Appendix 8C. A survey of US ballistic missile defence programmes

SHANNON N. KILE

I. Introduction

The United States continues to pursue an expansive array of programmes for active defence against perceived emerging threats from ballistic missiles, including missiles potentially carrying nuclear warheads. This appendix surveys the main US ballistic missile defence (BMD) programmes. It focuses on the weapon and sensor technologies being developed for defence systems designed to counter short-, medium- and long-range ballistic missiles. Section II summarizes the evolving plans of the US Department of Defense (DOD) for building an integrated BMD architecture to protect US territory and allies from missile attack. It highlights concerns about the technological readiness of individual programme elements and the likely effectiveness of the proposed system in realistic missile engagement scenarios. Section III looks at the international dimension of US missile defence activities. It describes joint BMD development programmes under way with Israel and Japan, which involve significant defence-industrial cooperation, and cooperation in the framework of the North Atlantic Treaty Organization (NATO). Section IV presents the conclusions.

II. US ballistic missile defence programmes

The US Administration of President George W. Bush entered office in 2001 committed to developing a robust missile defence system to protect the USA.[1] One argument put forward by senior administration officials was that a nationwide missile defence system would usefully supplement nuclear deterrence; this supplement was increasingly needed in the light of the emergence of states armed with long-range ballistic missiles—possibly armed with nuclear, biological or chemical weapons—which might not be deterred by threats of devastating retaliation.[2] Other arguments focused on the prospect that a state might initiate a regional conflict involving US allies and important US national interests in the mistaken belief that its missiles might deter the USA from intervening in the conflict. In the US Administration's view, the deployment of a nationwide missile defence system—even one using unproven technologies—would force potential adversaries to reassess the risks that they would face by confronting the USA, thereby enhancing US freedom of action when responding to regional crises.[3]

[1] The National 1999 Missile Defense Act had already committed the USA 'to deploy as soon as is technologically possible an effective National Missile Defense system capable of defending the territory of the United States against limited ballistic missile attack (whether accidental, unauthorized, or deliberate)'. The National Missile Defense Act of 1999, US Public Law 106-38, was signed into law on 22 July 1999.

[2] Wolfowitz, P., US Deputy Secretary of Defense, Prepared Statement before the Armed Services Committee, US Senate, 12 July 2001, <http://armed-services.senate.gov/hearings/2001/c010712a.htm>.

[3] Wolfowitz (note 2).

In January 2002, the Secretary of Defense, Donald Rumsfeld, identified four main missile defence priorities: (*a*) 'to defend the U.S., deployed forces, allies, and friends'; (*b*) 'to employ a Ballistic Missile Defense System (BMDS) that layers defenses to intercept missiles in all phases of their flight'; (*c*) 'to enable the Services to field elements of the overall BMDS as soon as practicable'; and (*d*) 'to develop and test technologies' and 'improve the effectiveness of deployed capability by inserting new technologies as they become available or when the threat warrants an accelerated capability'.[4] National Security Presidential Directive 23, signed by Bush in December 2002, mandated the deployment of an initial defence capability, beginning in 2004, 'as a starting point for fielding improved and expanded missile defenses later'.[5]

In order to accelerate the deployment of an initial defence capability, the US Missile Defense Agency (MDA)—the main body within the DOD responsible for missile defence activities—has adopted an 'evolutionary approach' to the development of key elements of the BMDS.[6] Rather than settling on a final missile defence architecture, the MDA decided to deploy an initial set of capabilities that would evolve over time to take advantage of technological developments. This capabilities-based acquisition process, also called 'spiral development', departs from the traditional US approach to weapon procurement in that the MDA cannot estimate the overall cost of the missile defence system or determine its final capabilities because the system's baseline architecture changes over time.[7] Spiral development also departs from usual DOD practice, to 'fly before buy', in that the MDA can procure individual systems before they are fully tested and certified as meeting established performance goals.[8]

As part of the spiral development process, the MDA has organized missile defence programme activities into two-year time periods, or 'blocks', consisting of specified capabilities (e.g. Block 2006 represents capability goals to be achieved in 2006–2007, Block 2008 represents 2008–2009 etc.). Each successive block is designed to build on the capabilities previously acquired. In the first block—Block 2004—the MDA began to deploy an integrated BMDS, which incorporated both theatre missile defences (those designed to intercept short- to medium-range ballistic missiles) and strategic defences (those designed to intercept long-range missiles) in a single 'layered' defence architecture.[9]

The MDA has focused its activities in blocks 2006 and 2008 on maintaining and sustaining the defence capability initiated in 2004 by completing the planned deployments of interceptors, sensors and command systems.[10] Over the same period, it is pursuing research, development, testing and evaluation (RDT&E) programmes aimed

[4] Rumsfeld, D., US Secretary of Defense, 'Missile defense program direction', Memorandum, 2 Jan. 2002, <http://www.defenselink.mil/releases/release.aspx?releaseid=3203>.

[5] The White House, 'National policy on ballistic missile defense', National Security Presidential Directive 23, 16 Dec. 2002. The text is available at <http://www.fas.org/irp/offdocs/nspd/>.

[6] Prior to Jan. 2002 the MDA was known as the Ballistic Missile Defense Organization (BMDO).

