



***THE CRUISE
MISSILE
CHALLENGE***

Thomas G. Mahnken

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The Cruise Missile Challenge

by

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Glossary

AESA	Active Electronically Scanned Array
ALCM	Air-Launched Cruise Missile
ASCM	Anti-Ship Cruise Missile
CEC	Cooperative Engagment Capability
CEP	Circular Error Probable
CIWS	Close-In Weapon System
DoD	Department of Defense
DSMAC	Digital Scene Matching Correlation
EORSAT	Electronic Intelligence Ocean Reconnaissance Satellite
GPS	Global Positioning System
IDEX	International Defense Exposition
INS	Inertial Navigation System

JLENS	Joint Land-Attack Cruise Missile Defense Elevated Netted Sensor
Joint-STARS	Joint Surveillance and Target Attack Radar System
LACM	Land-Attack Cruise Missile
MEADS	Medium Extended Air Defense System
MP-RTIP	Multi-Platform Radar Technology Insertion Program
OTH	Over the Horizon
PGM	Precision Guided Munition
PLAN	People's Liberation Army Navy
RAM	Rolling Airframe Missile
RCS	Radar Cross Section
RORSAT	Radar Ocean Reconnaissance Satellite
TASM	Tomahawk Anti-Ship Missile
TBMD	Theater Ballistic Missile Defense
TEL	Transporter Erector Launcher
TERCOM	Terrain Contour Matching
TLAM-N	Tomahawk Land-Attack Missile-Nuclear
UAV	Unmanned Aerial Vehicle
UCAV	Unmanned Combat Air Vehicle

Introduction

The growth of foreign ballistic missile arsenals has received considerable attention in recent years. Less noticed has been the spread of increasingly capable cruise missiles. The 2003 Iraq War showed that while the United States has made strides in protecting its forces against ballistic missiles, it has placed far less effort on addressing the threat posed by cruise missiles. While US and Kuwaiti *Patriot* theater ballistic missile defense (TBMD) batteries intercepted and destroyed all nine Iraqi ballistic missiles launched at military targets, they failed to detect or intercept any of the five HY-2/CSSC-3 *Seersucker* cruise missiles launched against Kuwait. One came close to hitting Camp Commando, the US Marine Corps headquarters in Kuwait, on the first day of the war. Another landed just outside a shopping mall in Kuwait City. The missiles also contributed to fratricide, causing the loss of two coalition aircraft and the death of three crewmembers.¹

The growth of foreign cruise missile capabilities should be of concern to the United States. The cruise missile threat is a component of three of the six operational challenges that the 2001 Quadrennial Defense Review identified as driving the transformation of US forces. These include:

¹ Dennis M. Gormley, "Missile Defense Myopia: Lessons from the Iraq War," *Survival* 45, No. 4 (Winter 2003-04), pp. 61, 63, 66.

Protecting critical bases of operations, including the US homeland, forces abroad, allies, and friends, and defeating weapons of mass destruction and their means of delivery...

Projecting and sustaining US forces in distant anti-access or area-denial environments and defeating anti-access and area-denial threats...[and]

Denying enemies sanctuary by providing persistent surveillance, tracking, and rapid engagement with high-volume precision strike against critical mobile and fixed targets.²

The cruise missile challenge also is reflected in the types of non-traditional threats that the 2005 Quadrennial Defense Review is reportedly examining.³

This paper provides a diagnostic assessment of the cruise missile challenge. It argues that while cruise missiles are hardly new, technological developments are making them increasingly lethal. The easiest path to acquire a cruise missile capability is to purchase missiles from the growing ranks of manufacturers. Indigenous development is the longest route to development and is unlikely to lead to a modern design. It is also possible to convert anti-ship cruise missiles (ASCMs) to land-attack cruise missiles (LACMs), though only a small proportion of anti-ship missiles are suitable for conversion into long-range systems. A greater concern involves the potential conversion of unmanned aerial vehicles (UAVs) and lightweight aircraft into autonomous attack vehicles.

