shipbuilding Trading Company at the IDEX-NAVDEX defence expo held in Abu Dhabi, 2017. According to reports, this variant is armed with both the Type 730s seven-barrelled 30 mm Gatling gun and 6 FL-3000N missiles.²¹⁴</p>

²⁰⁴ <https://weaponsystems.net/system/538-30mm+Type+730>

²⁰⁵ <https://www.navyrecognition.com/index.php/news/defence-news/year-2013-news/march-2013-navy-world-naval-forces-maritime-industry-technology-news/951-chinese-navy-liaoning-aircraft-carriers-hpj-14-type-1130-new-generation-ciws-.html>

²⁰⁶ <https://www.afcea.org/content/china%E2%80%99s-navy-deploys%E2%80%A8-three-tier-defensive-weapons>

²⁰⁷ <https://www.navyrecognition.com/index.php/news/defence-news/year-2013-news/march-2013-navy-world-naval-forces-maritime-industry-technology-news/951-chinese-navy-liaoning-aircraft-carriers-hpj-14-type-1130-new-generation-ciws-.html>

²⁰⁸ <https://www.navyrecognition.com/index.php/news/defence-news/year-2013-news/march-2013-navy-world-naval-forces-maritime-industry-technology-news/951-chinese-navy-liaoning-aircraft-carriers-hpj-14-type-1130-new-generation-ciws-.html>

²⁰⁹ <https://www.navalnews.com/naval-news/2020/12/type-054-a-p-frigate-for-pakistan-navy-to-feature-new-radar-configuration/>

²¹⁰ <https://weaponsystems.net/system/538-30mm+Type+730>

²¹¹ https://www.armyrecognition.com/china_artillery_vehicles_and_weapon_systems_uk/ld2000_ludun-2000_ground-based_air_defense_close-in_weapon_system_technical_data_sheet_specifications_pictures_video_12808161.html

²¹² https://www.armyrecognition.com/china_artillery_vehicles_and_weapon_systems_uk/ld2000_ludun-2000_ground-based_air_defense_close-in_weapon_system_technical_data_sheet_specifications_pictures_video_12808161.html

²¹³ <http://www.army-guide.com/eng/product4174.html>

²¹⁴ <https://www.navyrecognition.com/index.php/news/naval-exhibitions/2017-archives/navdex-2017-show-daily-news/4970-china-s-cssc-unveiled-the-type-730c-dual-gun-and-missile-ciws.html>

	The Type 1130 - H/PJ-11 - is a “third generation” CIWS designed to replace the Type 370. It “appears to be an evolution of Type 730” with a faster rate of fire and greater ammunition holding capacity. ²¹⁵ The Type 1130 CIWS has been installed on the Chinese aircraft carrier <i>Liaoning</i> and newer Type 054A class Guided Missile Frigates. ²¹⁶ It is also expected to be installed on the Type 055 class of destroyers. ²¹⁷	
Automation and autonomy in critical functions	Little information is available from open-source material regarding the integration of automation and autonomy into the critical functions of the Type 370. In principal however, it is likely to be comparable to the integration of automation and autonomy into the critical functions of other CIWS examined in this catalogue.	
Response time and simultaneous tracking capacity	Response time	Whilst the Type 370’s response time appears to be unknown, the LuDun-2000’s variants response time has been reported as being between 9-10 seconds. ²¹⁸ The Type 730C variant has a reported response time of less than 7 seconds. ²¹⁹
	Number of targets which can be simultaneously tracked/engaged	The Type 370’s LuDun-2000 variant is reportedly capable of tracking up to 48 targets simultaneously. ²²⁰ The Type 730C variant is reportedly capable of tracking up to 32 targets simultaneously. ²²¹

²¹⁵ <https://www.navyrecognition.com/index.php/news/defence-news/year-2013-news/march-2013-navy-world-naval-forces-maritime-industry-technology-news/951-chinese-navy-liaoning-aircraft-carriers-hpj-14-type-1130-new-generation-ciws-.html>

²¹⁶ <https://www.navyrecognition.com/index.php/news/defence-news/year-2015-news/january-2015-navy-naval-forces-defense-industry-technology-maritime-security-global-news/2342-chinese-navy-plan-commissioned-its-first-upgraded-type-054a-frigate-with-new-hpj-11-ciws.html>

²¹⁷ <https://www.navyrecognition.com/index.php/news/defence-news/year-2013-news/march-2013-navy-world-naval-forces-maritime-industry-technology-news/951-chinese-navy-liaoning-aircraft-carriers-hpj-14-type-1130-new-generation-ciws-.html>

²¹⁸ https://www.armyrecognition.com/china_artillery_vehicles_and_weapon_systems_uk/ld2000_ludun-2000_ground-based_air_defense_close-in_weapon_system_technical_data_sheet_specifications_pictures_video_12808161.html

²¹⁹ <https://www.navyrecognition.com/index.php/news/naval-exhibitions/2017-archives/navdex-2017-show-daily-news/4970-china-s-cssc-unveiled-the-type-730c-dual-gun-and-missile-ciws.html>

²²⁰ https://www.armyrecognition.com/china_artillery_vehicles_and_weapon_systems_uk/ld2000_ludun-2000_ground-based_air_defense_close-in_weapon_system_technical_data_sheet_specifications_pictures_video_12808161.html

²²¹ <https://www.navyrecognition.com/index.php/news/naval-exhibitions/2017-archives/navdex-2017-show-daily-news/4970-china-s-cssc-unveiled-the-type-730c-dual-gun-and-missile-ciws.html>

AREA DEFENCE SYSTEMS

BAMSE SRSAM	
System manufacturer	Saab (Sweden)
System users	Sweden
System history	<p>Saab advertises the BAMSE SRSAM (Short-Range Surface-To-Air Missile) as being “one of few systems in the world today that is developed and optimised as a dedicated Ground-Based Air Defence (GBAD) missile system”.²²² The system can be configured to include 4 BAMSE Missile Control Centres, a Surveillance and Control Centre and a GIRAFFE AMB surveillance radar.²²³ The system was “developed to have high redundancy where every single missile launcher has the capability to combat targets without any connection to an external information source or higher command”.²²⁴ Each Missile Control Centre mounts six missile launchers, and can be operated by up to two crewmen.²²⁵ The BAMSE SRSAM can be deployed either independently or as part of a larger integrated air defence network.²²⁶</p> <p>Development of the BAMSE SRSAM began during the 1990s, and Bofors Missiles and Ericsson were contracted to begin fully developing the system in 1993.²²⁷ The BAMSE SRSAM began production in 2000, and the first system entered service with the Swedish Army in 2008.²²⁸ In July 2019, Sweden deployed a BAMSE SRSAM system to the Baltic island of Gotland.²²⁹ As explained by Sweden’s Supreme Commander Micael Bydén: “[t]hrough its geographical location the island provides essential military advantages in regards to protection and control of shipping, air control over the Baltic Sea and the ability to place military units and weapons systems”.²³⁰</p> <p>Although at time of writing the BAMSE has not secured any export orders, Saab has cooperated with the Indian vehicle manufacturer Ashok Leyland to compete for the Indian Army’s Short Range Surface to Air Missile air defence programme.²³¹</p>
Maximum system range	20km ²³²
Target type	Aircraft, cruise missiles, precision guided munitions and UAV. ²³³
System updates and variants	NDA

²²² <http://saabfeiting.com/index-111.html>

²²³ <https://www.youtube.com/watch?v=xMzqACmpqS8>

²²⁴ <https://nhmilitary.weebly.com/air-defence-short-range-bamse-srsam.html>

²²⁵ <https://www.ainonline.com/aviation-news/defense/2009-11-14/saab-aims-bamse-gulf-region>

²²⁶ <https://www.saab.com/markets/india/stories/2015/bamse-srsam--for-unjammable-missile-guidance>

²²⁷ <https://www.army-technology.com/projects/bamse/>

²²⁸ <https://www.army-technology.com/projects/bamse/>

²²⁹ <http://www.defense-aerospace.com/cgi-bin/client/modele.pl?shop=dae&modele=release&prod=204018&cat=3>

²³⁰ <https://www.thelocal.se/20190701/sweden-boosts-gotland-air-missile-defence-quick-solution>

²³¹ https://defense-update.com/20140205_saab-group-ashok-leyland-team-offer-bamse-air-defense-indias-srsam.html

²³² <http://saabfeiting.com/index-111.html>

²³³ <http://saabfeiting.com/index-111.html>

Automation and autonomy in critical functions	Open source data reveals little about the integration of automation and autonomy into the critical functions of this system.	
Response time and simultaneous tracking capacity	Response time	Jan Widerström, Country Head and Chairman of Saab India Technologies Pvt Ltd, has noted that “the BAMSE SRSAM system has a very short reaction time - it is just a matter of seconds from first detection in the GIRAFFE AMB until the missile is in the air”. ²³⁴
	Number of targets which can be simultaneously tracked/engaged	Two BAMSE missiles can reportedly be launched simultaneously if targeted within the same area. ²³⁵ This systems Giraffe AMB radar is reportedly capable of tracking up to 150 targets. ²³⁶

²³⁴ <https://www.saab.com/markets/india/stories/2017/bamse-srsam-an-air-defence-system-with-unique-capabilities>

²³⁵ <https://www.ainonline.com/aviation-news/defense/2009-11-14/saab-aims-bamse-gulf-region>

²³⁶ <https://www.ainonline.com/aviation-news/defense/2009-11-14/saab-aims-bamse-gulf-region>

Buk-M2	
System manufacturer	Almaz-Antey (Russia)
System users	Russia, Algeria, Azerbaijan, Belarus, China, Egypt, Georgia, India, Iran, Kazakhstan, North Korea, Pakistan, Syria, Ukraine, and Venezuela. ²³⁷
System history	<p>The Buk M2 – NATO codename SA-17 Grizzly – is a medium-range air defense system manufactured by Almaz-Antey for the Russian military and the global export market. The Buk-M2E – an export variant of the system – is advertised by Rosoboronexport as offering “air defense of troops (military facilities) in various types of military operations, administrative and industrial facilities and territories of the country”.²³⁸ A typical Buk system is made up of three component parts: “an armored vehicle with a large radar device for target acquisition; the command vehicle, where there are monitors from which the battery is controlled; and finally, one or more mobile launching pads with four missiles each”.²³⁹</p> <p>The Buk M2 is a modernized variant of the Buk-M1 (NATO codename SA-11 Gadfly) which was designed for the Soviet military during the 1970s.²⁴⁰ During the 1990s, development work began on an upgraded Buk variant with more advanced radar, missile and countermeasure technologies.²⁴¹ Due to financial pressures however, this ‘Buk-M2’, as it was then called, could not enter mass production. Instead, an interim modernisation of the Buk M1 was proposed and designated the Buk-M1-2.²⁴² The Buk-M1-2 entered Russian military service in 1997, and was armed with the new 9M317 missile.²⁴³ When coupled with its radar, the Buk-M1-2’s ability to intercept “complex ... low-flying targets” including cruise missiles was “significantly expanded”.²⁴⁴ Research and development on the Buk-M2 continued into the following decade, with the system entering service in 2008.²⁴⁵ One impetus for the Buk-M2’s development was to defend against “[t]he possibility of sudden intense attacks launched from unmanned aircraft land and subtle precision and high-speed weapons”, and thus the system had a focus on “counter saturation air attack”.²⁴⁶</p> <p>A report authored by an international investigation team under the direction of the Dutch Safety Board established that a Buk air defence system (either Buk M1 or Buk M1-2) was responsible for the destruction of Malaysia Airlines Flight 17 over Eastern Ukraine in July 2014.²⁴⁷</p>

²³⁷ <https://odin.tradoc.army.mil/Search/WEG/buk>

²³⁸ <http://roe.ru/eng/catalog/air-defence-systems/air-defense-systems-and-mounts/%22Buk-M2E%22%20%289K317E%29/>

²³⁹ <https://www.spiegel.de/international/world/a-deadly-error-with-global-consequences-shooting-down-flight-mf17-a-982114.html>

²⁴⁰ https://www.armyrecognition.com/russia_russian_missile_system_vehicle_uk/9k37_buk-m1_sa-11_gadfly_technical_data_sheet_specifications_information_description_pictures_photos.html

²⁴¹ <http://www.ausairpower.net/APA-9K37-Buk.html>;

https://www.armyrecognition.com/russia_russian_missile_system_vehicle_uk/sa-17_grizzly_buk-m2_9a317e_missile_technical_data_sheet_specifications_description_pictures.html

²⁴² <https://en.missilery.info/missile/buk-2m>

²⁴³ <https://en.missilery.info/missile/bukm1-2>

²⁴⁴ <https://en.missilery.info/missile/bukm1-2>

²⁴⁵ <https://en.missilery.info/missile/buk-2m>

²⁴⁶ <https://odin.tradoc.army.mil/Search/WEG/buk>

²⁴⁷ <https://www.onderzoekraad.nl/en/page/3546/crash-mh17-17-july-2014>.