[7] The spiral development approach has been criticized for limiting the US Congress's ability to oversee spending on missile defence by 'making it difficult to reconcile outcomes with original expectations and to determine the actual cost . . . of individual operational assets'. US Government Accountability Office (GAO), *Defense Acquisitions: Missile Defense Agency's Flexibility Reduces Transparency of Program*, GAO-07-799T (GAO: Washington, DC, 30 Apr. 2007), <http://www.gao.gov/>, p. 9.

[8] Coyle, P., 'Is missile defense on target?', *Arms Control Today*, vol. 33, no. 8 (Oct. 2003), p. 9.

[9] US Missile Defense Agency, 'The Ballistic Missile Defense System', Fact sheet, Aug. 2007, <http://www.mda.mil/mdalink/html/factsheet.html>.

[10] US Missile Defense Agency, 'Fiscal year 2008 (FY08) budget estimates: overview', 31 Jan. 2007, <http://www.mda.mil/mdalink/pdf/budgetfy08.pdf>, p. 4.

Table 8C.1. Summary of principal US missile defence programmes, December 2007

Programme	System	Status
Interceptors		
Terminal phase		
Patriot Advanced Capability-3 (PAC-3)	Land-based, air-transportable launcher, single-stage Extended Range Interceptor (ERINT) missile armed with explosive warhead, phased array radar and engagement control station (ECS)[a]	Most technologically mature BMD system, in US Army service since 2003; a total of 712 missiles to be in US inventory at end of 2008
Terminal High Altitude Area Defence (THAAD)[b]	Truck-mounted launchers equipped with hit-to-kill interceptor missiles, mobile X-band radar, and battle management command and control (BMC^2) system	Resumed flight tests in 2005, after major design changes; successful interception tests in Jan. and Oct. 2007; first unit to be deployed in 2009
Mid-course phase		
Ground-based Midcourse Defense (GMD)	Long-range, multi-stage Ground-Based Interceptor (GBI) missile carrying an EKV for intercepting ICBMs; land- and sea-based tracking radars; and a GMD Fire Control and Communications (GFC/C) system	GBI and GMD radar network used in successful interception test in Sep. 2007; 40 GBI missiles to be based at Fort Greely, Alaska, 4 at Vandenberg AFB, California, and 10 in Poland by 2011
Aegis Ballistic Missile Defense	Aegis ships equipped with AN/SPY-1 radar reconfigured for a long-range surveillance and track (LRS&T) capability and Block 1A SM-3 hit-to-kill interceptors for engaging short- and medium-range ballistic missiles	3 Aegis BMD cruisers and 13 destroyers to be in US Navy service at end of 2008 with *c*. 40 SM-3s; the Block 2 SM-3 to be fielded in 2013 will have capability to intercept ICBMs
Multiple Kill Vehicle (MKV)	Long-range interceptor carrying 8–20 miniaturized EKVs which can independently track and target multiple warheads and mid-course countermeasures, such as decoy re-entry vehicles	Control system of payload carrier vehicle tested in 2006; testing of EKVs to begin in 2009; initial operational capability in 2014
Boost phase		
Airborne Laser (ABL)	Modified Boeing 747 aircraft carrying a modular, megawatt-class chemical oxygen iodine laser (COIL), beam control optics, infrared sensors, and target acquisition and tracking lasers	Continuing systems-integration problems; successful in-flight test of target tracking laser in Mar. 2007; first 'lethality test' of laser in 2009
Kinetic Energy Interceptor (KEI)	A fast-burn, high-velocity interceptor missile to be deployed on mobile land launchers or on sea-based platforms near an enemy launch site; may replace ABL as main boost-phase defence system	Land-based booster flight to be tested in 2008; sea-based platform to be selected in 2008; initial operational capability to be determined

Programme	System	Status
Sensors		
Sea-Based X-band (SBX) radar	High resolution radar based on manoeuvrable offshore platform for acquisition, tracking and discrimination of target missiles	Completed sea trials in 2007; used in successful test of GMD elements in Sep. 2007; to be based at Adak Island, Alaska
AN/TPY-2 radar[c]	Transportable high-resolution radar for detecting, tracking and discriminating missile threats; designed as part of the THAAD system	First radar activated in Oct. 2006 by US Army unit at Japanese airbase in Shariki, Japan
Space Tracking and Surveillance System (STSS)[d]	Constellation of low-earth orbit satellites designed to detect and track missiles in all phases of flight; size of constellation to be determined	Two satellites to be launched in 2008
Space-Based Infrared System–High (SBIRS-High)[e]	USAF procurement plan is for 3 satellites in geosynchronous orbit, and 2 satellites with infrared sensors in highly elliptical orbit, to provide early warning of ballistic missile launches	Programme beset by technical delays and cost overruns; restructured in 2002, 2004 and 2005; launch of first satellite scheduled for 2008
Upgraded Early-Warning Radar (UEWR)	Modified early-warning radar (EWR) for detection and tracking of post-boost and mid-course re-entry vehicles; data transmitted to 2 GMD Fire Control Centres, in Alaska and Colorado	Upgrade of US EWR at RAF Fylingdales, UK, completed in Aug. 2007; upgrade of US EWR at Thule, Greenland to be completed in 2009

AFB = Air Force Base; BMD = ballistic missile defence; EKV = exoatmospheric kill vehicle; ICBM = intercontinental ballistic missile; SM-3 = Standard Missile-3; USAF = US Air Force.

[a] US missile defence programmes are organized according to the 3 phases of a ballistic missile's flight: 'boost' (the powered ascent phase, from launch to booster-engine burnout), 'mid-course' (the exoatmospheric phase, between booster burnout and re-entry into the atmosphere), and 'terminal' (the re-entry phase, ending with the missile warhead's impact).