Cruise missiles have a number of characteristics that make them desirable as weapons; the dominance of US air forces and the emphasis on US ballistic missile defenses may further increase their attractiveness. As a result, the United States and its allies are likely to

² Donald H. Rumsfeld, *Transformation Planning Guidance* (Washington, DC: Department of Defense, June 2003), p. 10; *2001 Quadrennial Defense Review Report* (Washington, DC: Department of Defense, 2001), p. 30.

³ Bradley Graham, "Pentagon Prepares to Rethink Focus on Conventional Warfare," *The Washington Post*, January 26, 2005, p. 2.

face a growing cruise missile challenge, from their employment in a future regional contingency to their use by terrorists against the US homeland.

I. Defining the Scope of the Problem

The United States faces a growing array of threats to sea- and land-based forces abroad as well as to the US homeland. These include manned aircraft, ballistic missiles, cruise missiles, and unconventional delivery means. Both theater and continental air defense are traditional missions, though the effort expended on continental air defense has varied widely over time. The US government has expended considerable effort over the past two decades to defend the United States, friends and allies, and forward-deployed forces against the threat of ballistic missiles. Since the September 11, 2001 terrorist attacks there has been a growing focus on non-traditional threats such as terrorist attack. Cruise missile defense has received much less attention. This paper is an attempt to remedy this shortfall. It focuses upon the threat posed by ASCMs, LACMs, and other unmanned attack vehicles over the next ten to twenty years.

Definitions of what exactly constitutes a cruise missile abound. The official Department of Defense (DoD) definition states that a cruise missile is “a guided missile, the major portion of whose flight path to its target is conducted at approximately constant velocity; depends on the dynamic reaction of air for lift and upon propulsion forces to balance drag.”⁴ Similarly, the Federation of American

⁴ Joint Publication 1-02, *U.S. Department of Defense Dictionary of Military and Associated Terms*.

Scientists defines a cruise missile as “an unmanned self-propelled guided vehicle that sustains flight through aerodynamic lift for most of its flight path and whose primary mission is to place an ordnance or special payload on a target.”⁵ Another authoritative source states, “A cruise missile is an unmanned, expendable, armed, aerodynamic, airbreathing, autonomous vehicle.”⁶

Such definitions mask considerable diversity in the composition of the global cruise missile inventory. Although most of the world’s cruise missiles are relatively short-range anti-ship cruise missiles, the number of states possessing land-attack cruise missiles and the size of their inventories are both increasing. To complicate matters, a number of countries are producing families of cruise missiles that include both ASCMs and LACMs. Others appear to have programs to convert ASCMs to LACMs.

There is also significant diversity in the characteristics of cruise missiles now or soon to be available. They can be launched from aircraft, ships, submarines, or from the ground. Although most cruise missiles use airbreathing (i.e., pulsejet, ramjet, turbojet, or turbofan) engines, others are rocket propelled while still others are propeller-driven. Some fly at less than 100 mph, while others travel at greater than three times the speed of sound. Some have tactical ranges, while others are capable of spanning intercontinental distances. Some employ inertial guidance systems, while others use precision navigation information from the Global Positioning System (GPS) or other satellite navigation constellations. Some fly at a high altitude before descending on their targets, while others hug the terrain.⁷

The growth of UAV and unmanned combat air vehicle (UCAV) programs further blurs the line separating cruise missiles from other weapons. In general, UAVs are unarmed, reusable systems, while

⁵ “Cruise Missiles,” at <http://www.fas.org/nuke/intro/cm> (accessed February 3, 2005).

⁶ John C. Toomay, “Technical Characteristics” in Richard K. Betts, ed., *Cruise Missiles: Technology, Strategy, Politics* (Washington, DC: Brookings, 1981), p. 31.

⁷ Lt Col Rex R. Kiziah, *Assessment of the Emerging Biocruise Threat*, The Counterproliferation Papers, Future Warfare Series No. 6 (Maxwell AFB, AL: Air University Press, August 2000), p. 26.

cruise missiles are armed and not reusable. However, UAVs can be modified to carry weapons or become crude cruise missiles. The United States, for example, has modified some of its RQ-1 *Predator* UAVs to carry two *Hellfire* air-to-surface missiles. Israel, for its part, produces the *Harpy*, a loitering unmanned system that is designed to detect, attack and destroy surface-to-air missile radars. A number of countries are developing more sophisticated UCAVs.