Maximum system range	45km against “aerial targets”. ²⁴⁸
Target type	Rosoboronexport advertises the Buk-M2E as being “designed to defeat strategic and tactical airplanes, helicopters including while hovering, cruise missiles and other aerodynamic aircraft across the entire scope of their employment, tactical ballistic and air-launched missiles, and guided bombs”. ²⁴⁹
System updates and variants	<p>The earliest Buk variant – the Buk-M1 – was first operational with the Soviet Army in 1980.²⁵⁰ Thereafter, as discussed above, its baseline capabilities have been improved through multiple system upgrades including the Buk M1-2 and Buk M2.</p> <p>A third Buk variant is also in development: the Buk M3 Viking developed by Almaz-Antey. According to Rosoboronexport’s Deputy Director General Sergey Ladygin, the export variant of this system will “preserve the best characteristics of the famous line of the ‘Buk’ air defence missile such as force and infrastructure protection from present-day and future air assault weapons in conditions of radio-electronic countermeasures and firing”.²⁵¹ Its range will be one and a half times greater than the Buk-M2’s, and it will be capable of engaging a greater number of targets simultaneously (36 up from 24).²⁵² Like the Buk M2, the Buk M3 will be designed to intercept cruise missiles, stealth aircraft, and precision guided munitions amongst other targets.²⁵³ Tests on the Buk-M3 were conducted in southern Russia during June 2016, with a planned in-service date later in the year.²⁵⁴</p>
Automation and autonomy in critical functions	<p>As with other air defence systems, Buk variants can operate in automatic and manual modes.²⁵⁵ According to reports, the Buk-M3 “system is capable of automatically classifying targets such as helicopters, fixed-wing aircraft, cruise missiles, balloons, and unmanned aerial vehicles (UAVs) and can produce bearing data on different jamming sources”and “features an automated mobile command-and-control battle management station”.²⁵⁶</p> <p>The level of meaningful human control exercised in the context of the Malaysia Airlines Flight 17 disaster remains uncertain. According to some analysts, “[t]he systems may have been operated by amateurs and were in semi-automatic mode”.²⁵⁷ Other reports point to different capabilities and the inclusion of automated and autonomous features: “[o]n the screen there would be a target identified using a symbol and the Buk would do the rest.</p>

²⁴⁸ <http://roe.ru/eng/catalog/air-defence-systems/air-defense-systems-and-mounts/%22Buk-M2E%22%20%289K317E%29/>

²⁴⁹ <http://roe.ru/eng/catalog/air-defence-systems/air-defense-systems-and-mounts/%22Buk-M2E%22%20%289K317E%29/>

²⁵⁰ <http://www.military-today.com/missiles/buk.htm>

²⁵¹

https://www.defenseworld.net/feature/23/Russian_Buk_M3_Viking_Defense_Missile_System_Has_Enhanced_Features#.X-9Ch9j7Tcf

²⁵²

https://www.defenseworld.net/feature/23/Russian_Buk_M3_Viking_Defense_Missile_System_Has_Enhanced_Features#.X-9Ch9j7Tcf

²⁵³

https://www.armyrecognition.com/december_2018_global_defense_security_army_news_industry/russia_unveils_viking_export_version_of_buk-m3_air_defense_missile_system.html

²⁵⁴ <https://tass.com/defense/884398>

²⁵⁵ <https://www.globalsecurity.org/military/world/russia/buk-m3.htm>

²⁵⁶ <https://www.janes.com/defence-news/news-detail/belarus-unveils-buk-mb3k-sam-system>

²⁵⁷ <https://www.spiegel.de/international/world/a-deadly-error-with-global-consequences-shooting-down-flight-mf17-a-982114.html>

	<p>[...] This happens at such speeds that a human couldn't control it. It's all automatic after the launch starts".²⁵⁸ In a September 2016 BBC news segment, Lieutenant Colonel Sergey Leshchuk of the Ukrainian Air Force described the Buk air defence system as being capable of engaging six different targets within 90 seconds.²⁵⁹ Whilst the Buk system had an automatic friend/foe identification system, it came down to the "expertise and experience" of the operator to determine whether non-identified planes were civilian or military in nature.²⁶⁰</p>	
<p>Response time and simultaneous tracking capacity</p>	<p>Response time</p>	<p>10-12 seconds.²⁶¹</p>
	<p>Number of targets which can be simultaneously tracked/engaged</p>	<p>According to Rosoboronexport, when operating in "its full capacity", the Buk-M2E "provides for simultaneous engagement of 24 airborne targets".²⁶²</p>

²⁵⁸ <http://www.lexisnexis.com/hottopics/lnacademic>

²⁵⁹ <https://www.youtube.com/watch?v=PlcmziopqZA>

²⁶⁰ <https://www.youtube.com/watch?v=PlcmziopqZA>; <https://www.businessinsider.com/the-flaw-in-the-buk-missile-system-2014-7?r=US&IR=T>

²⁶¹ <http://roe.ru/eng/catalog/air-defence-systems/air-defense-systems-and-mounts/%22Buk-M2E%22%20%289K317E%29/>

²⁶² <http://roe.ru/eng/catalog/air-defence-systems/air-defense-systems-and-mounts/%22Buk-M2E%22%20%289K317E%29/>

HQ-9	
System manufacturer	China Academy of Defence Technology (China)
System users	China, Algeria, Morocco, Turkmenistan, and Uzbekistan. ²⁶³
System history	<p>The Hong Qi-9 (HQ-9) is an air defence system principally operated by the Chinese People's Liberation Army (PLA). The HQ-9 has been described as the “backbone of the Chinese missile defense program”²⁶⁴ and as “the most advanced example of the third generation of China's anti-aircraft missile systems”.²⁶⁵ When operated by the PLA, a HQ-9 battery consists of a “command vehicle, six control vehicles, 6 targeting radar vehicles, 6 search-radar vehicles, 48 missile-launch vehicles, and 192 missiles; plus a positioning vehicle, a communications vehicle, a power supply vehicle and a support vehicle”.²⁶⁶</p> <p>Development of the HQ-9 system began during the 1980s and the first battery entered service around 1997.²⁶⁷ Its development was prompted by concerns about American advancements in precision guided munitions and stealth aircraft.²⁶⁸ Some of the HQ-9's initial design is speculated to have been derived from the Russian S-300 (SA-20) air defence system which China purchased during the early 1990s.²⁶⁹ Design elements are also speculated to have been reverse engineered from the American MIM-104 Patriot system.²⁷⁰ In this way, the HQ-9 has been described as “a hybrid design based on a Russian SA-20 but with radar, seeker head and C2 [command-and-control] elements heavily influenced by American and Israeli technology”.²⁷¹ According to one analyst the HQ-9 was “designed from the outset for hide, shoot and scoot operations”.²⁷²</p> <p>HQ-9 batteries have been deployed to the Woody Island in the contested Paracel Islands to bolster the PLA's anti-access/area denial strategy in the South China Sea.²⁷³</p>
Maximum system range	25km ²⁷⁴

²⁶³ https://www.armyrecognition.com/china_chinese_army_missile_systems_vehicles/hq-9_ground-to-air_medium_range_air_defense_missile_technical_data_sheet_specifications_pictures.html

²⁶⁴ <https://missiledefenseadvocacy.org/missile-threat-and-proliferation/todays-missile-threat/china/china-anti-access-area-denial/hq-9/>

²⁶⁵ <https://missilery.info/missile/hq-9>

²⁶⁶ https://www.armyrecognition.com/china_chinese_army_missile_systems_vehicles/hq-9_ground-to-air_medium_range_air_defense_missile_technical_data_sheet_specifications_pictures.html

²⁶⁷ <http://www.military-today.com/missiles/hq9.htm>

²⁶⁸ <https://missiledefenseadvocacy.org/missile-threat-and-proliferation/todays-missile-threat/china/china-anti-access-area-denial/hq-9/>

²⁶⁹ <https://www.deagel.com/Artillery%20Systems/HQ-9/a001834>; <https://missiledefenseadvocacy.org/missile-threat-and-proliferation/todays-missile-threat/china/china-anti-access-area-denial/hq-9/>

²⁷⁰ <https://www.deagel.com/Defensive%20Weapons/HQ-9/a001833#001>; <http://www.military-today.com/missiles/hq9.htm>; <https://www.globalsecurity.org/military/world/china/hq-9.htm>

²⁷¹ https://rusi.org/sites/default/files/20191118_iads_bronk_web_final.pdf, p.20.

²⁷² <http://www.ausairpower.net/APA-HQ-9-12-Battery-Radars.html>

²⁷³ <https://www.rand.org/blog/2016/03/beijing-ups-the-ante-in-south-china-sea-dispute-with.html>;

<https://www.dw.com/en/what-is-chinas-hq-9-air-defense-system-capable-of/a-19053690>

²⁷⁴ <https://missilery.info/missile/hq-9>

Target type	Aircraft, cruise missiles, tactical ballistic missiles, UAV. ²⁷⁵
System updates and variants	<p>Multiple variants of the HQ-9 have been developed. These include the:</p> <ul style="list-style-type: none"> • The HQ-9A, an upgraded variant of the HQ-9 which began development in the late 1990s and entered production in 2013.²⁷⁶ When compared to the baseline HQ-9, the HQ-9A is reported to have greater interception accuracy, longer range and improved electronics.²⁷⁷ • A naval variant known as the HHQ-9 introduced in 2004 and installed on the Type-052C class of Chinese Navy destroyers.²⁷⁸ • The <i>FT-2000</i>, a HQ-9 variant “fitted with an anti-radiation seeker and intended for engagements against AEW&C (airborne early warning and control)/AWACS (Airborne Warning and Control System) and stand-off jamming aircraft”.²⁷⁹ • An export variant known as the <i>FD-2000</i> (Fang Dun 2000) which is reported to include some minor electronic upgrades.²⁸⁰ The FD-2000 was first revealed at the Africa Aerospace and Defence Exhibition held at Cape Town in March 2009.²⁸¹ It has been described as “a third generation medium-and-high altitude, medium-and-long range air-defense system with the capability of carrying out all-weather air-defense operations”.²⁸² • A “much upgraded version of the HQ-9”²⁸³ known as the HQ-19 designed to intercept longer ranged ballistic missiles.²⁸⁴ Chinese defence sources have compared this variant to the American made THAAD system also discussed in this catalogue.²⁸⁵
Automation and autonomy in critical functions	As one analyst has noted, “[t]he PLA have not been overly generous in disclosing details of [the HQ-9’s] design”. ²⁸⁶ This also applies to the integration of automation and autonomy into this systems core features as little information is available from open-source material.

²⁷⁵ https://www.armyrecognition.com/china_chinese_army_missile_systems_vehicles/hq-9_ground-to-air_medium_range_air_defense_missile_technical_data_sheet_specifications_pictures.html#:~:text=The%20HQ%2D9%20is%20a,missiles%2C%20and%20tactical%20ballistic%20missiles.

²⁷⁶ <https://missiledefenseadvocacy.org/missile-threat-and-proliferation/todays-missile-threat/china/china-anti-access-area-denial/hq-9/>

²⁷⁷ <https://missiledefenseadvocacy.org/missile-threat-and-proliferation/todays-missile-threat/china/china-anti-access-area-denial/hq-9/>; <https://nationalinterest.org/blog/buzz/chinas-hq-9-vs-russias-s-300-air-defense-system-whats-difference-35777>

²⁷⁸ <https://weaponsystems.net/system/947-HHQ-9>

²⁷⁹ <http://www.ausairpower.net/APA-HQ-9-FD-FT-2000.html#mozTocId527286>

²⁸⁰ <https://missiledefenseadvocacy.org/missile-threat-and-proliferation/todays-missile-threat/china/china-anti-access-area-denial/hq-9/>

²⁸¹ <https://www.globalsecurity.org/military/world/china/hq-9.htm>

²⁸² https://www.defenseworld.net/news/9239/How_Does_The_Chinese_FD_2000_Fare_Against_Its_Foreign_Peers_#_X-hakdj7Tcc

²⁸³ <http://www.military-today.com/missiles/hq9.htm>

²⁸⁴ <https://www.deagel.com/Defensive%20Weapons/HQ-19/a003583>

²⁸⁵

https://www.armyrecognition.com/weapons_defence_industry_military_technology_uk/china_air_defense_missile_systems_are_a_main_threat_for_united_states.html

²⁸⁶ <http://www.ausairpower.net/APA-HQ-9-FD-FT-2000.html#mozTocId527286>

Response time and simultaneous tracking capacity	Response time	Chinese media sources estimate this system's response time at around 15 seconds. ²⁸⁷
	Number of targets which can be simultaneously tracked/engaged	This system can reportedly track up to 100 targets simultaneously. ²⁸⁸

²⁸⁷ <https://thediplomat.com/2014/05/why-turkey-may-not-buy-chinese-missile-systems-after-all/#:~:text=Chinese%20media%20sources%20also%20reported,of%20its%20targets%20in%20trials.>

²⁸⁸ <https://www.deagel.com/Artillery%20Systems/HQ-9/a001834>

KM-SAM (Cheongung)	
System manufacturer	Agency for Defense Development (South Korea)
System users	South Korea
System history	<p>The KM-SAM – also known as Cheongung (Iron Hawk) – is a medium-range Surface to Air Missile system designed by the South Korean Agency for Defense Development as a domestically designed replacement for the MIM-23 Hawk air defence system.²⁸⁹ According to one South Korean defence official: “[o]nce the Cheongung is deployed, it will be able to fill the gap caused by the aging Hawk missiles...and be helpful in reducing the defense budget by replacing imported missiles”.²⁹⁰</p> <p>In comparison to the MIM-23 Hawk, the KM-SAM has greater range, accuracy and a more capable electronic warfare capability.²⁹¹ A KM-SAM battery can be configured to include four launchers each containing eight missiles, a multifunctional radar and a Command and Control (C2) centre.²⁹² According to its manufacturer, it is designed to protect “major military and industrial facilities against enemy air attacks”.²⁹³</p> <p>The development of this system dubbed the "Korean Patriot"²⁹⁴ was prompted by heightened concerns about North Korea’s Scud and ballistic missile capabilities.²⁹⁵ Prior to the Cheongung’s development, South Korea’s two primary air defence systems – the MIM-23 Hawk and ex-German MIM-104 Patriots – were perceived to provide inadequate defence against such threats.²⁹⁶ The Cheongung’s development was completed by 2011, with production beginning in 2015.²⁹⁷ In November 2017, when the system was entering the final phase of its development,²⁹⁸ it completed its first live-fire mission destroying a mock target at a range of twenty-four miles.²⁹⁹ The Republic of Korea Air Force received the first of seven upgraded KM-SAM batteries in November 2020.³⁰⁰ The KM-SAM’s missiles and radar was designed with technical design support from Almaz-Antey of Russia, the</p>

²⁸⁹ <https://missiledefenseadvocacy.org/defense-systems/km-sam-cheolmai-2/>

²⁹⁰ <https://koreajoongangdaily.joins.com/news/article/article.aspx?aid=3007277&cloc=etc%7Cjad%7Cgooglenews>

²⁹¹ https://www.defenseworld.net/news/28064/South_Korea_to_Deploy_M_SAM_II_Air_Defence_in_Response_to_North___s_Latest_Missiles#.X-L8Vdj7Tcd

²⁹² https://www.defenseworld.net/news/28064/South_Korea_to_Deploy_M_SAM_II_Air_Defence_in_Response_to_North___s_Latest_Missiles#.X-L8Vdj7Tcd

²⁹³ <https://www.add.re.kr/board?menuId=MENU02826&siteId=SITE00003>

²⁹⁴

https://www.armyrecognition.com/april_2020_news_defense_global_security_army_industry/south_korea_army_received_f_irst_local-made_cheongung_km-sam_air_defense_missile_systems.html