The PAC-3 system is designed to provide point defence against short-range ballistic missiles but can also engage aircraft and cruise missiles.

[b] THAAD has an 'endo-/exoatmospheric capability' to intercept medium-range ballistic missiles above the earth's atmosphere as well as inside the atmosphere.

[c] This was formerly known as Forward-Based X-band (FBX) radar.

[d] This was formerly known as Space-Based Infrared System–Low (SBIRS-Low).

[e] Because of continuing problems with SBIRS-High, the USAF began a parallel programme in 2006 known as the Alternative Infrared Satellite System (AIRSS).

Sources: Obering, H. A. (Lieut. Gen.), Director, US Missile Defense Agency, 'Fiscal year 2008 defense authorization ballistic missile defense', Statement before the US Senate Armed Services Committee, Strategic Forces Subcommittee, 11 Apr. 2007, <http://armed-services.senate.gov/testimony.cfm?wit_id=4103&id=2675>; US Missile Defense Agency, 'Fiscal Year 2008 (FY08) budget estimate: overview', 31 Jan. 2007, <http://www.mda.mil/mdalink/pdf/budgetfy08.pdf>; US Missile Defense Agency, Fact Sheets (various), <http://www.mda.mil/mdalink/html/factsheet.html>; *Jane's Missiles & Rockets* (various issues); and Boese, W., 'Missile defense remains budget priority', *Arms Control Today*, vol. 37, no. 2 (Mar. 2007).

Table 8C.2. Funding for the US Missile Defense Agency, financial years 2003–13

Figures are for requested funds, in US $m. at current prices. Years are financial years (1 Oct.–30 Sep.). Figures do not include Defense-Wide Resources funding for missile defence programmes.

Year	2003	2004	2005	2006	2007	2008	2008–13[a]
Funding	6 714	7 674	9 169	7 695	9 388	8 899	56 666

[a] This is a projected figure.

Sources: US Department of Defense (DOD), *Fiscal Year (FY) 2008 Budget Estimates: Research, Development, Test and Evaluation, Defense-Wide*, vol. 2, *Missile Defense Agency* (DOD: Washington, DC, 2007), <http://www.defenselink.mil/comptroller/defbudget/fy2008/budget_justification/>; US Missile Defense Agency, 'FY 2005 budget estimates overview', 2 Feb. 2004, <http://www.cdi.org/news/missile-defense/mdafy05.pdf>; and Kadish, R. (Lieut. Gen.), Director, Missile Defense Agency, 'Missile defense program and fiscal year 2004 budget', Statement before the US Senate Armed Services Committee, 18 Mar. 2003, <http://armed-services.senate.gov/testimony.cfm?wit_id=1708&id=646>.

at filling gaps in capabilities and improving the initial defence capability by adding new systems. These latter include boost-phase interceptors (the Airborne Laser and the Kinetic Energy Interceptor), a terminal-phase interceptor (Terminal High Altitude Area Defense, THAAD) and a 'volume kill capability' (the Multiple Kill Vehicle). In the longer term, beyond 2012, the MDA is making 'capabilities investments' in new space-based sensors (the Space Tracking and Surveillance System) and in advanced technologies in order to be able to defend against more sophisticated or unexpected missile threats.[11] The principal US missile defence programmes are summarized in table 8C.1.

The US Administration requested $8.9 billion in financial year 2008 for all of the programme elements of the Missile Defense Agency (see table 8C.2).[12] In 2007, the US Government Accountability Office (GAO) estimated that the USA had spent $107 billion on missile defence since the mid-1980s.[13]

The initial defence capability

At the end of 2007 the USA's deployed missile defence capability consisted of the following elements: Ground-based Midcourse Defense (GMD), Aegis Ballistic Missile Defense, Patriot Advanced Capability-3 (PAC-3) and the Command, Control, Battle Management and Communications (C^2BMC) system (see table 8C.3).

The centrepiece of the MDA's initial defence capability against long-range ballistic missiles threats is the Ground-based Midcourse Defense system. The GMD system consists of a 'hit-to-kill' interceptor missile and a network of land- and sea-based radars. The three-stage Ground-Based Interceptor (GBI) missile carries an exoatmospheric kill vehicle (EKV), which is designed to collide with and destroy intermediate-

[11] US Missile Defense Agency (note 10), p. 5.

[12] The request did not include funds for missile defence programmes managed by the armed services, such as the US Air Force's Space-Based Infrared System (SBIRS) satellite network and the US Army's Patriot missile defence system.