Rather than focusing on one element of the cruise missile challenge—LACMs, for example—this assessment seeks to examine it as a whole. This involves not only cruise missiles proper, but also other unmanned vehicles that could perform the same functions. Moreover, because the effectiveness of cruise missiles depends on more than the missile itself, it will also consider the launch and targeting capabilities of potential adversaries.

II. Key Trends in Cruise Missile Proliferation

Cruise missiles can be divided into two broad categories: ASCMs and LACMs. A comprehensive assessment must also consider opportunities to convert missiles from one mission to another, as well as converting other unmanned systems, such as UAVs, UCAVs, and kit aircraft, to perform substantially the same mission.⁸

ANTI-SHIP CRUISE MISSILES

The first ASCM to be deployed in large numbers was the Soviet SS-N-2 *Styx*, first fielded in 1959. The *Styx* weighs some 5,070 lbs and carries a 1,000-lb high-explosive warhead. Once launched, it flies toward its target at roughly Mach .9 to a maximum range of 45 km. It initially follows a prearranged flight profile using inertial guidance and a radio altimeter before activating an active radar sensor in its nose for

⁸ In his seminal monograph on cruise missile proliferation, Seth Carus divided cruise missiles into four categories: (1) strategic cruise missiles such as the US AGM-86 Air-Launched Cruise Missile and the BGM-109A *Tomahawk* Land-Attack Missile-Nuclear (TLAM-N); (2) anti-ship guided missiles; (3) conventional ground-attack missiles; and (4) harassment drones. W. Seth Carus, *Cruise Missile Proliferation in the 1990s*, Washington Paper 159 (Westport, CT: Praeger, 1992), p. 13.

terminal guidance. Early models fly at 100-300 meters above the surface; later models fly at 30-50 meters.

Forty-five years after the introduction of the basic *Styx* design, it is still one of the world's most numerous ASCMs. The militaries of Algeria, Angola, Bulgaria, Croatia, Cuba, Egypt, Ethiopia, Finland, India, Iraq, North Korea, Libya, Poland, Romania, Russia, Serbia, Syria, Vietnam, and Yemen possess *Styx* cruise missiles. China, North Korea, and India manufacture the missile.⁹ The *Styx* has spawned many variants, including the Chinese Hai Ying 1 (HY-1)/CSSC-2 *Silkworm* and HY-2/CSSC-3 *Seersucker*,¹⁰ as well as the turbojet-powered HY-4/CSSC-7 *Sadsack* and its air-launched counterpart, the YJ-6/CAS-1 *Kraken*.¹¹ Although the *Styx*'s large size, relatively slow speed, and relatively high flight altitude make it much less of a threat than it once was, its large size and simple design make it a prime candidate for conversion into a LACM.

The combat debut of the *Styx* during the 1967 Arab-Israeli War brought the ASCM to the attention of observers across the globe. On October 21, 1967 three *Styx* launched by Egyptian fast missile boats sank the Israeli destroyer *Eilat* off Port Said, Egypt.¹² To many, the

⁹ "SS-N-2 Styx" at <http://www.globalsecurity.org/military/world/russia/ss-n-2.htm> (accessed February 10, 2005).

¹⁰ Chinese missile nomenclature can be confusing. There are at least four sources of nomenclature for Chinese missiles: (1) the service designation apparently used by the Chinese military once a weapon enters operational service (i.e., HY-2); (2) the designation used by the manufacturer both prior to and following acceptance (i.e., C-201); (3) the NATO designation (i.e., *Seersucker*); and (4) the alphanumeric designation applied by the US intelligence community (i.e., CSSC-3). See "Chinese Conventional Missiles" at <http://www.fas.org/man/dod-101/sys/missile/row/prc.htm> (accessed February 10, 2005).

¹¹ China fields a number of variants of these missiles. The HY-1A replaces the HY-1's conical scanning terminal guidance radar with an advanced monopulse system that is resistant to interference from ocean waves and various forms of jamming. It also incorporates an advanced radio altimeter and new auto pilot that allows the missile to fly at an altitude of 50 m. The HY-2 features a longer fuselage to carry a larger volume of propellant. The HY-2A features an infrared terminal guidance seeker. On the *Silkworm* program, see Iris Chang, *Thread of the Silkworm* (New York: Basic Books, 1995), pp. 223-224.