²⁹⁵ https://defense-update.com/20111217_cheongung_mrsam.html

²⁹⁶ https://defense-update.com/20111217_cheongung_mrsam.html

²⁹⁷

https://www.armyrecognition.com/april_2020_news_defense_global_security_army_industry/south_korea_army_received_f_irst_local-made_cheongung_km-sam_air_defense_missile_systems.html; <https://www.janes.com/defence-news/news-detail/rokaf-receives-first-cheongung-ii-m-sam-battery>

²⁹⁸ <http://www.koreaherald.com/view.php?ud=20170416000054>

²⁹⁹ <https://defence-blog.com/news/army/s-koreas-air-defense-systems-accidentally-fires-anti-aircraft-missile.html>

³⁰⁰

https://www.armyrecognition.com/april_2020_news_defense_global_security_army_industry/south_korea_army_received_f_irst_local-made_cheongung_km-sam_air_defense_missile_systems.html

	manufacturer of the S-400 Triumpf and S-500 Prometey air defence systems also included in this catalogue. ³⁰¹	
Maximum system range	40km (KM-SAM Missile) ³⁰²	
Target type	Aircraft, ballistic missiles. ³⁰³	
System updates and variants	<p>The Cheongung system’s design will reportedly inform the development of future South Korean air defence systems. Speaking in 2020, one Defence Acquisition Program Administration official noted: “[b]y succeeding in developing a system to intercept ballistic missiles based on the radar technology additionally secured in the process of developing Cheongung, we have established a base to build a Korean-style missile defense system”.³⁰⁴</p> <p>A naval variant of this system – the Cheongung III – is also reportedly in the conceptual phase of development for service with the South Korean Navy.³⁰⁵</p>	
Automation and autonomy in critical functions	Little information is available from open source materials regarding the integration of automation and autonomy into the critical functions of the Cheongung. According to Lignex, a defence company involved in the KM-SAM’s development however, “its single radar can attack multiple targets at once, requiring only a small number of people for operation”. ³⁰⁶	
Response time and simultaneous tracking capacity	Response time	NDA
	Number of targets which can be simultaneously tracked/engaged	The KM-SAM is reportedly capable of engaging up to 6 targets simultaneously. ³⁰⁷

³⁰¹

https://www.defenseworld.net/news/28064/South_Korea_to_Deploy_M_SAM_II_Air_Defence_in_Response_to_North___s_Latest_Missiles#.X-L8Vdj7Tcd

³⁰² <https://missiledefenseadvocacy.org/defense-systems/km-sam-cheolmai-2/>

³⁰³ <https://missiledefenseadvocacy.org/defense-systems/km-sam-cheolmai-2/>

³⁰⁴ <https://dfnc.ru/en/world-news/s-korea-completes-the-delivery-of-cheongung-missile-system/>

³⁰⁵ <https://www.navalnews.com/naval-news/2020/05/south-koreas-mid-term-defense-procurement-plan-largely-unaffected-by-covid-19-crisis/>

³⁰⁶ https://www.lignex1.com/eng/product/product01_01.jsp

³⁰⁷ <https://missiledefenseadvocacy.org/defense-systems/km-sam-cheolmai-2/>

MIM-104 Patriot	
System manufacturer	Raytheon (US)
System users	The US, Germany, Greece, Israel, Japan, Kuwait, the Netherlands, Saudi Arabia, South Korea, Poland, Sweden, Qatar, Romania, Spain, Taiwan, and the UAE. ³⁰⁸
System history	<p>The MIM-104 “Phased Array Tracking Radar to Intercept on Target” (Patriot)³⁰⁹ system is a surface-to-air air defence system. It is described by the Missile Defence Agency as “[p]rovid[ing] simultaneous air and missile defense capabilities as the Lower Tier element in defense of U.S. deployed forces and allies”.³¹⁰</p> <p>Development on the SAM-D programme, as it was then called, began in 1976 and was designed to replace the Nike Hercules and the MIM-23 Hawk air defence systems. The first Patriot system was declared fully operational by the US Army, its principal user, in 1985.³¹¹ Shortly thereafter, the system rose to international prominence during Operation Desert Storm when it was deployed to Israel and Saudi Arabia to protect against Iraqi SCUD missile attacks.³¹² The systems performance during this conflict is widely debated. An upgraded variant of the Patriot system - PAC-3 - was deployed to Kuwait during the 2003 invasion of Iraq and intercepted several Iraqi surface-to-surface missiles.³¹³ During this conflict, a MIM-104 Patriot systems was involved in two fratricidal engagements which destroyed a RAF Tornado fighter jet (24 March 2003) and a US Navy F-18 fighter jet (2 April 2003), killing three crewmembers in total.³¹⁴ There was a further close-call friendly fire incident on 25 March 2003 when a Patriot battery locked onto an US Air Force F-16. In this case, the pilot “was alerted to the fact that he had been targeted by radar” and launched a counter-attack that destroyed the Patriot battery.³¹⁵</p> <p>The US has operated Patriot systems in South Korea since 1994 to protect against possible North Korean missile attacks.³¹⁶ Between January 2013 and the end of 2015, five NATO Patriot batteries were deployed to Turkey to help defend against possible ballistic missile attacks from Syria. The UAE and Saudi Arabia have also deployed variants of the Patriot system to defend against aerial attacks from Houthi rebels fighting in Yemen.³¹⁷</p>
Maximum system range	150km ³¹⁸
Target type	Aircraft, short range ballistic missiles, cruise missiles, UAV. ³¹⁹

³⁰⁸ <https://www.army-technology.com/projects/patriot/>

³⁰⁹ https://www.nato.int/nato_static_fl2014/assets/pdf/pdf_2015_05/20150508_1505-Factsheet-PATRIOT_en.pdf

³¹⁰ <https://www.mda.mil/global/documents/pdf/pac3.pdf>

³¹¹ <https://missilethreat.csis.org/system/patriot/>

³¹² <https://missilethreat.csis.org/system/patriot/>; <https://missilethreat.csis.org/system/patriot/>

³¹³ <https://www.army-technology.com/projects/patriot/>

³¹⁴ <https://dsb.cto.mil/reports/2000s/ADA435837.pdf>, p.2.

³¹⁵ https://www.theregister.co.uk/2004/05/20/patriot_missile/.

³¹⁶ <https://missiledefenseadvocacy.org/defense-systems/patriot-missile-defense-system/>

³¹⁷ <https://missiledefenseadvocacy.org/defense-systems/patriot-missile-defense-system/>

³¹⁸ https://www.nato.int/nato_static_fl2014/assets/pdf/pdf_2015_05/20150508_1505-Factsheet-PATRIOT_en.pdf

³¹⁹ <https://www.raytheonmissilesanddefense.com/capabilities/products/global-patriot-solutions;>
<https://s3.amazonaws.com/files.cnas.org/documents/CNAS-Report-EthicalAutonomy5-PatriotWars-FINAL.pdf>, p.5.

<p>System updates and variants</p>	<p>According to the system’s manufacturer Raytheon, “[e]ach and every time Patriot is tested or live fired, engineers uncover new ways to further improve or enhance the system”.³²⁰ To this end, Raytheon claim to have “continually embraced new technologies to stay ahead of evolving threats”.³²¹ For example, upgrades to the Patriot system’s software made during the late 1980s enabled it to track and intercept short-range ballistic missiles (Patriot PAC-1 upgrades).³²² This anti-ballistic missile capability is reported to have required a greater level of automation because “[t]he nuts and bolts of the ballistic missile engagement process are too complex and time-limited for direct, in-the-loop human participation”.³²³</p> <p>A series of different Patriot missile variants have also been developed, with the most recent being the PAC-3: “a high velocity interceptor that defeats incoming targets by direct, body-to-body impact”.³²⁴</p>	
<p>Automation and autonomy in critical functions</p>	<p>Raytheon press releases from 2005 described the Patriot as having “automated operations - including man-in-the-loop (human) override” as a key feature.³²⁵ The CSIS Missile Defence Project describe the Patriot system as being “nearly autonomous, with only the final launch decision requiring human interaction”. The AN/MSQ-104 Engagement Control Station – “essentially the brain of the Patriot system” – is the only crewed part of the Patriot and is operated by three people.³²⁶ According to the BBC, the Patriot system “can be automated, although an operator is able to override it”.³²⁷ Others have labelled the Patriot as an example of “human-supervised autonomous weapon systems”.³²⁸</p> <p>John Hawley, an expert who has both researched this system and been involved with its development, describes the Patriot as being “highly automated”.³²⁹ According to Hawley, the Patriot was one of the first systems operated by the US to be capable of “lethal autonomy” defined as a “system that is capable of applying lethal force with little or minimal direct human oversight”.³³⁰ When operating in automatic mode, Hawley describes the Patriot system as being capable of “the conduct of near-autonomous operations”.³³¹</p>	
<p>Response time and simultaneous tracking capacity</p>	<p>Response time</p>	<p>Whilst the authors were unable to find the exact response time for this system, according to a 2015 NATO factsheet, the Patriot system has a “short response time [and] the ability to engage multiple targets simultaneously”.³³²</p>

³²⁰ <https://www.raytheonmissilesanddefense.com/capabilities/products/global-patriot-solutions>

³²¹ <https://www.raytheonmissilesanddefense.com/capabilities/products/global-patriot-solutions>

³²² <https://missiledefenseadvocacy.org/defense-systems/patriot-missile-defense-system/>

³²³ <https://s3.amazonaws.com/files.cnas.org/documents/CNAS-Report-EthicalAutonomy5-PatriotWars-FINAL.pdf>, p.6.

³²⁴ https://www.armyrecognition.com/united_states_american_missile_system_vehicle_uk/patriot_mim-104_surface-to-air_defense_missile_data_sheet_specifications_information_description.html

³²⁵ <https://web.archive.org/web/20050826224850/http://www.raytheon.com/products/patriot/>

³²⁶ <https://missilethreat.csis.org/system/patriot/>

³²⁷ <https://www.bbc.co.uk/news/world-20594466>

³²⁸ https://www.files.ethz.ch/isn/188865/Ethical%20Autonomy%20Working%20Paper_021015_v02.pdf, p.12.

³²⁹ <https://s3.amazonaws.com/files.cnas.org/documents/CNAS-Report-EthicalAutonomy5-PatriotWars-FINAL.pdf>, p.1.

³³⁰ <https://s3.amazonaws.com/files.cnas.org/documents/CNAS-Report-EthicalAutonomy5-PatriotWars-FINAL.pdf>, p.4.

³³¹ <https://s3.us-east-1.amazonaws.com/files.cnas.org/documents/CNAS-Report-EthicalAutonomy5-PatriotWars-FINAL.pdf?mtime=20170106135013&focal=none>, p.6.

³³² https://www.nato.int/nato_static_fl2014/assets/pdf/pdf_2015_05/20150508_1505-Factsheet-PATRIOT_en.pdf

	Number of targets which can be simultaneously tracked/engaged	This system can reportedly “track up to 100 targets and can provide missile guidance data for up to nine missiles”. ³³³
--	---	--

³³³ <https://www.army-technology.com/projects/patriot/>

Iron Dome	
System manufacturer	Rafael Advanced Defense Systems and Israel Aerospace Industries (Israel)
System users	Israel and the US.
System history	<p>The Iron Dome is a mobile air defence system principally used by Israeli Defence forces “to defend populated areas and critical assets” from short and medium range artillery attacks and rockets.³³⁴ It has been described by Israeli officials as “a game-changer” capable of “determin[ing] within split seconds whether an incoming rocket is headed for an open space or a populated area—and saves its fire for the latter case”.³³⁵</p> <p>Development of the Iron Dome began in 2007, and the first battery entered service with the Israeli Air Force in 2011.³³⁶ In 2014, the American government finalised a co-production agreement with Israel to build elements of the Iron Dome system and gain access to its proprietary technologies.³³⁷ By 2020, the US had provided over \$1.5 billion in financial support for the Iron Dome programme.³³⁸ In August 2020, Raytheon Technologies and Rafael Advanced Defense Systems announced a joint venture to manufacture the Iron Dome in the US. As explained by one senior Raytheon employee: “[t]his will be the first Iron Dome all-up-round facility outside of Israel, and it will help the U.S. Department of Defense and allies across the globe obtain the system for defense of their service members and critical infrastructure”.³³⁹</p> <p>As of late 2020, Israeli defence forces operated ten Iron Dome batteries which each consist of three launchers armed with 20 Tamir missiles, a detection and tracking radar and a battle management and missiles control unit.³⁴⁰ Media reports describe the Iron Dome as operating in the following way:</p> <p style="padding-left: 40px;">A radar tracks the rocket as it is fired across the border into Israel, and then advanced software predicts the rocket's trajectory. The information it provides is used to guide Tamir interceptor missiles, which are fired from the ground to blow the rocket into harmless pieces in the sky.³⁴¹</p>
Maximum system range	70km (Tamir missile) ³⁴²
Target type	Rocket, artillery and mortar attacks.
System updates and variants	The C-Dome is a naval variant of the Iron Dome system which is designed to defend warships against saturation attack from aircraft, anti-ship missiles helicopters and UAV. ³⁴³ This variant was announced in October 2014 and

³³⁴ <https://www.raytheonmissilesanddefense.com/capabilities/products/irondome>

³³⁵ <https://embassies.gov.il/washington/NewsAndEvents/Pages/The-Iron-Dome-Military-Revolution.aspx>

³³⁶ <https://www.rafael.co.il/wp-content/uploads/2019/06/Multi-Mission-IRON-DOME-Brochure.pdf>

³³⁷ <https://fas.org/sgp/crs/mideast/RL33222.pdf>, p.16.

³³⁸ <https://fas.org/sgp/crs/mideast/RL33222.pdf>, p.16.