[13] US Government Accountability Office (note 7), p. 4.

and intercontinental-range ballistic missiles in the mid-course phase of flight. A series of technical problems and accidents in developing the GBI significantly delayed the selection and flight testing of the booster vehicle. Despite these setbacks, the MDA began to deploy the interceptor missiles at the end of 2004.[14] A GAO report in March 2007 noted that the GBI programme continued to face technical challenges with the EKV's infrared seeker as well as with the redesign and testing of the booster's guidance, navigation and control subsystems.[15]

The MDA's Block 2006 programme has also focused on deploying GMD sensor elements. These are land- and sea-based radars for detecting and tracking long-range ballistic missiles and transmitting targeting information though the C^{2}BMC system. In June 2006 the US Army deployed a transportable AN/TPY-2 X-band radar at a Japan Air Self-Defense Force airbase in north-eastern Japan.[16] The Sea-Based X-band (SBX) radar completed calibration tests while undergoing sea trials in 2007 and was expected to be fully integrated into the GMD system after reaching its homeport in the Aleutian Islands.[17] In addition, the upgrading of the 1960s-era Ballistic Missile Early Warning System (BMEWS) radar at Royal Air Force (RAF) Fylingdales base in the United Kingdom was completed in August 2007, pursuant to a 2003 British–US agreement to allow the DOD to use the US radar at the base for missile defence purposes.[18] In June 2007 the US Air Force began work on upgrading its early-warning radar at Thule, Greenland, which was scheduled to be completed in the autumn of 2009.[19]

The GMD test programme was restructured in 2005 because of flight-test failures and quality-control problems. After a lengthy hiatus, the MDA conducted two successful flight tests in 2006 using interceptors; the second was an 'end-to-end' test of an engagement scenario and resulted in a target intercept.[20] In September 2007 the MDA conducted a flight test involving a successful intercept by a GBI missile. The test evaluated the performance of the interceptor missile's rocket motor system and the EKV. It was also designed to evaluate the performance of several elements of the BMDS.[21] This included demonstrating the ability of the upgraded early-warning radar at Beale Air Force Base, California, and the SBX radar to acquire and track a target missile and transmit the data through the C^{2}BMC system. The target missile was also successfully tracked by an Aegis cruiser using the AN/SPY-1 radar.

The Aegis BMD test programme reached another milestone in 2007. On 6 November an Aegis cruiser in the Pacific Ocean, USS *Lake Erie*, successfully intercepted two target missiles launched from Hawaii with two Standard Missile-3 (SM-3) Block

[14] Graham, B., 'Missile defense testing may be inadequate', *Washington Post*, 22 Jan. 2004.

[15] US Government Accountability Office (GAO), '*Defense Acquisitions: Assessments of Selected Weapon Programs*, GAO-07-406SP (GAO: Washington, DC, Mar. 2007), pp. 83–84.

[16] Coleman, J., 'U.S., Japan expand missile-defense plan', *Washington Post*, 23 June 2006.

[17] US Missile Defense Agency, 'Sea-based X-band radar (SBX)', Fact sheet, Aug. 2007, <http://www.mda.mil/mdalink/html/factsheet.html>; and 'Sea-Based X-band radar completes fine calibration testing', *Space War*, 15 Mar. 2007, <http://www.spacewar.com/pageone/spacewar-2007-03-15.html>.

[18] 'Upgrade to the early warning radar at Fylingdales', *Royal Air Force News*, 26 July 2007; and British Ministry of Defence, 'MOD replies to US request to upgrade RAF Fylingdales', Press release, 5 Feb. 2003, <http://www.gnn.gov.uk/content/detail.asp?ReleaseID=28649&NewsAreaID=2>.

[19] 'Thule EWR upgrade begins', *CDI Missile Defense Update*, no. 6 (11 July 2007), <http://www.cdi.org/program/document.cfm?documentid=4011>.

[20] Samson, V. and Black, S., 'Flight tests for Ground-based Midcourse Defense (GMD) system', Center for Defense Information, 18 June 2007, <http://www.cdi.org/pdfs/gmd ift2.pdf>.

[21] US Missile Defense Agency, 'Missile defense exercise and flight test successfully completed', News release, 28 Sep. 2007, <http://www.mda.mil/mdalink/html/newsrel.html>.

Table 8C.3. Deployed US Ballistic Missile Defense System (BMDS) elements, December 2007

Category	BMDS element	Location
Silo-based interceptors	22 GBI missiles	Fort Greely, Alaska
	3 GBI missiles	Vandenberg AFB, Calif.
Mobile interceptors	3 Aegis BMD engagement cruisers[a]	US Pacific Fleet
	7 Aegis BMD engagement destroyers[a]	US Pacific Fleet
	546 PAC-3 missiles	US Army worldwide
Fixed site sensors	Cobra Dane radar[b]	Shemya Island, Alaska
	2 upgraded early-warning radar	Beale AFB, Calif., and RAF Fylingdales, UK
Transportable/ mobile sensors	Sea-based X-band radar	Adak Island, Alaska
	AN/TPY-2 X-Band radar	Shariki AFB, Japan
	7 Aegis Long-range Surveillance and Track (LRS&T) destroyers[c]	US Pacific Fleet

AFB = Air Force Base; BMD = ballistic missile defence; GBI = Ground-Based Interceptor; PAC-3 = Patriot Advanced Capability-3

[a] At the end of 2007 the US Navy had 21 Standard Missile-3 (SM-3) missile interceptors available for deployment on Aegis BMD engagement ships

[b] The modified Cobra Dane phased-array radar, which was originally designed to track missiles launched from the Soviet Union, has a limited capability to detect missiles launched towards the USA from North Korea.

[c] The destroyers are to be refitted with a BMD engagement capability by the end of 2008.

Sources: Obering, H. A. (Lieut. Gen.), Director, US Missile Defense Agency, 'Fiscal year 2008 defense authorization ballistic missile defense', Statement before the US Senate Armed Services Committee, Strategic Forces Subcommittee, 11 Apr. 2007, <http://armed-services.senate.gov/testimony.cfm?wit_id=4103&id=2675>; and US Missile Defense Agency, 'Fiscal year 2008 (FY08) budget estimate: overview', 31 Jan. 2007, <http://www.mda.mil/mdalink/pdf/budgetfy08.pdf>.