¹² LCDR Asen Kojukharov, "In Retrospect: The Employment of Antiship Missiles," *Naval War College Review* (Autumn 1997).

combination of ASCMs and fast missile boats portended a revolution in naval warfare that would render major surface combatants and aircraft carriers obsolete.¹³ It led other navies to produce their own ASCMs and fast missile boats and to deploy missile countermeasures.

Characteristic of the second generation of ASCMs is the US AGM/UGM/RGM-84 *Harpoon*, first deployed in 1981. At 1,520 lbs, it is much smaller than the *Styx*; its 488-lb warhead weighs less than half that of the *Styx*. After launch from an aircraft, surface vessel, or submarine, the *Harpoon* flies at low altitude and uses an active radar seeker for terminal guidance. The *Harpoon* Block II, first fielded in 2002, incorporates GPS-assisted inertial navigation that allows it to attack both ships and land targets.

Another ASCM of the *Harpoon* generation is the French *Exocet*, which exists in both ship-and air-launched versions. The missile, which weighs 670 kg and has a 165 kg high-explosive shaped charge fragmentation warhead, uses inertial mid-course guidance and an active radar terminal seeker. The ship-launched version, introduced in 1975, has a range of about 50 km; the air-launched version, introduced in 1979, has a range of 70 km when released from medium altitude.¹⁴

Despite predictions to the contrary, small combatants armed with ASCMs have thus far posed only a limited threat to major navies such as the US Navy. Given the long sensor reach and strike capability of the US carrier battle groups, the few times the US Navy has faced an adversary armed with ASCM-equipped combatants, naval aircraft or helicopters have sunk or disabled them before they could come within striking range of US combatants. In March 1986 during Operation PRAIRIE FIRE, the naval confrontation with Libya, US Navy A-6E *Intruders* sank or damaged two Libyan missile corvettes and one fast missile attack craft with *Harpoon* ASCMs and *Rockeye* cluster bombs before they could threaten US ships.¹⁵ Two years later, the US Navy

¹³ See, for example, Anthony H. Cordesman and Abraham R. Wagner, *The Lessons of Modern War*, Volume 1, *The Arab-Israeli Conflicts, 1973-1989* (Boulder, CO: Westview Press, 1990), pp. 104-107.

¹⁴ "Exocet AM.39 / MM.40" at <http://www.fas.org/man/dod-101/sys/missile/row/exocet.htm> (accessed February 10, 2005).

¹⁵ Joseph T. Stanik, *El Dorado Canyon: Reagan's Undeclared War with Qaddafi* (Annapolis, MD: Naval Institute Press, 2003), pp. 134-138.

engaged the Iranian Navy during Operation PRAYING MANTIS after an Iranian mine struck and damaged the USS *Samuel B. Roberts* (FFG-58). Over a two-day period, US forces sank or destroyed three Iranian warships. During the operation, the Iranian fast missile craft *Joshan* fired a *Harpoon* ASCM at a US naval formation. In response, the USS *Simpson* (FFG-56) fired four *Harpoons*, disabling the *Joshan*.¹⁶

Air-launched cruise missiles (ALCMs) have posed a more significant threat to advanced navies. To many, Argentina's use of air- and ground-launched *Exocet* ASCMs against the Royal Navy during the 1982 Falklands War demonstrated the effectiveness of cruise missiles. During the war, *Exocets* sank the destroyer HMS *Sheffield* and the transport ship *Atlantic Conveyor* and damaged the amphibious ship HMS *Glamorgan*, killing 45.¹⁷ In 1987, 37 sailors died when two Iraqi *Exocets* accidentally struck the frigate USS *Stark* (FFG-31) while on patrol in the Persian Gulf. It should be noted, however, that neither the *Sheffield* nor the *Stark* were equipped with advanced air defense systems such as the AEGIS Combat System.