³³⁹ <https://www.defensenews.com/land/2020/08/03/raytheon-and-rafael-to-build-iron-dome-in-us/>

³⁴⁰ <https://fas.org/sgp/crs/mideast/RL33222.pdf>, p.13;

<https://www.raytheonmissilesanddefense.com/capabilities/products/irondome;>

https://odin.tradoc.army.mil/WEG/Asset/Iron_Dome_Israeli_Missile_Defense_System

³⁴¹ <https://www.theweek.co.uk/world-news/middle-east/59368/iron-dome-how-israels-missile-defence-system-works>

³⁴² <https://www.raytheonmissilesanddefense.com/capabilities/products/irondome>

³⁴³ https://www.youtube.com/watch?v=wZ3SGWdRobw&feature=emb_rel_pause

	<p>was declared operational in late 2017 after tests conducted using the Israeli Navy’s Saar 5-class corvette INS Lahav.³⁴⁴ According to media reporting, this variants “[r]eaction time is very short and enables automatic and semi-automatic engagements”.³⁴⁵ The C-Dome will be installed on Israel’s new SAAR–6 class of corvettes.³⁴⁶</p> <p>The SkyHunter is an American built variant of the Iron Dome system jointly developed by Raytheon and Rafael. It has been described as a “mobile all-weather air defense system designed to destroy short-range rockets and artillery shells fired from distances of 4 to 70 kilometers”.³⁴⁷ In 2019, the US Army decided to purchase two Iron Dome batteries as an interim move to strengthen its defences against artillery, cruise missile, and rocket attacks.³⁴⁸ According to one analyst, this “procurement is likely aimed at evaluation of the system as a force protection asset for the army to counter rocket and mortar fire as well as some classes of missiles”.³⁴⁹ The US Army received its first Iron Dome Battery in late 2020.³⁵⁰</p> <p>I-Dome is a mobile variant of the Iron Dome system designed to defend mobile units of the Israeli defence force and static installations from aerial attack.³⁵¹ The I-Dome “consists of a wheeled chassis launcher (6x6 truck chassis) with 10 Iron Dome interceptors, a radar, and a Battle Management & Control (BMC) operating station”.³⁵² According to Rafael CEO Pini Yungman, “[b]asically, we put a missile launcher, radar and a control system in the cab of a vehicle”.³⁵³ It is advertised as a “Dual Mission” system capable of both short range air defence and counter Mortar, Artillery, Rocket defence.³⁵⁴</p> <p>Media reports from early 2020 suggested that an upgraded version of the Iron Dome had been successfully tested. This variant would be capable of better responding to “evolving threats in the region” including small UAV, more agile rockets and cruise missiles.³⁵⁵</p>
<p>Automation and autonomy in critical functions</p>	<p>As with other air defence systems, the Iron Dome can reportedly operate in both automatic and manual modes.³⁵⁶ Early in the systems development, Israeli defence officials were reported as describing the Iron Dome as being “designed for man-in-the-loop as well as autonomous operations”. As this official continued: “[b]ut right now, our emphasis is on algorithms, not autonomy. Man-machine interface is the name of the game, because the more clever we make the interface, the more successful we’ll be in providing</p>

³⁴⁴ <https://defpost.com/israel-declares-naval-iron-dome-air-defense-system-operational/>

³⁴⁵ <https://www.navalnews.com/event-news/imdex-asia-2019/2019/05/imdex-2019-rafael-promotes-360-multi-layer-naval-defense-solutions/>

³⁴⁶ <https://www.navyrecognition.com/index.php/news/defence-news/2019/january/6729-c-dome-defense-system-to-be-extended-to-the-israeli-navy.html>

³⁴⁷ https://www.armyrecognition.com/ausa_2017_show_daily_news_tv_coverage_report/raytheon_skyhunter_us-certified_version_of_iron_dome_at_ausa_2017.html

³⁴⁸ <https://www.army-technology.com/news/us-army-confirms-iron-dome-air-defence-system-purchase/>

³⁴⁹ <https://www.army-technology.com/news/us-army-confirms-iron-dome-air-defence-system-purchase/>

³⁵⁰ <https://www.timesofisrael.com/us-army-receives-1st-of-2-iron-dome-batteries-doesnt-plan-to-buy-more/>

³⁵¹ <https://www.rafael.co.il/wp-content/uploads/2019/03/I-DOME-Brochure.pdf>

³⁵² <https://www.rafael.co.il/wp-content/uploads/2019/03/I-DOME-Brochure.pdf>

³⁵³ <https://www.timesofisrael.com/israel-unveils-portable-iron-dome-at-paris-air-show/>

³⁵⁴ <https://www.rafael.co.il/wp-content/uploads/2019/03/I-DOME-Brochure.pdf>

³⁵⁵ <https://www.thedrive.com/the-war-zone/31822/upgraded-israeli-iron-dome-defense-system-swats-down-100-percent-of-targets-in-tests>

³⁵⁶ <https://www.pbs.org/newshour/world/5-weapons-that-dont-need-a-human-to-pull-the-trigger>

operators and commanders the situational awareness they'll need to make very tough decisions...". To this end, Israeli defence officials noted that:

[o]ur approach cannot be based exclusively on man-in-the-loop, nor can it rely only on the opposite. Rather, we need to build an operational concept and a system that is flexible and situationally dependent.³⁵⁷

In an October 2020 news report discussing Defense Secretary Mark Esper's visit to Israel, the American Department of Defence presented the Iron Dome as always being operated with a 'man in the loop'. The system's automated features were also discussed:

There is an artificial intelligence function that analyzes incoming rounds and determines if people or facilities are in danger. If not, the AI would not recommend a shot.³⁵⁸

Whilst human operators may remain 'in the loop', as with other air defence systems, they are given only a short window of time to authorise interception. In March 2018, an Iron Dome system fired 3 missile salvos in response to heavy machinegun fire in the Gaza Strip.³⁵⁹ As the Commander of Israel's Air Defense Forces General Zvika Haimovich noted after this incident:

The system identified a launch toward Israel, toward the community of Zikim, which acted like a ballistic missile in every way. It was a serious threat... There was neither a human nor technical error... There was system over-sensitivity, and we had five seconds to decide. The moment something is launched from the ground toward Israeli territory, we consider that a threat... We are operating in a very complex environment in which there are mortars, missiles, rockets, machine guns and heavy machine guns, some of which are standard and some of which are not... Today, there are rockets that are fired like artillery shells and there are mortars that behave like missiles. Our enemies are learning and developing.³⁶⁰

To this end, Haimovich continued:

We want to maximize defense, and that carries a price. The cost is outside of military and operational considerations when it comes time to make a decision. Not only was there no human or technical error last night, but the forces acted with the utmost professionalism and will learn from the event.³⁶¹

As with the THAAD system also discussed in this catalogue, the Iron Dome has been described by analysts as being "fully autonomous in selecting and

³⁵⁷ <https://www.wired.com/2008/01/israel-thinking/>

³⁵⁸ <https://www.defense.gov/Explore/News/Article/Article/2400629/esper-sees-iron-dome-missile-defense-system-in-tel-aviv/>

³⁵⁹ <https://www.thedrive.com/the-war-zone/19651/too-sensitive-watch-iron-dome-accidentally-launch-11-interceptors-at-machine-gun-fire>

³⁶⁰ <https://www.thedrive.com/the-war-zone/19651/too-sensitive-watch-iron-dome-accidentally-launch-11-interceptors-at-machine-gun-fire>

³⁶¹ <https://www.ynetnews.com/articles/0,7340,L-5198507,00.html>

	attacking targets”. ³⁶² Others have described the Iron Dome as a “human-supervised autonomous system”. ³⁶³	
Response time and simultaneous tracking capacity	Response time	System manufacturer Rafael describe the Iron Dome as having a “[q]uick reaction time”. ³⁶⁴
	Number of targets which can be simultaneously tracked/engaged	According to Rafael, the Iron Dome “can handle multiple threats simultaneously and efficiently”. ³⁶⁵

³⁶² https://icrcndresourcecentre.org/wp-content/uploads/2017/11/4283_002_Autonomus-Weapon-Systems_WEB.pdf, p.31.

³⁶³ <https://scholarlycommons.law.case.edu/cgi/viewcontent.cgi?referer=https://www.google.co.uk/&httpsredir=1&article=1005&context=jil>, p.28.

³⁶⁴ https://www.rafael.co.il/worlds/air-missile-defense/short-range-air-missile-defense/?utm_source=google&utm_medium=cpc&utm_campaign=gsn

³⁶⁵ <https://www.rafael.co.il/wp-content/uploads/2019/06/Multi-Mission-IRON-DOME-Brochure.pdf>

Sea Ceptor	
System manufacturer	MBDA (Europe/UK)
System users	UK, Brazil, and New Zealand. ³⁶⁶
System history	<p>Like the Sky Sabre, the Sea Ceptor uses the supersonic Common Anti-Air Modular missile. MBDA advertise the system as providing “complete protection against all known and projected air targets”.³⁶⁷ The Sea Ceptor provides local area air defense for Royal Navy warships and it has been described as “an advanced air defense system that is designed to counterattack modern threats”.³⁶⁸</p> <p>The Sea Ceptor can be installed on warships of various sizes, including offshore patrol vessels.³⁶⁹ The Sea Ceptor system utilises “soft launch technology” which means that it can be installed at different positions on a warship “thereby reducing overall mass and onboard footprint characteristics”.³⁷⁰ In comparison to the Sea Wolf missile system which it replaces, the Sea Ceptor “is faster, has longer range, has a two-way data link and has a more advanced seeker, all of which enable the missile to intercept more challenging targets”.³⁷¹</p> <p>Development of the Sea Ceptor formally began in January 2012 when MBDA were awarded a £438 million demonstration contract to develop the system as a replacement for the Sea Wolf.³⁷² In September 2017, the system was successfully tested on the Type 23 frigate HMS Argyll,³⁷³ and it entered service in May 2018. The Sea Ceptor will be integrated onto the Royal Navy’s new Type 26 Global Combat Ship frigate as they replace the currently in-service Type 23 frigates.³⁷⁴</p>
Maximum system range	25km ³⁷⁵
Target type	According to the Royal Navy, the Sea Ceptor system is capable of engaging “airborne threats, including hostile combat jets, helicopters and other missiles”. ³⁷⁶
System updates and variants	NDA
Automation and autonomy in critical functions	Whilst little is publicly known about the integration of automation and autonomy into this systems critical features, it has been described by First Sea Lord Admiral Sir Philip Jones, “[t]he Sea Ceptor missile defence system represents a significant technological leap forward and a huge uplift to our warfighting capability”. ³⁷⁷

³⁶⁶ <https://missiledefenseadvocacy.org/defense-systems/sea-ceptor/>; <https://mbdainc.com/brazilian-navy-selects-mbdas-sea-ceptor-air-defense/>

³⁶⁷ <https://www.mbdainc.com/solutions-and-services/>

³⁶⁸ <https://missiledefenseadvocacy.org/defense-systems/sea-ceptor/>

³⁶⁹ <https://www.naval-technology.com/projects/sea-ceptor-missile-system/>

³⁷⁰ <https://mbdainc.com/brazilian-navy-selects-mbdas-sea-ceptor-air-defense/>

³⁷¹ <https://des.mod.uk/first-firings-sea-ceptor-air-defence-system/>

³⁷² <https://missiledefenseadvocacy.org/defense-systems/sea-ceptor/>

³⁷³ <https://des.mod.uk/first-firings-sea-ceptor-air-defence-system/>

³⁷⁴ <https://missiledefenseadvocacy.org/defense-systems/sea-ceptor/>

³⁷⁵ <https://www.mbdainc.com/solutions-and-services/>

³⁷⁶ <https://www.royalnavy.mod.uk/news-and-latest-activity/news/2018/may/24/180524-sea-ceptor-missile-system-enters-service>

³⁷⁷ <https://www.royalnavy.mod.uk/news-and-latest-activity/news/2018/may/24/180524-sea-ceptor-missile-system-enters-service>

<p>Response time and simultaneous tracking/engagement capacity</p>	<p>Response time</p>	<p>NDA</p>
	<p>Number of targets which can be simultaneously tracked/engaged</p>	<p>MBDA advertise the Sea Ceptor as having a “[h]igh rate of fire against multiple simultaneous targets”.³⁷⁸ The Sea Ceptor is also listed as providing “all-weather, night and day, 360° local area air defense coverage against multiple simultaneous targets including sea-skimming anti-ship missiles, helicopters and fast combat jets”.³⁷⁹ Some have estimated that the Sea Ceptor is capable of engaging up to eight targets simultaneously.³⁸⁰</p>

³⁷⁸ <https://www.mbda-systems.com/product/sea-ceptor/>

³⁷⁹ <https://mbdainc.com/brazilian-navy-selects-mbdas-sea-ceptor-air-defense/>

³⁸⁰ <https://www.naval-technology.com/features/camm-missile-uk/>

Sky Sabre	
System manufacturer	MBDA (Europe/UK) and Raphael (Israel)
System users	The UK
System history	<p>Like the Sea Ceptor system, the Sky Sabre – also known as the Land Ceptor – uses the Common Anti-air Modular Missile.³⁸¹ The Sky Sabre system consists of three components: (1) the Common Anti-air Modular Missile; (2) the SAAB Giraffe radar; and (3) the Rafael Modular, Integrated C4I Air and Missile Defense System.³⁸² The Sky Sabre has been described as a “truly integrated air defence system”³⁸³ and has been “developed to protect British troops on operations from aerial threats, including hostile combat aircraft and air-launched munitions”.³⁸⁴</p> <p>The Sky Sabre was developed in collaboration with the MBDA, and was selected to meet the Future Local Area Air Defence System requirement.³⁸⁵ In March 2018, the system was successfully tested at the Vidsel Test Range in Sweden.³⁸⁶ It has a significantly greater detection and interception range than the Rapier system which it replaces.³⁸⁷ The British Ministry of Defence have described the Sky Sabre as “a step change in the UK’s air defences, taking it from short to medium range capability”.³⁸⁸</p> <p>The system is set to enter service at some point in the early 2020s, and will be operated by the Royal Artillery.³⁸⁹ At least one Sky Sabre system will be deployed to the Falkland Islands.³⁹⁰ Its development has been presented as an important part of the recent shift in UK defence planning away from counterterrorism and counterinsurgency toward state-based threats such as Russia.³⁹¹</p>
Maximum system range	At least 25km ³⁹²
Target type	According to the Ministry of Defence, Sky Sabre is capable of engaging “aerial threats, including hostile combat aircraft and air-launched munitions”. ³⁹³
System updates and variants	NDA
Automation and autonomy in critical functions	Little is publicly known about the integration of automation and autonomy into the critical functions of the Sky Sabre system. It has been described as