IA interceptor missiles. This was the sea-based system's first test involving the simultaneous engagement of multiple targets. According to the MDA's criteria, these were the tenth and eleventh successful intercepts, of 13 targets in 12 flight tests for the Aegis BMD programme.[22]

Concerns about technology readiness

In July 2006 the Department of Defense placed the BMDS on limited operational alert for the first time in response to North Korea's resumption of long-range ballistic missile flight tests.[23] President Bush's statement that US missile defences would have had 'a reasonable chance' of shooting down a North Korean test missile was disputed by Philip Coyle, who was the DOD's director of Operational Test and Evaluation

[22] US Missile Defense Agency, 'Sea-based missile defense "hit to kill" intercept achieved', News release, 6 Nov. 2007, <http://www.mda.mil/mdalink/html/newsrel.html>.

[23] Shanker, T., 'Missile defense system is up and running, military says', *New York Times*, 3 Oct. 2007.

from 1994 to 2001. Coyle said that the system had 'no demonstrated capability to defend the United States against enemy attack under realistic conditions'.[24] Critics inside and outside the US Government have long complained that the MDA did not subject key weapon systems and sensors to operational tests designed to simulate real-world conditions.[25] In particular, they have charged that the tests to date have been highly orchestrated and failed to include even simple countermeasures, such as warhead decoys, that an adversary would be likely to use.[26] This led the DOD's Defense Science Board to warn at the end of 2006 that 'Fielding the current systems in larger numbers will not lead to a robust system'.[27] In response to these complaints, the director of the MDA told the US Congress in 2007 that, as part of its Block 2008 activities, the agency would conduct increasingly realistic operational tests, including adding countermeasures to a GMD system test scheduled for 2008.[28]

III. International missile defence cooperation

Proposed US missile defence deployments in Europe

In 2007 the USA began negotiations with the Czech Republic and Poland on a US proposal to deploy on their territories missile interceptors and a tracking radar developed as part of its GMD system. The US Government claims that the proposed deployments are needed to counter threats posed by Iran's emerging long-range ballistic missile capabilities.[29] However, they have sparked a public debate about the feasibility and desirability of missile defences in Europe. The USA's plan has also faced strenuous objections from the Russian Government.[30]

The US proposal involves the deployment of US BMDS assets at two sites in Europe. The first is an airbase near Koszalin, in northern Poland, where 'up to ten' silo-based interceptor missiles will be deployed in 2011–13.[31] The interceptors will be a two-stage variant of the GBI missile and will consist of a booster stage and an EKV attached to the second rather than the third stage. They will have greater acceleration but a shorter range than the three-stage missiles being deployed on US territory. According to the MDA, the two-stage GBI missile will be 'better suited for

[24] Center for Defense Information, 'Former and current officials skeptical of missile defense efficacy', *CDI Missile Defense Update*, no. 7 (10 Aug. 2006), <http://www.cdi.org/program/document.cfm?documentid=3620>.

[25] Boese, W., 'More testing urged for missile defense', *Arms Control Today*, vol. 35, no. 6 (July/Aug 2005); and Thompson, M., 'Can America's missile defense handle North Korea?', *Time*, 3 July 2006.

[26] See e.g. Cloud, D. S., 'Missile Defense System intercepts rocket in test', *New York Times*, 2 Sep. 2006; and Watson, R., 'Physicist blows whistle on US missile defence', *The Times*, 3 Jan. 2003.

[27] US Department of Defense (DOD), Defense Science Board Task Force, *Nuclear Capabilities*, Report summary (DOD: Washington, DC, Dec. 2006), <http://www.acq.osd.mil/dsb/reports.htm>, p. 7.

[28] Obering, H. A. (Lieut. Gen.), Director, US Missile Defense Agency, 'Fiscal year 2008 defense authorization ballistic missile defense', Statement before the US Senate Armed Services Committee, Strategic Forces Subcommittee, 11 Apr. 2007, <http://armed-services.senate.gov/testimony.cfm?wit_id=4103&id=2675>, pp. 21–26.

[29] Rood, J., US Assistant Secretary for International Security and Non-Proliferation, 'International missile defence: challenges for Europe', Remarks to the 8th Royal United Services Institute (RUSI) Missile Defence Conference, London, 27 Feb. 2007, <http://www.state.gov/t/isn/rls/rm/81242.htm>.

[30] See chapter 1 in this volume, section III.

[31] US departments of State and Defense, *Proposed U.S. Missile Defense Assets in Europe* (Missile Defense Agency: Washington, DC, June 2007), <http://www.mda.mil/mdaLink/html/thirdsite.html>, p. 3.

the engagement ranges and timelines for Europe', since the three-stage interceptor's minimum flight range is too long for it to be able to engage missiles launched from Iran.[32]

The second site is in the Brdy district of the Czech Republic and would host a large X-band radar called the European Midcourse Radar (EMR). The radar equipment is currently deployed at Kwajalein atoll in the Marshall Islands, central Pacific Ocean, in support of the MDA's BMDS test programme and would be upgraded and moved to Europe in 2011.[33] This narrow-beam, high-resolution radar will allow its US operators to discriminate target clusters (i.e. distinguish the missile warhead from other missile parts and potential countermeasures) travelling above the atmosphere. The EMR will also provide precision tracking and guidance information (known as 'cueing' data) to the interceptor missiles, thereby significantly expanding the latter's area of defensive coverage. In addition, the MDA may deploy an X-band radar at a site closer to Iran, such as in Turkey or the Caucasus, to provide early detection and enhanced tracking information to the EMR.[34]