Current ASCMs are faster, stealthier, and fly at lower levels than the *Exocets* that struck the *Stark*. The Russian 3M-80E *Moskit* (SS-N-22 *Sunburn*), for example, carries a 300-kg semi-armor piercing warhead and uses a liquid ramjet engine and four solid boosters to fly at Mach 2.1 at 7-20 meters above the surface. Its high speed and low altitude reduce the warning time available to its targets. Moreover, it performs terminal maneuvers that make it extremely difficult to engage.¹⁸ The air-launched version of the *Sunburn*, the Kh-41 *Moskit*, carries a 200-kg payload and has a range of 250 km.¹⁹ The missile's

¹⁶ "Operation Praying Mantis" at http://www.globalsecurity.org/military/ops/praying_mantis.htm (accessed February 14, 2005).

¹⁷ It is worth noting that air-delivered bombs sank or severely damaged a destroyer, two frigates, and two landing ships.

¹⁸ "3M-80E Supersonic Anti-Ship Missile (SS-N-22)," at <http://www.sinodefense.com/navy/weapon/3m80.asp> (accessed February 3, 2005).

¹⁹ Col Geoffrey T. Lum, "China's Cruise Missile Program," *Military Review* (January-February 2004), p. 68.

designers have stated that the *Moskit* was developed to defeat the US Navy's Aegis air defense system.²⁰

The next generation of ASCMs will be equipped with advanced target seekers and stealthy designs that will make them even more difficult to detect and defeat.²¹ For example, the 3M55 *Yakhont* (SS-NX-26) has a ramjet engine that gives it a range of 300 km, a payload of 200 kg, and it flies just 5 meters above the surface of the ocean. The *Klub* family includes both ASCM and LACM variants and appears to include components of the 3M55 *Yakhont* (SS-NX-26) ASCM. The 3M54 *Klub* ASCM flies a low subsonic cruise profile to a range of 20 km from its target, then drops its cruise-stage engine and executes a supersonic sprint to the target.

ASSESSING THE ASCM THREAT

Nearly 70 nations possess sea- and land-launched ASCMs, and 20 possess air-launched cruise missiles (ALCMs), for a total inventory of more than 75,000 missiles. There are over 100 existing and projected missile varieties with ranges up to about 185 miles.²²

According to one study, 19 countries currently produce ASCMs. Of these, 11 export them.²³ In general, the countries that produce the most advanced ASCMs—France, Germany, Israel, Italy, Norway, Sweden, and the United Kingdom—are friends and allies of the United

²⁰ "3M-80E Supersonic Anti-Ship Missile (SS-N-22)," at <http://www.sinodefense.com/navy/weapon/3m80.asp> (accessed February 3, 2005).

²¹ General Accounting Office, *Comprehensive Strategy Needed to Improve Ship Cruise Missile Defense*, GAO/NSIAD-00-149 (Washington, DC: General Accounting Office, July 2000), p. 5.

²² GAO, *Comprehensive Strategy Needed to Improve Ship Cruise Missile Defense*, p. 5.

²³ Argentina, Brazil, China, France, Germany, India, Iran, Iraq, Israel, Italy, Japan, North Korea, Norway, Russia, South Africa, Sweden, Taiwan, the United Kingdom, and the United States are listed as producers; China, France, Israel, Italy, North Korea, Norway, Russia, South Africa, Sweden, the United Kingdom, and the United States are exporters. See Northrop Grumman Corporation, "Theater Missile Defense: The Cruise Missile Threat," briefing dated July 6, 2004, slide 12.

States. Conversely, the countries that are of greatest concern to the United States, such as Iran, North Korea, and China, tend to have ASCM inventories that are dominated by older weapon systems. Russia occupies a special place as a world-class producer of ASCMs that has also shown a willingness to spread such technology.

The global inventory of ASCMs is composed of a large number of relatively old short-range missiles as well as a smaller number of modern and more capable weapons. The most numerous are the *Harpoon*, *Exocet*, and those of the *Styx* family.²⁴ However, several navies are acquiring more capable ASCMs. China, for example, received the SS-N-22 *Sunburn* with the two *Sovremenny* destroyers it purchased from Russia. India fielded the Russian 3M-24E *Uran*/SS-N-25 *Switchblade* even before the Russian Navy did, purchased the ASCM version of the *Klub* for deployment on its *Kilo*-class submarines, and is developing the *BrahMos* ASCM with Russia.²⁵

The technical parameters of a cruise missile itself are only one factor determining its effectiveness as a weapon system. Much also depends upon the characteristics of the launch platform, the quality of targeting information available, and the geographic setting. The attacker must be able to identify and track its target and survive at least long enough to launch its weapons.