³⁸¹ <https://www.gov.uk/government/news/british-armys-new-air-defence-missile-blasts-airborne-target-by-baltic-sea>

³⁸²

https://www.armyrecognition.com/weapons_defence_industry_military_technology_uk/british_army_unveils_its_new_sky_sabre_air_defense_missile_system.html

³⁸³ https://defence.nridigital.com/global_defence_technology_apr18/sky_sabre_inside_the_uks_missile_defence_system

³⁸⁴ <https://www.gov.uk/government/news/british-armys-new-air-defence-missile-blasts-airborne-target-by-baltic-sea>

³⁸⁵ https://defence.nridigital.com/global_defence_technology_apr18/sky_sabre_inside_the_uks_missile_defence_system

³⁸⁶ <https://www.mbdasystems.com/press-releases/land-ceptor-target-latest-success-mbdas-camm-interceptor/>

³⁸⁷ <https://www.army-technology.com/features/sky-sabre-inside-uks-missile-defence-system/>;

https://defence.nridigital.com/global_defence_technology_apr18/sky_sabre_inside_the_uks_missile_defence_system;

<https://www.mbdasystems.com/press-releases/land-ceptor-target-latest-success-mbdas-camm-interceptor/>

³⁸⁸ <https://www.army.mod.uk/news-and-events/news/2018/02/army-unveils-sky-sabre-air-defence-system/>

³⁸⁹ <https://www.gov.uk/government/news/british-armys-new-air-defence-missile-blasts-airborne-target-by-baltic-sea>

³⁹⁰ <https://www.defensenews.com/global/europe/2017/03/07/britain-beefs-up-defenses-in-the-falkland-islands/>

³⁹¹ <https://www.youtube.com/watch?v=XL1qjGL8fXI>

³⁹² <https://www.mbdasystems.com/product/camm/>

³⁹³ <https://www.gov.uk/government/news/british-armys-new-air-defence-missile-blasts-airborne-target-by-baltic-sea>

	<p>“a step change” in the UK’s air defence capabilities.³⁹⁴ In part, this is because it possesses “far greater battlefield awareness and intelligence than the current Rapier system”.³⁹⁵</p> <p>The Sky Saber’s command element – the Modular, Integrated C4I Air & Missile Defence System – has been described by its manufacturer as providing “end-to-end, highly automated air and missile protection, assessing and classifying hostile targets at any level of command”.³⁹⁶ The Giraffe radar is described by Saab as having “highly automated functions for planning, threat evaluation, weapon assignment and target distribution”. This helps “the system [be] able to handle multiple defended assets and various types of firing units”.³⁹⁷</p>	
<p>Response time and simultaneous tracking capacity</p>	<p>Response time</p>	<p>NDA</p>
	<p>Number of targets which can be simultaneously tracked/engaged</p>	<p>According to the British Ministry of Defence, this system can “defeat as many as eight different threats at once”.³⁹⁸</p>

³⁹⁴ <https://www.army.mod.uk/news-and-events/news/2018/02/army-unveils-sky-sabre-air-defence-system/>

³⁹⁵ <https://www.gov.uk/government/news/british-armys-new-air-defence-missile-blasts-airborne-target-by-baltic-sea>

³⁹⁶ <https://www.rafael.co.il/worlds/air-missile-defense/c41-air-missile-defense-system/>

³⁹⁷ <https://www.saab.com/products/giraffe-amb>

³⁹⁸ <https://www.army.mod.uk/news-and-events/news/2018/05/british-army-s-new-air-defence-system-completes-firing-trials/>

Spada 2000		
System manufacturer	MBDA (Europe/Italy)	
System users	Italy, Spain, Kuwait, and Pakistan. ³⁹⁹	
System history	<p>The Spada 2000 is a ground-based air defence system which is described by its manufacturer as offering “[e]nhanced all-weather air defence system for the protection of sensitive ground sites (air bases, ports, industrial plants, important buildings)”.⁴⁰⁰ This system can be configured to include: a detection centre consisting of a Search and Identification Radar and command centre; and up to four firing sections consisting of one-two missile launcher(s) per firing section.⁴⁰¹ The Spada 2000 is armed with Aspide 2000 semi-active missiles which are also used on the Skyguard and Skyguard El air defence systems.⁴⁰²</p> <p>The Spada 2000 is an upgraded variant of the Spada air defence system. It achieved initial operational capability in 2000.⁴⁰³ The Spada 2000 provides “significant operational and technological improvements, including increased firepower and range, and the capability of coordinating additional anti-air weapons”.⁴⁰⁴ As part of a \$475 million contract agreed in 2007, Pakistan purchased ten MBDA Spada 2000 batteries, radars and maintenance and testing facilities. This was to replace the Pakistan Air Force’s aging Crotale air defence systems.⁴⁰⁵</p>	
Maximum system range	20km (Aspide 2000 missile) ⁴⁰⁶	
Target type	Aircraft, cruise missiles, helicopters and UAV. ⁴⁰⁷	
System updates and variants	NDA	
Automation and autonomy in critical functions	The Spada 2000 has been described as a “highly automated” air defence system. ⁴⁰⁸ Its operations centre is crewed by two personnel, and “[t]he computer displays the air threat data in 3D coordinates”. ⁴⁰⁹ As explained by Army Technology, “[t]he system tracks, identifies and prioritises the targets and assigns the firing sections to the priority targets”. ⁴¹⁰	
Response time and simultaneous tracking capacity	Response time	Whilst this system’s exact response time is unknown, the Spada 2000 has been described as having a “quick reaction time”. ⁴¹¹
	Number of targets which can be simultaneously tracked/engaged	This system’s Selex Sistemi Integrati radar is reportedly capable of simultaneously tracking up to 100 targets. ⁴¹² According to its manufacturer, the Spada

³⁹⁹ <https://missiledefenseadvocacy.org/defense-systems/spada-2000/>

⁴⁰⁰ <https://www.mbda-systems.com/product/spada-2000/>

⁴⁰¹ <https://www.mbda-systems.com/product/spada-2000/>

⁴⁰² <https://www.mbda-systems.com/wp-content/uploads/2015/07/Press-release-2009-02-19-EN.pdf>

⁴⁰³ <https://www.deagel.com/Artillery%20Systems/Skyguard/a000653>

⁴⁰⁴ <https://www.army-technology.com/projects/spada/>

⁴⁰⁵ <https://quwa.org/2016/05/09/pakistan-italy-agree-strengthen-defence-ties/>

⁴⁰⁶ <https://www.mbda-systems.com/product/spada-2000/>

⁴⁰⁷ <https://www.mbda-systems.com/wp-content/uploads/2015/07/Press-release-2009-02-19-EN.pdf>

⁴⁰⁸ <https://www.army-technology.com/projects/spada/>

⁴⁰⁹ <https://www.army-technology.com/projects/spada/>

⁴¹⁰ <https://www.army-technology.com/projects/spada/>

⁴¹¹ <https://www.army-technology.com/projects/spada/>

⁴¹² <https://www.army-technology.com/projects/spada/>

		2000 is capable of engaging up to 4 targets simultaneously. ⁴¹³
--	--	--

⁴¹³ <https://www.mbda-systems.com/product/spada-2000/>

S-400 Triumph	
System manufacturer	Almaz-Antey (Russia)
System users	Russia, China, and Turkey. ⁴¹⁴ As part of a \$5 billion deal signed in October 2018, India also currently has five S-400 sets on order with an initial expected delivery date of sometime in 2021. ⁴¹⁵
System history	<p>The S-400 – NATO codenamed SA-21 Growler – is an advanced long range air defense system which has been compared to the American Patriot system in terms of its “mission set and capabilities”.⁴¹⁶ Defence analysts have described this system as “among the most advanced air defence systems available, on par with the best the West has to offer”.⁴¹⁷</p> <p>The S-400’s development began in the 1990s and the system entered service with the Russian military in April 2007.⁴¹⁸ The S-400 differs from the earlier S-300P and S-200 systems on the basis of its improved radar, software and missiles.⁴¹⁹ The S-400 system can be equipped with different missiles to intercept a range of different types of targets. These include the 48N6E3 which has an estimated range of 250km and the 40N6 which has a reported range of 400km. 9M96E and 9M96E2 missiles are reported to be used to intercept medium-range ballistic missiles, amongst other targets.⁴²⁰</p> <p>The S-400 has been deployed by the Russian military to Moscow, Kaliningrad, Syria and the Crimea amongst other sites.⁴²¹ In July 2019, Turkey was suspended from the F-35 Joint Strike Fighter project because of its decision to purchase the S-400 system.⁴²²</p>
Maximum system range	400km (40N6 missile) ⁴²³
Target type	Ballistic missiles, cruise missiles, aircraft, helicopters and UAV. ⁴²⁴
System updates and variants	Reports suggest that a naval version of the S-400 system is in development and, despite delays to the programme, may be installed on to the Russian Navy’s Kirov class nuclear-powered missile cruisers. ⁴²⁵
Automation and autonomy in critical functions	According to the Army Technology website, the S-400 operates “autonomous detection and targeting systems” amongst its other

⁴¹⁴ https://www.armyrecognition.com/russia_russian_missile_system_vehicle_uk/s-400_triumf_sa-21_growler_missile_russia_air_defence_system.html; <https://economictimes.indiatimes.com/news/defence/china-successfully-tests-russias-s-400-missile-air-defence-system/articleshow/67267551.cms?from=mdr>

⁴¹⁵ <https://timesofindia.indiatimes.com/india/working-hard-to-ensure-early-supply-of-s-400-missile-systems-to-india-russia/articleshow/79189588.cms>

⁴¹⁶ <https://missilethreat.csis.org/defsyst/s-400-triumf/>

⁴¹⁷ <https://www.aljazeera.com/features/2018/10/8/why-do-countries-want-to-buy-the-russian-s-400>

⁴¹⁸ <https://www.army-technology.com/projects/s-400-triumph-air-defence-missile-system/>

⁴¹⁹ <http://www.ausairpower.net/APA-S-400-Triumf.html>

⁴²⁰ <https://missiledefenseadvocacy.org/missile-threat-and-proliferation/todays-missile-threat/russia/russia-anti-access-area-denial/s-400-triumf-air-defense-system/>

⁴²¹ <https://missilethreat.csis.org/defsyst/s-400-triumf/>

⁴²² <https://www.defensenews.com/air/2019/07/17/turkey-officially-kicked-out-of-f-35-program/>

⁴²³ <https://www.army-technology.com/projects/s-400-triumph-air-defence-missile-system/>

⁴²⁴ <https://missilethreat.csis.org/defsyst/s-400-triumf/>

⁴²⁵ <https://missiledefenseadvocacy.org/missile-threat-and-proliferation/todays-missile-threat/russia/russia-anti-access-area-denial/s-400-triumf-air-defense-system/>

	subsystems. ⁴²⁶ Defence IQ has also reported that the S-400 has an “autonomous detection” capability. ⁴²⁷	
Response time and simultaneous tracking capacity	Response time	9-10 seconds. ⁴²⁸
	Number of targets which can be simultaneously tracked/engaged	This system can reportedly engage up to 36 targets simultaneously. ⁴²⁹

⁴²⁶ <https://www.army-technology.com/projects/s-400-triumph-air-defence-missile-system/>

⁴²⁷ <https://www.defenceiq.com/air-land-and-sea-defence-services/articles/how-capable-is-the-s-400>

⁴²⁸ https://www.armyrecognition.com/russia_russian_missile_system_vehicle_uk/s-500_prometheus_55r6m_triumfator-m_air_defense_missile_data_pictures_video.html

⁴²⁹ <https://www.army-technology.com/projects/s-400-triumph-air-defence-missile-system/>

Tor-M1	
System manufacturer	Almaz-Antey (Russia)
System users	Russia, Armenia, Azerbaijan, Belarus, China, Cyprus, Egypt, Greece, and Iran. ⁴³⁰
System history	<p>The Tor-M1 – NATO codename SA-15 Gauntlet – is a short-range air defense system which “provides anti-aircraft defense capability to tactical and strategic targets by engaging aircraft and missiles in low and medium altitudes”.⁴³¹ The system, which is mounted onto a single combat vehicle, consists of “a turret a search and track RADAR, a fire control system and a missile launcher system”.⁴³² The Tor-M1 is armed with eight 9M330/9M331 missiles.⁴³³</p> <p>The Tor-M1 is an upgraded variant of the Tor-M air defence system which began its development during the 1980s and entered service in 1991.⁴³⁴ The system was designed to replace the 9K33 Osa – NATO codename SA-8 Gecko – air defence system which was developed during the Cold War.⁴³⁵ The development of the Tor-M series was prompted by Russian concerns about the growing threat posed by precision guided munitions.⁴³⁶ According to commentators, “[t]he principal advantages of [the] Tor-M1 is its ability to simultaneously destroy two targets in any weather or at any time of day and night; the use of both the powerful and jamming-resistant radar with electronic beam control and vertically launched missiles able to maintain high speed and manoeuvrability inside an entire engagement envelope; [and] the high degree of automation of combat operation provided by the electronic equipment suite”.⁴³⁷</p> <p>The Tor-M1 rose to international prominence following the destruction of the Ukraine International Airlines flight PS752 over Teheran in January 2020. Iran began its delivery of Tor-M1 systems in 2005 as part of a \$1 billion arms deal agreed with Russia. Media reporting at the time suggested that the system would be deployed to protect Iran’s nuclear test facilities against possible American or Israeli attack.⁴³⁸ In total, Iran is estimated to have purchased 29 Tor-M1 systems.⁴³⁹ As of January 2020, it was reported that at least 235 Tor-M1 units had been ordered by seven states of which the Russian military accounted for 172.⁴⁴⁰</p>
Maximum system range	15km (9M331 missile) ⁴⁴¹
Target type	Almaz-Antey, this system’s manufacturer, advertises the Tor-M1 as providing “effective protection against advanced threats including aircraft, helicopters, UAVs, cruise missiles and high precision weapon flying at

⁴³⁰ <https://missilethreat.csis.org/defsystor/>

⁴³¹ <https://www.haf.gr/en/equipment/tor-m1/>

⁴³² <https://www.haf.gr/en/equipment/tor-m1/>

⁴³³ <https://missilethreat.csis.org/defsystor/>

⁴³⁴ <https://missilethreat.csis.org/defsystor/>

⁴³⁵ <https://www.globalsecurity.org/military/world/russia/sa-15.htm>

⁴³⁶ <http://www.ausairpower.net/APA-9K331-Tor.html>

⁴³⁷ <https://www.globalsecurity.org/military/world/russia/sa-15.htm>

⁴³⁸ <https://jamestown.org/program/iran-takes-delivery-of-russian-tor-m1-missiles/>