According to a DOD analysis, the Czech Republic and Poland are the 'optimal' locations for the interceptors and the radar in terms of maximizing defensive coverage of European territory against intermediate-range ballistic missiles launched from the Middle East.[35] However, in 2007 some observers disputed the MDA's claim, noting that the current plan left south-eastern Europe unprotected.[36] In addition, two prominent non-governmental experts concluded that the proposed US missile defence deployments in the Czech Republic and Poland would be capable of engaging all Russian intercontinental ballistic missiles (ICBMs) launched from sites west of the Urals and flying towards the east coast of the USA.[37] They argued that positioning the interceptors and radar closer to Iran would better defend Europe from Iranian missiles while being too far away from Russia to pose a threat to its ICBM force.

The North Atlantic Treaty Organization[38]

As part of its 1999 Strategic Concept, NATO is developing a theatre missile defence system: the Active Layered Theatre Ballistic Missile Defence (ALTBMD) programme to protect its deployed forces within or outside its territory against short- and medium-range ballistic missiles.[39] ALTBMD is a multi-layered 'system of systems' consisting of low- and high-altitude defences, communications, command and control

[32] US departments of State and Defense (note 31), p. 4.

[33] US departments of State and Defense (note 31), p. 4.

[34] US departments of State and Defense (note 31), p. 5.

[35] US departments of State and Defense (note 31), p. 6. The deployments will also provide 'redundant coverage' for the continental USA against intercontinental ballistic missiles launched from the Middle East.

[36] See e.g. Tauscher, E., 'European missile defense: a congressional perspective', *Arms Control Today*, vol. 37, no. 8 (Oct. 2007).

[37] Lewis, G. N. and Postol, T. A., 'European missile defense: the technological basis of Russian concerns', *Arms Control Today*, vol. 37, no. 8 (Oct. 2007).

[38] For more on NATO's consideration of missile defences see chapter 1 in this volume, section V.

[39] See NATO, Active Layered Theatre Ballistic Missile Defence Programme Office, 'The ALTBMD system', 6 Nov. 2007, <http://www.tmd.nato.int/system.html>; and Yost, D. S., 'Missile defence on NATO's agenda', *NATO Review*, no. 3/2006 (autumn 2006), <http://www.nato.int/docu/review/2006/issue3/english/analysis1.html>; and NATO, 'The alliance's strategic concept', Press Release NAC-S(99)65, 24 Apr. 1999, <http://www.nato.int/docu/pr/1999/>.

systems, early-warning sensors, radar and various interceptors.[40] It will integrate into a single NATO command and control network the sensors and interceptors provided by member states, such as the Franco-Italian Surface Air Moyenne Portée/Terre (SAMP/T) system and the US Patriot anti-missile missile system. In September 2006 the first contract for the development of a key component of the system, the NATO Battlefield Management Command, Control, Communication and Intelligence (BMC^{3}I) capability, was awarded. ALTBMD is scheduled to achieve an initial operational capability by 2010 and to be fully operational by 2016.[41]

The Medium Extended Air Defense System (MEADS) continues to be developed under a NATO contract awarded in 2004. MEADS is a joint German–Italian–US air defence programme designed to defend against short-range ballistic missiles, cruise missiles and aircraft.[42] The system consists of a lightweight launcher, 360-degree fire control and surveillance radars, and a battle management command and control (BMC^2) system designed to be interoperable within NATO forces. When it enters into service in 2014, MEADS will initially use the current PAC-3 interceptor missile, augmented by Missile Segment Enhancement (MSE) technologies that will give it greater range and performance.[43] In 2003 the MEADS development programme was combined with the US Army's PAC-3 programme in order to create an integrated PAC-3–MEADS capability.[44]

Japan

Japan's interest in missile defence intensified in the wake of North Korea's unexpected test-firing in 1998 of a long-range Taepodong ballistic missile over the main Japanese island of Honshu. Japanese missile defence plans are predicated on close cooperation with the USA. In December 2004 the Japanese cabinet approved its National Defense Program Guidelines, which inter alia envisioned increased Japanese–US 'cooperation on ballistic missile defense' and 'equipment and technology exchange'.[45] The two countries subsequently concluded a deal to allow Japan's licensed production of the US PAC-3 missile and also undertook to jointly develop the Standard Missile-3 interceptor.[46] In June 2006 Japan and the USA followed up these ventures with a new cooperation agreement under which missile defence tech-

[40] NATO, 'Missile defence: what does this mean in practice?', Topics, 13 June 2007, <http://www.nato.int/issues/missile_defence/practice.html>.

[41] NATO, Active Layered Theatre Ballistic Missile Defence Programme Office, 'NATO missile defence–evolution', 6 Nov. 2007, <http://www.tmd.nato.int/mdevolution.html>.

[42] The USA has a 58% share in the programme, Germany 25% and Italy 17%. 'Beyond Patriot: the MEADS program SD&D phase', *Defense Industry Daily*, 14 Aug. 2007. The USA is expected to procure 48 MEADS firing units, Germany 24 units and Italy 9 units. Six launchers with up to 12 missiles each make up a firing unit.