Targeting, particularly against mobile targets over the horizon (OTH), represents a particular challenge. The main threat facing US carrier battle groups during the later stages of the Cold War came from Soviet Naval Aviation's bombers equipped with air-launched cruise missiles. US naval planning during the 1980s assumed an attacking force of one or more regiments of 18 to 24 ALCM-equipped *Backfire* or *Badger* bombers, supported by reconnaissance and electronic

²⁴ Dennis M. Gormley, "UAVs and Cruise Missiles as Possible Terrorist Weapons" in James Clay Moltz, ed., *New Challenges in Missile Proliferation, Missile Defense, and Space Security*, Occasional Paper No. 12 (Monterey, CA: Monterey Institute Center for Nonproliferation Studies, 2003), pp. 3, 6.

²⁵ David Tanks, *Assessing the Cruise Missile Puzzle: How Great a Defense Challenge?* (Washington, DC: Institute for Foreign Policy Analysis, 2000), pp. 13-14.

warfare aircraft, which would launch their missiles 200 nm from their targets.²⁶

OTH targeting in support of such operations proved to be a difficult task. The Soviet Union developed a complex architecture for detecting and tracking US naval combatants, one that included not only submarines, surface ships and aircraft, but also two classes of satellites: the Radar Ocean Reconnaissance Satellite (RORSAT) and Electronic Intelligence Ocean Reconnaissance Satellite (EORSAT).²⁷

OTH targeting proved a challenge to the US Navy as well. The Tomahawk was originally developed as an OTH ASCM, the BGM-109B *Tomahawk* Anti Ship Missile, or TASM. The TASM used an inertial navigation system (INS) for navigation and passive and active terminal seekers. It would be launched in the general direction of its target, search it out, identify it, and attack it. However, because it might take the missile half an hour to reach its target, it required in-flight targeting updates. Although the US Navy developed an extensive targeting infrastructure for TASM, OTH targeting remained the Achilles Heel of the system and it never gained acceptance within the fleet.²⁸

Of course not all adversaries need develop such sophisticated—and expensive—approaches as those the Soviet Union and United States pursued. It may be possible, for example, to use fishing vessels or merchantmen to locate and track naval combatants. And ships operating in narrow waters—including both combatants and merchant vessels—are likely to be particularly easy to both track and strike. Very few countries currently possess the ability to conduct OTH attacks, though several more could acquire it over the next ten to twenty years. One country that appears to be seeking such a capability is China. A derivative of the C-802, the YJ-83/C-803, reportedly has a range of 250 km and the ability to receive targeting updates in flight. The

²⁶ Norman Friedman, *Seapower and Space: From the Dawn of the Missile Age to Net-Centric Warfare* (Annapolis, MD: Naval Institute Press, 2000), p. 237.

²⁷ *Ibid.*, pp. 157, 160-161, 196-197.

²⁸ *Ibid.*, p. 211.

missile can reportedly be launched from aircraft, ships, and submarines.²⁹

Countries of Concern

North Korea's ASCM force is unlikely to pose a major threat to the US Navy or Republic of Korea Navy over the next ten to twenty years. P'yongyang possesses several *Styx* variants, including the land-based SSC-2b *Samlet* and HY-1/CSSC-2 *Silkworm* or HY-2/CSSC-3 *Seersucker*. It has the ability to produce the HY-2 as well as an indigenous, extended-range version, dubbed the AG-1. The missiles are organized into two coastal defense missile regiments and deployed at hardened sites to cover the sea approaches to major North Korean ports and naval bases as well as the northern extremities of South Korea's coast.³⁰ The Korean People's Navy also includes 3 frigates and 15 small missile boats equipped with *Styx* ASCMs.³¹

Although P'yongyang's cruise missiles could threaten merchant shipping off North Korea, their range is insufficient to target the southern ports through which reinforcements and resupply would flow. Moreover, their large size and low speed would make them relatively easy targets for US and South Korean naval air defense systems. It is also likely that North Korea's missile sites and support facilities would be subjected to strikes from the outset of a war.