⁴³⁹ <https://missilethreat.csis.org/defsystor/>

⁴⁴⁰ <https://www.shephardmedia.com/news/defence-notes/what-tor-m1/>

⁴⁴¹ <https://missilethreat.csis.org/defsystor/>

	<p>medium, low and nap-of-the-earth altitudes under complicated air and jamming environments”.⁴⁴² The Greek Air Force, which has operated the Tor-M1 since 2001, describes this system as “provide[ing] anti-aircraft defense capability to tactical and strategic targets by engaging aircraft and missiles in low and medium altitudes”.⁴⁴³</p>		
<p>System updates and variants</p>	<p>According to analysts, the baseline Tor-M1 system’s capabilities have been improved through five upgrades since 2005: the M1A, M1B, M1V, M1G, and M1-2U. These upgrades have improved the system’s radar, engagement range, jamming capability and interoperability with other air defence systems.⁴⁴⁴</p> <p>In 2012, a more advanced Tor variant – Tor-M2 – entered service with the Russian military. This variant is equipped with longer-range 9M338 missiles and an improved fire control radar.⁴⁴⁵ An tracked export variant of the Tor-M2 – Tor-M2E – has also been developed and, according to Rosoboronexport, is “designed to defeat fixed- and rotary-winged aircraft, aerodynamic unmanned aerial vehicles, guided missiles, and other elements of precision munitions at medium, low and extremely low altitudes in contested air and jamming environment”.⁴⁴⁶ In November 2019, the Russian Ministry of Defence signed an \$1.53 billion contract with Almaz-Antey for the delivery of Tor-M2 systems.⁴⁴⁷</p> <p>The Russian Navy also operates a navalized variant of this system known as the M-Tor. According to reports, this variant can “simultaneously detect 48 targets, track up to ten targets and engage four of them at the same time”.⁴⁴⁸</p>		
<p>Automation and autonomy in critical functions</p>	<p>According to Almaz-Antey, the Tor-M1’s “[a]utomatic air situation analysis, selection of the most dangerous targets and their identification, assignment of advantageous firing modes make the independent Tor-M1 combat vehicle operation more effective from target detection to its destruction”.⁴⁴⁹</p> <p>Analysts have described the Tor-M1 as a “fully automated system ... able to perform air surveillance and missile firing, against two targets simultaneously, on the move”.⁴⁵⁰ Others have noted how the Tor-M1’s “high degree of battle performance automation, employment of artificial intellect and unique algorithms make it possible to perform all the operations, involving detection of targets ... virtually without operator intervention”.⁴⁵¹</p>		
	<table border="1"> <tr> <td>Response time</td> <td>5-8 seconds.⁴⁵²</td> </tr> </table>	Response time	5-8 seconds. ⁴⁵²
Response time	5-8 seconds. ⁴⁵²		

⁴⁴² <https://www.kupol.ru/en/missile-systems/tor-m1/>

⁴⁴³ <https://www.haf.gr/en/equipment/tor-m1/>

⁴⁴⁴ <https://missilethreat.csis.org/defsystor/>

⁴⁴⁵ <https://missilethreat.csis.org/defsystor/>; <https://www.army-technology.com/news/newsalmaz-antey-new-tor2-variant/>;

https://www.armyrecognition.com/russia_russian_missile_system_vehicle_uk/tor-m2_tor-m2e_sa-15d_short_range_air_defense_missile_system_data_sheet_specifications_information.html

⁴⁴⁶ <http://roe.ru/eng/catalog/air-defence-systems/air-defense-systems-and-mounts/%22Tor-M2E%22%20%28%22Tor-M2K%22%2C%20%22Tor-M2KM%22%29/>

⁴⁴⁷ <https://www.janes.com/defence-news/news-detail/russian-mod-speeds-up-acquisition-of-tor-sam-systems>

⁴⁴⁸ <https://www.deagel.com/Artillery%20Systems/Tor-M1/a000375>

⁴⁴⁹ <https://www.kupol.ru/en/missile-systems/tor-m1/>

⁴⁵⁰ <https://www.deagel.com/Artillery%20Systems/Tor-M1/a000375>

⁴⁵¹ <http://www.ausairpower.net/APA-9K331-Tor.html>

⁴⁵² <http://www.army.gr/en/organosi/oplika-systimata/tor-m1-guided-missile-system>

Response time and simultaneous tracking capacity	Number of targets which can be simultaneously tracked/engaged	According to the system manufacturer, the Tor-M1 is capable of tracking up to ten targets simultaneously. ⁴⁵³ The upgraded Tor-M2E variant is advertised by Rosoboronexport as being capable of engaging up to 4 targets simultaneously. ⁴⁵⁴
---	---	--

⁴⁵³ <https://www.kupol.ru/en/missile-systems/tor-m1/>

⁴⁵⁴ <http://roe.ru/eng/catalog/air-defence-systems/air-defense-systems-and-mounts/%22Tor-M2E%22%20%28%22Tor-M2K%22%2C%20%22Tor-M2KM%22%29/>

BALLISTIC MISSILE DEFENCE SYSTEMS

Aegis Combat System BMD	
System manufacturer	Lockheed Martin (US)
System users	The US, Australia, Canada, Japan, Norway, Spain, and South Korea. ⁴⁵⁵
System history	<p>The Aegis Combat System comes in two variants: a land-based variant called “Aegis Ashore” and a sea-based variant called “Aegis Afloat”. This system is named after the shield used by the Greek god Zeus.⁴⁵⁶ The naval variant is described by Lockheed Martin as “the shield of the fleet”⁴⁵⁷ and is designed to “detect, track, and engage sophisticated ballistic missile and advanced air threats”.⁴⁵⁸</p> <p>The development of what would become the Aegis Combat System began during the early 1960s. Its air and surface radar were first tested on the <i>USS Norton Sound</i> in 1973, and a decade later the Aegis Combat System was integrated onto the “first Aegis Cruiser” - the <i>USS Ticonderoga</i>. The first Aegis equipped Arleigh Burke guided missile destroyer - <i>USS Arleigh Burke</i> – was commissioned in 1991.⁴⁵⁹ The Aegis Combat System is used by several of the US’ strategic partners including Australia, Japan and Spain.⁴⁶⁰ An Aegis Ashore site has been operational in Romania since 2016 and a second site is currently under construction in Poland.⁴⁶¹</p> <p>When first commissioned, the Aegis system was “capable of simultaneous operations against multi-mission threats: anti-air, anti-surface and anti-submarine warfare”.⁴⁶² An anti-ballistic missile capability was added in 2005 and has since been further developed.⁴⁶³ To operate in an anti-ballistic missile capacity, the Aegis’ computer system and software requires reconfiguration and longer ranged interceptors are needed.⁴⁶⁴</p>
Maximum system range	NDA
Target type	Short, medium, and intermediate-range ballistic missiles and “low-flying cruise missiles”. ⁴⁶⁵
System updates and variants	<p>According to Lockheed Martin, the Aegis system has been constantly upgraded to “continue to keep pace with evolving integrated air and missile threats”. These efforts have been spearheaded by the Lockheed Martin Ship Integration and Test team which provides “both planned upgrades and engineered innovations to make ships more capable and survivable”.⁴⁶⁶</p> <p>One important component of the Aegis’ modernisation has been the use of “[a]n open architecture that takes full advantage of evolving technology to</p>

⁴⁵⁵ <https://www.lockheedmartin.com/en-us/products/aegis-combat-system.html>

⁴⁵⁶ <https://www.militaryaerospace.com/sensors/article/14186584/shipboard-aegis-weapon-system-sensor>

⁴⁵⁷ <https://www.lockheedmartin.com/en-us/products/aegis-combat-system.html>

⁴⁵⁸ https://www.lockheedmartin.com/content/dam/lockheed-martin/rms/documents/aegis/SPY-7_FactSheet.pdf

⁴⁵⁹ <https://www.lockheedmartin.com/en-us/products/aegis-combat-system.html>

⁴⁶⁰ <https://www.lockheedmartin.com/en-us/products/aegis-combat-system.html>

⁴⁶¹ <https://fas.org/sgp/crs/weapons/RL33745.pdf>, pp.6-7.

⁴⁶² <https://www.navy.mil/Resources/Fact-Files/Display-FactFiles/Article/2166739/aegis-weapon-system/>

⁴⁶³ <https://missiledefenseadvocacy.org/defense-systems/aegis-afloat/>

⁴⁶⁴ <https://fas.org/sgp/crs/weapons/RL33745.pdf>, p.2.

⁴⁶⁵ <https://missiledefenseadvocacy.org/defense-systems/aegis-afloat/>; <https://missiledefenseadvocacy.org/defense-systems/aegis-afloat/>

⁴⁶⁶ <https://www.lockheedmartin.com/en-us/products/aegis-combat-system.html>

	<p>rapidly deliver real-time, reliable, and actionable information to the warfighter”.⁴⁶⁷ The decision to install a “plug and play computing environment”⁴⁶⁸ was driven by concerns about both the growing costs of upgrading the Aegis’s software and rapid advances in commercial computing technologies.⁴⁶⁹ It was intended to make upgrading the systems software easier and less costly, whilst improving the interoperability of the various classes of ship which use the system.⁴⁷⁰ It was also needed to aid the Aegis systems development as an anti-ballistic missile platform. As one US Navy engineer noted in 2003: “[c]urrent computing plants are pretty full... If you want to add [ballistic missile defence] on top of that, that is going to be pretty tough. ... If we go to open architecture—with distributed computing—we would have virtually unlimited [computational power] resources”.⁴⁷¹</p> <p>It is not possible from the available open source material to determine whether the adoption of an open-architecture (OA) software has accelerated the integration of automated and autonomous features into the Aegis system. Nevertheless, it has reportedly helped standardise software upgrades by enabling advanced capability builds to be rolled out every four years to all ships using the system.⁴⁷² This differs from the ‘legacy’ model in which “[u]pgrades to the Aegis combat system (ACS) were developed every five to six years and fielded only to new-construction ships and those receiving a midlife upgrade”.⁴⁷³</p> <p>Recent upgrades to the software used on the Aegis BMD have increased the range at, and accuracy with, which the system can “identify, track, target, and intercept missile threats”. First tested in November 2014, the Baseline 9 upgrade “integrates Aegis BMD vessels with other missile defense sensors and systems and allows them to engage cruise and ballistic missiles simultaneously”.⁴⁷⁴ As part of the AEGIS Modernization programme, Lockheed Martin have also been contracted to improve the computer hardware used in the Aegis system.⁴⁷⁵</p>
<p>Automation and autonomy in critical functions</p>	<p>The Aegis Combat System is described in an US Navy Fact file as a “centralized, automated, command-and-control (C2) and weapons control system that was designed as a total weapon system, from detection to kill”⁴⁷⁶ – a description used elsewhere.⁴⁷⁷ Others have described the Aegis as “a centralized, automated, command-and-control and weapons-control</p>

⁴⁶⁷ <https://www.lockheedmartin.com/en-us/products/aegis-combat-system.html>

⁴⁶⁸ <https://www.nationaldefensemagazine.org/articles/2003/5/1/2003may-navy-to-upgrade-aegis-ships-with-open-software-standards>

⁴⁶⁹ https://www.rand.org/content/dam/rand/pubs/research_reports/RR100/RR161/RAND_RR161.pdf, p.xiii.

⁴⁷⁰ <https://www.nationaldefensemagazine.org/articles/2003/5/1/2003may-navy-to-upgrade-aegis-ships-with-open-software-standards>

⁴⁷¹ <https://www.nationaldefensemagazine.org/articles/2003/5/1/2003may-navy-to-upgrade-aegis-ships-with-open-software-standards>

⁴⁷² https://www.rand.org/content/dam/rand/pubs/research_reports/RR100/RR161/RAND_RR161.pdf, p.1.

⁴⁷³ https://www.rand.org/content/dam/rand/pubs/research_reports/RR100/RR161/RAND_RR161.pdf, p.1.

⁴⁷⁴ <https://missiledefenseadvocacy.org/defense-systems/aegis-afloat/>

⁴⁷⁵ <https://www.upi.com/Defense-News/2019/09/04/Lockheed-nabs-503M-Navy-contract-for-Aegis-system-upgrades/7951567614184/>

⁴⁷⁶ <https://www.navy.mil/Resources/Fact-Files/Display-FactFiles/Article/2166739/aegis-weapon-system/>

⁴⁷⁷ <https://www.military.com/equipment/aegis-weapon-system>

	system”. ⁴⁷⁸ When defending against cruise missile attacks, the Aegis can operate in automatic mode. ⁴⁷⁹	
Response time and simultaneous tracking capacity	Response time	NDA
	Number of targets which can be simultaneously tracked/engaged	This system’s AN/SPY-1 radar is reportedly capable of detecting and tracking up to over a hundred targets simultaneously. ⁴⁸⁰ Media reports also present this system as being able to “identify, track, and systematically shoot down up to hundreds of targets at a time”. ⁴⁸¹

⁴⁷⁸ <https://www.militaryaerospace.com/sensors/article/14186584/shipboard-aegis-weapon-system-sensor>

⁴⁷⁹ [https://www.sipri.org/sites/default/files/2017-](https://www.sipri.org/sites/default/files/2017-11/siprireport_mapping_the_development_of_autonomy_in_weapon_systems_1117_0.pdf)

[11/siprireport_mapping_the_development_of_autonomy_in_weapon_systems_1117_0.pdf](https://www.sipri.org/sites/default/files/2017-11/siprireport_mapping_the_development_of_autonomy_in_weapon_systems_1117_0.pdf), pp.39-40.