[43] 'Beyond Patriot' (note 42).

[44] Kingston, T. and Ratnam, G., 'Europe wary of U.S. missile defense promises', *Defense News*, 13 Oct. 2003, pp. 1, 8.

[45] Japanese Ministry of Defense (MOD), *Defense of Japan 2007*, White Paper (MOD: Tokyo, 2007), <http://www.mod.go.jp/e/publ/w_paper/>, 'National Defense Program Guidelines, FY 2005–', pp. 462—69.

[46] 'Japan licensed to produce Patriot PAC-3s', *Defense Industry Daily*, 19 July 2005, <http://www.defenseindustrydaily.com/japan-licensed-to-produce-patriot-pac3s-0876>; and Japan Defense Agency (JDA), *Defense of Japan 2006*, White Paper (JDA: Tokyo, 2006), <http://www.mod.go.jp/e/publ/w_paper/>, 'Statement by the Chief Cabinet Secretary "Japan–U.S. cooperative development of advanced SM-3 missile for ballistic missile defense"', p. 459.

nology developed by Japanese defence contractors could be shared with US partners.[47] The technology transfer issue was a politically sensitive one in Japan, which had long adhered to a self-imposed ban on arms exports in line with its pacifist constitution.

Japan is developing a high-altitude, exoatmospheric anti-missile capability that will consist of six Japan Maritime Self-Defense Force (JMSDF) destroyers equipped with the Aegis BMD radar and weapon control system and SM-3 missiles. These will be fitted on two new Aegis destroyers currently under construction in Nagasaki. The JMSDF is also refitting four Kongo Class Aegis destroyers with the upgraded radar as well as with Block 1A SM-3 missiles and associated launch canisters.[48] Japan and the USA are proceeding with development work on a Block 2 SM-3 missile which will have an enhanced capability for engaging ICBMs.

The Japanese Government's concern about North Korea's intentions and missile capabilities led to the deployment to Japan, in August 2006, of one of the US Navy's Aegis cruisers. The arrival of the USS *Shiloh* at the US Navy base in Yokosuka sparked public protests over Japan's integration into US missile defence plans.[49]

Japan's low-altitude anti-missile capability will initially consist of 16 land-based PAC-3 missile batteries.[50] In 2006 the Japan Defense Agency (JDA, which became the Ministry of Defense in January 2007) announced plans to buy 124 Patriot surface-to-air missiles by 2010.[51] It ordered a total of 36 interceptors from the USA, with the remainder to be produced in Japan beginning in 2008. The JDA subsequently announced that it intended to purchase additional US-built Patriot missiles.[52] In March 2007, approximately one year ahead of schedule, the Japan Self-Defense Forces (JSDF) deployed its first Patriot missile battery at the Iruma base near Tokyo.[53] In addition to the deployments by the JSDF, in October 2006 the first PAC-3 battalion was deployed at the US Air Force's Kadena Air Base on Okinawa.[54]

Israel

The Israeli–US Arrow Weapon System (AWS) is the most technologically mature of the USA's collaborative missile defence development programmes.[55] The AWS was designed to track and destroy Scud-type ballistic missiles in the terminal phase of their flight trajectory. The centrepiece of the system is the Arrow 2 interceptor mis-

[47] Coleman (note 16).

[48] This work is being done in cooperation with Lockheed Martin under a 3-year, $124 million contract. Wolf, J., 'Experimental U.S.-Japan missile tip passes first test', *Defense News*, 8 Mar. 2006.

[49] Kyodo News Agency, 'U.S. deploys missile-intercept ship here', *Japan Times*, 30 Aug. 2006.

[50] Japanese Ministry of Defense (note 45), p. 171.

[51] Yamaguchi, M., Associated Press, 'U.S. to put Patriot interceptors in Japan', *Washington Post*, 26 June 2006.

[52] Agence France-Presse, 'US offers Japan 80 Patriot missiles', *Space Daily,* 24 Aug. 2006; and Obering (note 28), p. 26.

[53] Hogg, C., 'Japan mounts missile self-defence', BBC News, 30 Mar 2007, <http://news.bbc.co.uk/2/6509211.stm>.

[54] Associated Press, 'U.S. Patriot missile parts arrive on Okinawa, sparking local protest', *International Herald Tribune*, 3 Oct. 2006.

[55] Israel Aerospace Industries (IAI) is the prime contractor and lead system integrator for the AWS. A US consortium led by the Boeing Company produces nearly 40% of the components for the Arrow 2 interceptor missile. Lennox, D. (ed.), *Jane's Strategic Weapon Systems* (Jane's Information Group: Coulsdon, 2007), p. 248; and Sampson, V., 'Israel's Arrow missile defense: not ready for prime time', Center for Defense Information, 9 Oct. 2002, <http://www.cdi.org/missile-defense/arrow.cfm>.

sile, which is equipped with both infrared and active radar sensors and a blast-fragmentation warhead. The Israeli Air Force (IAF) currently deploys two Arrow 2 batteries, one located at an airbase near Tel Aviv, which became operational in 2000, and the other at an undisclosed site in northern Israel. Each battery is believed to consist of four to eight mobile launchers, one Green Pine multifunction phased-array radar, one Citron Tree fire-control centre, one launch-control centre and approximately 50 Arrow 2 interceptor missiles.[56] The IAF has reportedly decided to augment this 'thin deployment', which was intended primarily to counter Scud missiles launched from Iraq, with additional Arrow 2 batteries in northern Israel. The goal is to enhance Israel's ability in a future conflict to defend against potential barrage attacks by the growing ballistic missile forces of Iran and Syria.[57]