Iran also has a significant cruise missile arsenal. Although much of it is composed of older missile designs, the confined waters of the Persian Gulf could magnify the challenge they pose. The Islamic Republic of Iran Navy includes 3 frigates and 10 missile craft armed with Chinese Ying Ji-82 (YJ-82)/C-802 ASCM, a 120-km missile based upon the *Exocet*. The Iranian Revolutionary Guard Corps Navy operates 10 C-802-armed missile craft as well as HY-2/CSSC-3

²⁹ Lum, "China's Cruise Missile Program," p. 70.

³⁰ The missile's designation comes from the site of its first test, the An-gol Army Barracks south of Ch'ongjin. See Joseph S. Bermudez, "North Korea Continues Anti-Ship Cruise Missile Tests," *Jane's Navy International*, April 1, 2003.

³¹ International Institute for Strategic Studies, *The Military Balance 2003-2004* (Oxford: Oxford University Press, 2004), p. 160.

Seersucker coastal defense batteries.³² In addition, Iran has deployed C-802s on Qeshm Island in the Straits of Hormuz, posing a threat to both merchant shipping and naval vessels.

In recent years the Iranian government has announced the development of several new cruise missiles. The *Ra'ad*, unveiled in 2004, appears to be a modification of the HY-2/CSSC-3 *Seersucker*, with a fuselage that has been lengthened to accommodate a turbojet engine and supposedly a more advanced guidance system.³³ In June 2004, the Iranian Defense Ministry announced that Iran had produced the *Kosar*, an indigenous and allegedly stealthy ASCM.³⁴ The veracity of these claims is difficult to evaluate from open sources, however.

China has an even more formidable missile posture. The People's Liberation Army Navy (PLAN) possesses 2 *Hangzhou (Sovremenny)*-class destroyers armed with the SS-N-22 *Sunburn*, and more than 150 other missile armed destroyers, frigates, and fast attack craft armed with less capable missiles such as the HY-1 and YJ-8/C801, a derivative of the *Exocet*.

China is notable for its ability to deliver ASCMs not only from the land and sea, but also from the air and under the sea. China possesses a range of air-launched ASCMs, including the YJ-6/C-601, YJ-61/C-611, and YJ-81/C-801L, as well as the H-6 bombers to deliver them. Moreover, the Chinese submarine force has the ability to deliver ASCMs. The PLAN's order of battle contains 5 *Han*-class SSNs and 3 *Song*-class SSKs armed with the YJ-82, a submarine-launched version of the C-802 with a range of 120 km.³⁵ Such a force could be used against merchants, the Taiwanese Navy, or the US Navy.

³² *Ibid.*, p. 109.

³³ Scott Jones, "Ra'ad Cruise Missile Boosts Iran's Military Capability," *Jane's Intelligence Review*, April 1, 2004.

³⁴ Ed Blanche, "Iran Claims to Produce 'Stealth' Anti-Ship Cruise Missile," *Jane's Missiles and Rockets*, July 1, 2004.

³⁵ The YJ-82 is a derivative of the C-802 ASCM. For more on the development of China's submarine force, see Lyle Goldstein and William Murray, "Undersea Dragons: China's Maturing Submarine Force," *International Security* 28, No. 4 (Spring 2004), pp. 167-196.

Trends

While the global ASCM inventory is dominated by older systems that pose a minimal threat to the US Navy, there are several areas of concern. First, as noted above, a number of sophisticated ASCMs are beginning to make their way into more and more hands. Second, the US Navy's cruise missile defense capability is not keeping up with the evolution of the threat. While the Navy developed a formidable capability to meet the Soviet threat, its current capability is less robust. The Navy more often operates in formations that possess less defensive capability than the carrier battle group. Moreover, today's littoral environment affords naval combatants less warning than the open-ocean deployments of the Cold War. Vessels operating near land are likely to have less of an opportunity to spot missiles before launch as well as less time to react after they are launched.