⁴⁸⁰ <https://www.navy.mil/Resources/Fact-Files/Display-FactFiles/Article/2166739/aegis-weapon-system/>

⁴⁸¹ <https://www.popularmechanics.com/military/weapons/a27287344/virtualization-navy-computers/>

Arrow Weapon System	
System manufacturer	Israel Aerospace Industries and Boeing (Israel/US)
System users	Israel
System history	<p>The Arrow Weapon System is described by its principal manufacturer as “the world’s first operational, national, stand-alone ATBM (Anti Tactical Ballistic Missiles) defense system”.⁴⁸² It is advertised as having a modular design and a high degree of interoperability with missile defence systems used by NATO states.⁴⁸³ The Arrow Weapon’s subsystems include: (1) the ‘Golden Citron’ command and control centre; (2) mobile launchers containing the Arrow 2 and/or Arrow 3 interceptors; (3) the ELM-2080 Green Pine Radar system; and (4) a ‘Brown Hazelnut’ control centre.⁴⁸⁴</p> <p>This system’s development formally began in 1986 when the US and Israel signed a memorandum of understanding as part of the Strategic Defense Initiative enacted by the Ronald Reagan administration.⁴⁸⁵ Tests on the Arrow Weapon System were conducted throughout the 1990s, and the system entered service with Israeli Defence Forces in 2000.⁴⁸⁶ The US has funded almost half of the Arrow Weapon Systems annual development costs: a sum totalling at least \$3.7 billion by 2020.⁴⁸⁷ In return the US has benefited from “critical data and technology for its missile defense programs”.⁴⁸⁸ In March 2017, media reports suggested that an Arrow 2 system had “successfully intercepted a Syrian surface-to-air missile (SAM) that had been fired on an Israeli jet returning to Israel from an operation inside Syria”.⁴⁸⁹</p>
Maximum system range	2,400km (Arrow 3 missile); ⁴⁹⁰ 90km (Arrow 2 missile) ⁴⁹¹
Target type	Short range ballistic missiles. ⁴⁹²
System updates and variants	<p>Since this system’s initial development, the Arrow System Improvement Program (ASIP) which is managed by the Israel Missile Defense Organization in collaboration with the US Missile Defense Agency has continuously upgraded and improved the systems baseline capabilities. As part of this programme, two different classes of interceptor have been developed: the Arrow 2 and the Arrow 3.</p> <p>The Arrow 2 interceptor is designed to intercept ballistic missiles within the atmosphere.⁴⁹³ It was first tested in 1995. By 2004, the Arrow 2 had successfully intercepted a Scud missile during a simulated trial at the Point</p>

⁴⁸² <https://www.iai.co.il/p/arrow-2>

⁴⁸³ <https://www.iai.co.il/drupal/sites/default/files/2020-05/Arrow%20Brochure.pdf>

⁴⁸⁴ <https://missilethreat.csis.org/defsyst/arrow-2/>

⁴⁸⁵ <https://missilethreat.csis.org/defsyst/arrow-2/>

⁴⁸⁶ <https://www.iai.co.il/drupal/sites/default/files/2020-05/Arrow%20Brochure.pdf>

⁴⁸⁷ <https://fas.org/sgp/crs/mideast/RL33222.pdf>, p.18.

⁴⁸⁸ https://embassies.gov.il/washington/Obama_in_Israel/Pages/US-Israel-Missile-Defense-Cooperation.aspx

⁴⁸⁹ <https://fas.org/sgp/crs/mideast/RL33222.pdf>

⁴⁹⁰ https://www.armyrecognition.com/israel_israeli_military_missile_vehicles_systems_u/arrow_3_long-range_anti-ballistic_missile_technical_data_sheet_specifications_pictures_video_12901173.html

⁴⁹¹ <https://missiledefenseadvocacy.org/defense-systems/arrow-israel/>

⁴⁹² <https://missiledefenseadvocacy.org/defense-systems/arrow-israel/>

⁴⁹³ <https://www.iai.co.il/p/arrow-2>

	<p>Mugu naval range in California.⁴⁹⁴ Two Arrow 2 batteries are operated by Israeli Defence Forces: the first, near Tel Aviv; the second, near Haifa.⁴⁹⁵</p> <p>The Arrow 3 interceptor has been in service since 2017, and provides “upper-tier, Exo-Atmospheric” defence against ballistic missiles.⁴⁹⁶ The US provided \$450 million in funding between the 2008 and 2015 financial years.⁴⁹⁷ Whilst this interceptor has a longer range, faster speed and more sophisticated sensory suite than the Arrow 2, it nevertheless shares some of the older variants sub-systems.⁴⁹⁸ According to Israel Aerospace Industries the Arrow 3 is “designed to intercept and destroy the newest, longer-range threats, especially those carrying weapons of mass destruction”.⁴⁹⁹ By 2020, the US had appropriated \$1.1 billion in funding for the Arrow III’s development.⁵⁰⁰</p>	
<p>Automation and autonomy in critical functions</p>	<p>Israel Aerospace Industries advertise the Arrow Weapons System as having both an “[a]utomated and Man-in-the-Loop battle management mode”.⁵⁰¹ Its Battle Management, Command, Control, Communication and Intelligence system is also listed as having both manual and “fully automatic battle management modes”.⁵⁰² Consistent with these claims, early reporting on the Arrow Weapon System suggested that it operated with a man ‘in the loop’: “[t]he Arrow’s tracking system identifies and locks onto the missile and at the optimal point the [anti-ballistic missile] missile is released. Unlike the Patriot system used in the Gulf War, whose fire control system is essentially automated, the Israeli system leaves it to officers to decide when to fire the Arrow interceptor”.⁵⁰³</p>	
<p>Response time and simultaneous tracking capacity</p>	<p>Response time</p>	<p>Israel Aerospace Industries present both the Arrow 2 and the Arrow 3 interceptors as having a “very short reaction time”.⁵⁰⁴</p>
	<p>Number of targets which can be simultaneously tracked/engaged</p>	<p>The Arrow’s Battle Management, Command, Control, Communication and Intelligence system is advertised as being able to handle “multiple threats” simultaneously.⁵⁰⁵ The Arrow 2’s command and control system can reportedly “control up to 14 intercepts simultaneously”.⁵⁰⁶</p>

⁴⁹⁴ <https://missilethreat.csis.org/defsyst/arrow-2/>

⁴⁹⁵ <https://missilethreat.csis.org/defsyst/arrow-2/>

⁴⁹⁶ <https://www.iai.co.il/drupal/sites/default/files/2020-05/Arrow%20Brochure.pdf>

⁴⁹⁷ <https://missilethreat.csis.org/defsyst/arrow-3/>

⁴⁹⁸ <https://www.iai.co.il/drupal/sites/default/files/2020-05/Arrow%20Brochure.pdf>

⁴⁹⁹ <https://www.iai.co.il/p/arrow-3>

⁵⁰⁰ <https://fas.org/sgp/crs/mideast/RL33222.pdf>, p.20.

⁵⁰¹ <https://www.iai.co.il/drupal/sites/default/files/2020-05/Arrow%20Brochure.pdf>

⁵⁰² <https://www.iai.co.il/drupal/sites/default/files/2020-05/Arrow%20Brochure.pdf>

⁵⁰³ <http://www.ishitech.co.il/1102ar1.htm>

⁵⁰⁴ <https://www.iai.co.il/drupal/sites/default/files/2020-05/Arrow%20Brochure.pdf>

⁵⁰⁵ <https://www.iai.co.il/drupal/sites/default/files/2020-05/Arrow%20Brochure.pdf>

⁵⁰⁶ <https://www.army-technology.com/projects/arrow2/>

DRDO Ballistic Missile Defence System	
System manufacturer	Defence Research and Development Organisation (DRDO) (India)
System users	India
System history	<p>The DRDO Ballistic Missile Defence System (BMDS) is designed as a two-tier ballistic missile defence system designed to intercept ballistic missiles. Prithvi Air Defence missiles are used for interception at higher altitudes; and Advanced Air Defence missiles are used for interception at lower altitudes.⁵⁰⁷ The DRDO BMD “aims to secure the country from all kinds of incoming missiles, including nuclear, and flying objects”.⁵⁰⁸</p> <p>Development of this system began in 1999, and its testing was managed by the Indian Air Force. Its development was prompted by concerns about China’s and Pakistan’s ballistic missile capabilities.⁵⁰⁹ India’s development of an indigenous anti-ballistic missile system is reported to have been given greater impetus by the US’ decision to veto India’s purchase of the Israeli Arrow-2 missile in 2002.⁵¹⁰</p> <p>The first phase of the DRDO’s development, which was declared operational in 2012,⁵¹¹ centered on the system’s Prithvi-II and Advanced Air Defence missiles. Phase 2, which began in 2016, aimed to develop longer range D-1 and AD-2 interceptors capable of destroying intermediate-range ballistic missiles.⁵¹² According to Indian media reports, this system’s development was completed by January 2020 when the Indian Air Force and DRDO began working on proposals to deploy the system to protect New Delhi.⁵¹³</p>
Maximum system range	NDA
Target type	Ballistic missiles
System updates and variants	In March 2019, an anti-satellite capacity was reportedly tested for this system. ⁵¹⁴
Automation and autonomy in critical functions	Indian government officials have described the DRDO BMD as “a state-of-the-art defence system with very unique features”. ⁵¹⁵ Speaking to the Indian media, DRDO chief V.K. Saraswat has described it as being “automated” to the degree that human intervention would only be needed to abort the mission”. ⁵¹⁶ This system has similarly been described in the Indian media as “a two-tier fully automated system”. ⁵¹⁷
	Response time
	NDA

⁵⁰⁷ <https://euro-sd.com/2020/06/news/17401/india-ready-to-install-ballistic-missile-defence/>

⁵⁰⁸ https://www.drdo.gov.in/sites/default/files/drdo-news-documents/DRDO_News_08_Jan_2020.pdf

⁵⁰⁹ <https://nationalinterest.org/blog/the-buzz/americas-killer-m1-abrams-tank-now-has-its-own-shields-22719>

⁵¹⁰ <https://nationalinterest.org/blog/the-buzz/americas-killer-m1-abrams-tank-now-has-its-own-shields-22719>

⁵¹¹ <https://www.thehindu.com/news/national/missile-defence-shield-ready-drdo-chief/article3390404.ece>

⁵¹² <https://www.army-technology.com/projects/drdo-bmd/>

⁵¹³ <https://theprint.in/defence/indias-ballistic-missile-shield-ready-iaf-drdo-to-see-govt-nod-to-protect-delhi/345853/>

⁵¹⁴ <https://theprint.in/india/governance/modi-govt-pushes-through-a-sat-missile-test-that-upa-had-not-permitted/212670/>

⁵¹⁵ https://www.drdo.gov.in/sites/default/files/drdo-news-documents/DRDO_News_08_Jan_2020.pdf

⁵¹⁶ <https://www.thehindu.com/news/national/missile-defence-shield-ready-drdo-chief/article3390404.ece>

⁵¹⁷

http://timesofindia.indiatimes.com/articleshow/57105516.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst

Response time and simultaneous tracking capacity	Number of targets which can be simultaneously tracked/engaged	This system's Swordfish Long-Range tracking radar, which is a domestically manufactured variant of the Israeli Green Pine radar, is reportedly capable of tracking up to 200 targets simultaneously. ⁵¹⁸
---	---	---

⁵¹⁸ <https://nationalinterest.org/blog/the-buzz/americas-killer-m1-abrams-tank-now-has-its-own-shields-22719>

SAMP/T Air Defense System	
System manufacturer	MBDA/Thales (Europe/ France and Italy)
System users	France, Azerbaijan, Italy, and Singapore. ⁵¹⁹
System history	<p>The SAMP/T (Sol-Air Moyenne Portée – Terrestre) – known as the Mamba in France – is a medium range air defence system described by its manufacturer as the “cornerstone of Italy and France’s contributions to the North Atlantic Alliance tactical ballistic missile defence capability”.⁵²⁰</p> <p>The SAMP/T is made up of a “fire control system based on a Command and Control system”, Arabel radar and up to 6 vertical launchers.⁵²¹ The system is armed with Aster 30 missiles and, as noted by the French Ministry of Defence, “is capable of engaging all types of threats from the sky, and contributes not only to the protection of the territory, but also protection of forces during foreign operations”.⁵²²</p> <p>Development of the SAMP/T began during the late 1980s as part of the EUROSAM initiative and was a joint collaboration between the French and Italian militaries.⁵²³ It was designed to replace the MIM-23 Hawk system operated by both militaries and also provide some defence against ballistic missiles.⁵²⁴ According to the Singaporean Ministry of Defence, which also operates the system, the SAMP/T’s “capabilities are many times more potent” than the MIM-23 Hawk.⁵²⁵ Initial production began in 1997, with limited qualification trials commencing two years later.⁵²⁶ The SAMP/T had entered service with both the French and Italian militaries by 2011.⁵²⁷ In 2016, two Italian SAMP/T batteries were deployed to Southern Turkey as part of a NATO operation to protect against missile attacks from Syria.⁵²⁸</p>
Maximum system range	120km (Aster 30 missile) ⁵²⁹
Target type	Aircraft, short range ballistic missiles, cruise missiles and UAV. ⁵³⁰
System updates and variants	MBDA is currently developing a longer range variant of the Aster missile to improve this systems ability to intercept ballistic missiles. ⁵³¹ According to reports, “[t]he Aster Block 1 NT (New Technology) programme will cover the modernization of the Aster 30 interceptor and associated SAMP/T extended range air defense system that will evolve to provide missile defense capabilities”. ⁵³²

⁵¹⁹ <https://missiledefenseadvocacy.org/defense-systems/sampt-air-defense-system/>

⁵²⁰ <https://www.thalesgroup.com/en/worldwide/defence/samp-t>

⁵²¹ <https://www.mbda-systems.com/product/aster-30-sampt/>

⁵²² <https://www.defense.gouv.fr/actualites/dossiers/dossiers-archives/le-bourget-2013/les-materiels-presentes/samp-t-mamba>

⁵²³ <https://www.mbda-systems.com/about-us/mbda-worldwide/eurosam/>

⁵²⁴ <https://www.mbda-systems.com/about-us/mbda-worldwide/eurosam/>

⁵²⁵ https://www.defense-aerospace.com/articles-view/feature/5/185045/samp_t-is-better-and-cheaper%3A-why-doesn%E2%80%99t-it-sell%3F.html

⁵²⁶ <https://www.army-technology.com/projects/aster-30/>

⁵²⁷ <http://www.military-today.com/missiles/sampt.htm>

⁵²⁸ <https://missilethreat.csis.org/defsys/samp-t/>

⁵²⁹ <https://missiledefenseadvocacy.org/defense-systems/sampt-air-defense-system/>