In 2007 US and Israeli concern about Iran's development of longer-range variants of its Shahab missile led the two countries to extend by five years the Arrow System Improvement Program (ASIP), which had been scheduled to conclude in 2008. The US Missile Defence Agency also significantly increased funding for Arrow upgrades and interoperability testing as well as for future joint missile projects.[58] As part of ASIP activities in 2007, the Israel Missile Defense Organization (IMDO) conducted the first flight tests of a Block 3 Arrow 2 interceptor missile.[59] The upgraded missile is designed to intercept target missiles at higher altitudes and longer ranges, so that the debris from possible nuclear, biological or chemical warheads will fall farther away from Israeli territory. The tests also employed the Block 3 Green Pine radar, which has improved resolution for identifying decoys and other penetration aids that Iran may be developing to defeat missile defences.[60]

Israeli defence officials are studying a new exoatmospheric interceptor missile—designated Arrow 3—capable of defending against attacks by ballistic missiles with ranges in excess of 2000 kilometres and possibly carrying nuclear, biological or chemical warheads. The IMDO's preliminary plans envision the Arrow 3 as being the first line in a layered missile defence architecture; current and improved versions of the Arrow 2 would be deployed as a second-echelon guard against target missiles that 'leak' through the initial defence as well as against lesser missile threats.[61] Israel may supplement the lower defence tier with the US-built PAC-3 system.[62]

There is intense interest in Israel in developing an affordable system capable of intercepting artillery rockets and short-range ballistic missiles (SRBMs).[63] In October 2007 the US and Israeli defence ministers agreed to establish a panel to examine an Israeli proposal to augment their countries' missile defence cooperation to include short-range rockets and missiles.[64] Israel is currently developing a system, known as Iron Dome, to address the threat of short-range rockets, including Qassam improvised

[56] ed. Lennox (note 55), p. 248;

[57] Katz, Y., 'IDF modifying Arrow deployment in the north', *Jerusalem Post*, 23 Aug. 2007.

[58] Opall-Rome, B., 'Pentagon extends Arrow funding through 2013', *Defense News*, 15 Feb. 2007.

[59] Hughes, R. and Ben-David, A., 'Arrow 2 test exceeds Israeli expectations', *Jane's Defence Weekly*, 24 Dec. 2003, p. 17.

[60] Isby, D. C., 'Israel upgrades Green Pine', *Jane's Missiles & Rockets*, vol. 10, no. 6 (Mar. 2006), p. 12.

[61] Opall-Rome, B., 'Israel to develop top-tier missile interceptor,' *Defense News*, 22 Oct. 2007.

[62] Katz, Y., 'Air force might buy latest Patriot missile systems', *Jerusalem Post*, 20 Aug. 2007.

[63] Associated Press, 'Israel: Hezbollah militants in Lebanon have new rockets that can hit Tel Aviv, UN chief says', *International Herald Tribune*, 31 Oct. 2007.

[64] Roberts, K. and Williams, D., 'U.S., Israel to study layered missile defenses', Reuters, 10 Oct. 2007, <http://www.reuters.com/article/topNews/idUSN1645256320071017>.

rockets and the 122-mm Katyusha artillery rockets fired into Israel from the Gaza Strip and southern Lebanon by Palestinian and Hezbollah guerrillas.[65] Israel's defence minister has indicated that the system could be ready for deployment by 2010.[66] In addition, in 2006 the IMDO and the US MDA awarded a multi-year contract to an Israeli–US consortium to develop a new Short Range Missile Defense (SRMD) system, which is known as David's Sling, capable of defeating a variety of short-range ballistic missile threats, such as the Iranian-produced Fajr and Zelzal SRBMs deployed by Hezbollah forces in southern Lebanon.[67]

IV. Conclusions

Missile defence remains a high priority for the United States. The DOD's Missile Defense Agency is pursuing a phased set of research and development and procurement programmes for weapon and sensor systems that will be integrated, over time, into a single, multi-layered Ballistic Missile Defence System. The US Administration accelerated key weapon system and sensor programmes in order to begin deploying an initial set of missile defence capabilities by the end of 2004. This has raised concerns about the maturity of the missile defence technologies being developed and about the cost and likely effectiveness of the systems to be deployed.

There are signs of growing interest in missile defence systems in countries other than the USA. This marks a departure from the cold war era, when interest in missile defence was limited primarily to the superpowers. The new interest has been motivated in part by the desire of some countries to promote their defence-industrial cooperation with the USA. More importantly, it has been motivated by the proliferation of short- and medium-range ballistic missiles in specific regional settings, namely East Asia, South Asia and the Middle East.

[65] On Hezbollah's supplies of arms see Wezeman, S. T. et al., 'International arms transfers', *SIPRI Yearbook 2007: Armaments, Disarmament and International Security* (Oxford University Press: Oxford, 2007), pp. 409–11.

[66] Reuters, 'Barak: system for shooting down short-range rockets to be ready by 2010', *Haaretz*, 18 Oct. 2007.

[67] 'Rafael, Raytheon win contract for Israeli defence system', *Jane's Missiles & Rockets*, vol. 10, no. 7 (July 2006), p. 13. The system will reportedly consist of a hit-to-kill interceptor equipped with an infrared sensor