⁵³⁰ <https://missiledefenseadvocacy.org/defense-systems/sampt-air-defense-system/>

⁵³¹ <https://www.army-technology.com/projects/aster-30/>

⁵³² https://defense-update.com/20160114_aster30.html

Automation and autonomy in critical functions	According to MBDA, “the ASTER 30 SAMP/T system is highly automated”. ⁵³³ Others have described this system as being “fully automated and able to face a wide range of air threats, demonstrating its agile rapid reaction capability”. ⁵³⁴	
Response time and simultaneous tracking capacity	Response time	The French Ministry of Defence describe this system as having a “[v]ery short reaction time”. ⁵³⁵ MBDA also advertise it as having an “[e]xtremely quick response time”. ⁵³⁶
	Number of targets which can be simultaneously tracked/engaged	According to Thales, the SAMP/T’s Arabel radar can track up to 100 targets simultaneously, and engage ten simultaneously. ⁵³⁷ MBDA note that a “key capability” of the SAMP/T is its “360° effectiveness in simultaneously engaging multiple targets in any combination of air threat type”. ⁵³⁸ The French Ministry of Defence have noted that this system has an “unique ability to simultaneously engage conventional and ballistic threats”. ⁵³⁹

⁵³³ <https://www.mbda-systems.com/product/aster-30-sampt/>

⁵³⁴ <http://www.occar.int/fsaf-french-sampt-mamba-system-delivery>

⁵³⁵ <https://www.defense.gouv.fr/actualites/dossiers/dossiers-archives/le-bourget-2013/les-materiels-presentes/samp-t-mamba>

⁵³⁶ <https://www.mbda-systems.com/product/aster-30-sampt/>

⁵³⁷ <https://www.thalesgroup.com/sites/default/files/database/d7/asset/document/SAMP-T.pdf>

⁵³⁸ <https://www.mbda-systems.com/about-us/mbda-worldwide/eurosam/>

⁵³⁹ <https://www.defense.gouv.fr/actualites/dossiers/dossiers-archives/le-bourget-2013/les-materiels-presentes/samp-t-mamba>

S-500 Prometey	
System manufacturer	Almaz-Antey (Russia)
System users	Russia
System history	<p>The S-500 system is an upgraded version of the S-400. Reports suggest that the S-500 will be armed with a variety of missiles including the 77N6 missile series being developed for the S-400, and will operate with 4 radar sets per battery.⁵⁴⁰ These radar systems are speculated to include “the 91N6A(M) acquisition and battle management radar, the revised 96L6-TsP acquisition radar, and the new 76T6 multimode engagement and 77T6 ABM engagement radars”.⁵⁴¹</p> <p>Russian Air Force Colonel General Alexander Zelin has described the S-500’s as being a “qualitatively new system”.⁵⁴² One reported difference between the S-400 and the S-500 is that the S-500 system is designed to intercept fifth-generation aircraft such as the F-35 Joint Strike Fighter and low orbit satellites.⁵⁴³ To this end, chief of the Aerospace Forces of Russia Sergei Surovikin has noted: “[a]ccording to its tactical and technical characteristics, the S-500 can be considered the first generation of space defense systems, since it will be able to destroy low-orbit satellites and space weapons”. As he continued, “[t]he main task of the complex is the destruction of medium-range ballistic missiles, and, if necessary, the warheads of intercontinental ballistic missiles in the final section of their flight path”.⁵⁴⁴ According to analysts, the S-500 is not designed to replace the S-400 but supplement it with an enhanced set of capabilities.⁵⁴⁵</p> <p>The S-500’s development reportedly began in 2009.⁵⁴⁶ Whilst the Russian Defense Ministry claimed that the S-500 regiment was scheduled to enter service in 2020,⁵⁴⁷ testing is set to continue into 2022.⁵⁴⁸</p>
Maximum system range	500-600kms ⁵⁴⁹
Target type	This system is being tested and developed to intercept fifth-generation aircraft, low orbit satellites and hypersonic cruise and ballistic missiles. ⁵⁵⁰
System updates and variants	NDA

⁵⁴⁰ <https://missilethreat.csis.org/defsys/s-500-prometheus/>

⁵⁴¹ https://www.armyrecognition.com/russia_russian_missile_system_vehicle_uk/s-500_prometheus_55r6m_triumfator-m_air_defense_missile_data_pictures_video.html

⁵⁴² https://wikileaks.org/gifiles/docs/83/837566_rus-russia-former-soviet-union-.html

⁵⁴³ <https://missilethreat.csis.org/defsys/s-500-prometheus/>; <https://eurasianimes.com/not-only-stealth-f-35s-russian-s-500-missile-can-also-shoot-down-low-orbit-satellites/>

⁵⁴⁴

https://www.defenseworld.net/news/27340/Russian_S_500_Space_Defense_System_to_be_deployed_this_year#.X9j1Cdj7Tcd

⁵⁴⁵ <https://eurasianimes.com/not-only-stealth-f-35s-russian-s-500-missile-can-also-shoot-down-low-orbit-satellites/>

⁵⁴⁶ https://www.armyrecognition.com/russia_russian_missile_system_vehicle_uk/s-500_prometheus_55r6m_triumfator-m_air_defense_missile_data_pictures_video.html

⁵⁴⁷ <https://sputniknews.com/military/201804091063362316-russia-missiles-features/>

⁵⁴⁸ <https://caspiannews.com/news-detail/development-of-next-generation-s-500-air-defense-system-nears-completion-2020-11-29-15/>; <https://nationalinterest.org/blog/buzz/s-500-russias-f-35-killer-coming-next-year-173514>

⁵⁴⁹ <https://missilethreat.csis.org/defsys/s-500-prometheus/>

⁵⁵⁰ <https://missilethreat.csis.org/defsys/s-500-prometheus/>

https://www.defenseworld.net/news/27340/Russian_S_500_Space_Defense_System_to_be_deployed_this_year#.X YOo dj7Tcc

<p>Automation and autonomy in critical functions</p>	<p>Given its ongoing testing and development, there has been little concrete reporting on the integration of automation and autonomy into this system’s critical functions. Because of its development status, many of the S-500’s technical characteristics remain subject to speculation.⁵⁵¹</p> <p>Pavel Sozinov, a designer at Almaz-Antey is however reported as saying that the S-500 is “completely different” from the S-400 in part because of its greater focus on automation.⁵⁵² According to media reports:</p> <p style="padding-left: 40px;">The key differentiator of the S-500 “Prometheus” system over the S-400 is a combat control point (PBU) with an automatic control system (ACS). All information from the radars of not only the S-500, but also third-party radars, anti-aircraft systems and higher air defense command posts are assimilated into the PBU <i>which then operates automatically to select and defeat the threat.</i>⁵⁵³</p>	
<p>Response time and simultaneous tracking capacity</p>	<p>Response time</p> <hr/> <p>Number of targets which can be simultaneously tracked/engaged</p>	<p>3-4 seconds.⁵⁵⁴</p> <hr/> <p>According to media reports, the S-500 will be capable of tracking and engaging up to ten ‘hypersonic’ targets simultaneously.⁵⁵⁵</p>

⁵⁵¹ <https://nationalinterest.org/blog/reboot/why-russia-being-so-quiet-about-its-new-s-500-air-defense-system-162595>

⁵⁵² <https://www.ainonline.com/aviation-news/defense/2018-03-14/russias-next-generation-s-500-sam-enters-production>

⁵⁵³

https://www.defenseworld.net/news/25612/Russian_S_500_Serial_Production_in_2020_After_Succesful_Test_in_Syria#.X-nLjt7Tcc

⁵⁵⁴ https://www.armyrecognition.com/russia_russian_missile_system_vehicle_uk/s-500_prometheus_55r6m_triumfator-m_air_defense_missile_data_pictures_video.html

⁵⁵⁵ <https://www.defensenews.com/global/europe/2020/01/10/wests-reluctance-to-share-tech-pushes-turkey-further-into-russian-orbit/>

Terminal High Altitude Area Defense (THAAD)	
System manufacturer	Lockheed Martin (US)
System users	US and the UAE. ⁵⁵⁶
System history	<p>The Terminal High Altitude Area Defense (THAAD) system was developed for the US Army to defend “U.S. troops, allied forces, population centers and critical infrastructure against short and medium-range ballistic missiles”.⁵⁵⁷ The THAAD is described as using “hit to kill” technology because its interceptors are designed to kinetically smash into ballistic missiles during the “terminal” phase of their flight.⁵⁵⁸ The THAAD uses the AN/TPY-2 radar, a “indigenous THAAD Fire Control and Communications system” and the Extended Range Interceptor (amongst other missiles).⁵⁵⁹ The THAAD’s interceptors are fired from truck-mounted launchers.⁵⁶⁰</p> <p>Conceptual development on the THAAD system began during the late 1980s, and Lockheed Martin was selected as the system’s primary contractor in 1992.⁵⁶¹ Designed to defend “against regional missile threats and reinforce regional stability,⁵⁶² the first of the US Army’s seven THAAD batteries was delivered in 2009. The system was first operationally deployed in April 2013 when a THAAD battery was sent to Guam.⁵⁶³ The 2016 decision to send a THAAD battery to South Korea generated considerable diplomatic opposition from China.⁵⁶⁴ Speaking in May 2017, a spokesperson for the Chinese Ministry of Foreign Affairs reiterated that “[w]e’re opposed to the United States’ deploying the THAAD antimissile system in South Korea, and we urge all sides involved to immediately halt deployment”.⁵⁶⁵</p>
Maximum system range	200km ⁵⁶⁶
Target type	Short, medium, and intermediate-range ballistic missiles. ⁵⁶⁷
System updates and variants	<p>The US Missile Defence Agency factsheet on the THAAD notes the commitment to “[c]ontinuing element development to improve missile defense capability against current and future threats”.⁵⁶⁸</p> <p>In an August 2019 test conducted in the Marshall Islands, a THAAD battery is reported to have successfully detected, tracked and intercepted a medium-range ballistic missile via a remote launch: “[t]he THAAD radar detected, acquired and tracked the target. The THAAD system then developed a fire control solution and launched an interceptor from a remotely-located</p>

⁵⁵⁶ <https://www.mda.mil/system/thaad.html>.

⁵⁵⁷ <https://www.lockheedmartin.com/content/dam/lockheed-martin/mfc/pc/thaad/mfc-thaad-pc.pdf>

⁵⁵⁸ <https://www.lockheedmartin.com/en-us/products/thaad.html>

⁵⁵⁹ <https://missilethreat.csis.org/system/thaad/>

⁵⁶⁰ <https://www.armscontrol.org/factsheets/usmissiledefense>

⁵⁶¹ <http://www.designation-systems.net/dusrm/app4/thaad.html>

⁵⁶² <https://www.lockheedmartin.com/en-us/products/thaad.html>

⁵⁶³ <https://www.lockheedmartin.com/content/dam/lockheed-martin/mfc/pc/thaad/mfc-thaad-pc.pdf>

⁵⁶⁴ <https://thediplomat.com/2016/02/what-is-thaad-what-does-it-do-and-why-is-china-mad-about-it/>

⁵⁶⁵ https://www.nytimes.com/2017/05/02/world/asia/thaad-north-korea-missile-defense-us.html?_r=0.

⁵⁶⁶

https://www.armyrecognition.com/united_states_american_missile_system_vehicle_uk/thaad_terminal_high_altitude_area_defense_missile_system_data_sheet_specifications_pictures_video.html

⁵⁶⁷ <https://www.lockheedmartin.com/en-us/products/thaad.html>

⁵⁶⁸ <https://www.mda.mil/global/documents/pdf/thaad.pdf>

	<p>THAAD launcher that destroyed the target's reentry vehicle".⁵⁶⁹ Tests conducted by the Missile Defense Agency at the White Sands Missile Range in October 2020 also demonstrated the THAAD's interoperability with the Patriot defence system discussed elsewhere in this catalogue.⁵⁷⁰</p> <p>Media reports suggest that the THAAD ER programme, which is currently in the concept development phase, will increase the THAAD's interception range: "[t]he THAAD ER interceptor would add a stage to the current interceptor to allow both extended range and more divert capability, potentially including an ability to intercept hypersonic missiles".⁵⁷¹</p>	
<p>Automation and autonomy in critical functions</p>	<p>Alongside the Iron Dome system also discussed in this catalogue, the THAAD has been described as being capable of operating "autonomously": "a long-range radar detects and tracks an incoming missile, calculates its trajectory and then attacks it with an interceptor missile".⁵⁷² The THAAD's engagement cycle works in the following way:</p> <p style="padding-left: 40px;">When a threat missile gets launched, an infrared satellite detects its heat signature and sends an early warning and other useful real-time tracking data to the ground based system through a communications satellite. When the threat is confirmed by analysis (with no human involvement), the appropriate command gets delivered to sensors and weapon systems. After that, the long-range radar detects and tracks the missile for some time to improve accuracy. The tracking data helps to calculate the near-accurate trajectory of the incoming threat missile. Among the group of batteries available to address the threat, the most effective interceptor battery is engaged and carries out the interception. The complete process of killing the missile is fully autonomous in nature and hypothetically has very high efficiency.⁵⁷³</p>	
<p>Response time and simultaneous tracking capacity</p>	<p>Response time</p>	<p>NDA</p>
	<p>Number of targets which can be simultaneously tracked/engaged</p>	<p>According to Lockheed Martin, the THAAD can intercept "two near-simultaneous medium-range ballistic missile targets".⁵⁷⁴</p>

⁵⁶⁹ https://news.lockheedmartin.com/2019-08-30-Lockheed-Martins-THAAD-System-Successfully-Demonstrates-Remote-Launcher-Capability-During-Intercept-Test?_ga=2.52660203.2105468133.1609166717-1660905700.1607946455#assets_all

⁵⁷⁰ <https://www.mda.mil/news/20news0002.html>

⁵⁷¹ <https://missilethreat.csis.org/system/thaad/>

⁵⁷² https://icrndresourcecentre.org/wp-content/uploads/2017/11/4283_002_Autonomus-Weapon-Systems_WEB.pdf, p.10.

⁵⁷³ https://icrndresourcecentre.org/wp-content/uploads/2017/11/4283_002_Autonomus-Weapon-Systems_WEB.pdf, p.32.

⁵⁷⁴ <https://www.lockheedmartin.com/en-us/products/thaad.htmlbuk>