Much, of course, depends upon the future acquisition choices of foreign navies. Specifically, what will navies do as their inventory of *Styx* variants becomes obsolescent? While some states may seek an OTH capability, many if not most will be satisfied with short-range ASCMs for use against regional rivals. Some of the latter may choose to maintain an increasingly obsolete fleet, while others may seek to acquire a new generation of increasingly capable short-range ASCMs.

Russia stands out as a pivotal player in determining the future composition of the cruise missile inventory. It is a world-class producer of supersonic, sea-skimming, maneuvering ASCMs. It has demonstrated a willingness to sell advanced cruise missiles to countries of concern to the United States, as it did when it sold *Sunburn*-equipped *Sovremenny* destroyers to China.³⁶ It has also entered into programs to produce highly advanced missiles with foreign partners. For example, Russia and India are jointly developing the 290-km *BrahMos* ASCM. The missile, which is designed to deliver a 300 kg warhead to a range of 290 km at over Mach 3, incorporates a Russian liquid fuel ramjet engine and an Indian guidance system. According to the missile's Indian program manager, the *BrahMos* may

³⁶ On the other hand, despite persistent reports that Russia planned to sell SS-N-22s to Iran, no such deal has materialized.

also be fielded as a LACM.³⁷ India is not a threat to the United States. If anything, it is a potential ally in the global war against radical Islam. However, it might sell the system to potential adversaries. Russia's willingness to enter into a joint development program with India also raises the possibility that Moscow might be willing to do the same with less savory partners. Moscow's future ASCM sales and production agreements will thus do much to shape the future cruise missile challenge.

Land-Attack Cruise Missiles

Although ASCMs predominate today, cruise missiles were first employed to attack land-based targets. Between June 1944 and March 1945, Germany launched approximately 21,000 V-1 cruise missiles against Britain (primarily London) and Belgium (primarily Antwerp), causing more than 18,000 casualties in London alone.³⁸ While the missiles were deadly, they were hardly invincible. Of the 2,759 V-1s the Germans fired at the port of Antwerp, for example, Allied fighters and anti-aircraft artillery destroyed 1,766.³⁹

Early Cold War cruise missile development focused on LACMs as well. The United States, for example, deployed the *Matador*, *Mace*, and *Snark* ground-launched cruise missiles and developed the longer-range *Navaho*. The Navy fielded the surface- and sub-launched *Regulus*.⁴⁰ The Soviets tested, but did not deploy, an intercontinental cruise missile.⁴¹ Such early weapons suffered from poor navigational accuracy and vulnerability to air defenses. During the 1973 Arab-Israeli War, for example, Egypt launched 25 AS-5 *Kelt* ALCMs against

³⁷ "India to Resume Trial of Supersonic Missile Brahmos," *The Asian Age*, February 6, 2002, p. 2; David C. Isby, "India to Develop Land-Attack Cruise Missiles," *Jane's Missiles and Rockets*, March 1, 2004.

³⁸ Dennis M. Gormley, *Dealing with the Threat of Cruise Missiles*, Adelphi Paper 339 (London: International Institute for Strategic Studies, 2001), p. 10.

³⁹ Carus, *Cruise Missile Proliferation in the 1990s*, p. 19.

⁴⁰ Kenneth P. Werrell, *The Evolution of the Cruise Missile* (Maxwell AFB, AL: Air University Press, 1996), ch. 4.

⁴¹ Steven Zaloga, *The Kremlin's Nuclear Sword: The Rise and Fall of Russia's Strategic Nuclear Forces, 1945-2000* (Washington, DC: Smithsonian Institution Press, 2002), p. 43.

Israeli targets, but Israeli fighters and anti-aircraft weapons shot down all but five.⁴²

Between the 1950s and the 1980s, improvements in engine, materials, fuel, and guidance technology transformed the cruise missile, making it a more effective weapon.⁴³ The result was cruise missiles such as the *Tomahawk*, first deployed in 1984, and its Soviet counterpart, the RKP-55/SS-N-21 *Granat*, deployed in 1987.

Until the late 1980s, accurate land-attack missiles required the use of sophisticated guidance and navigation technologies. Key to the effectiveness of these systems were high accuracy inertial navigation systems (INS) and navigational update systems such as Terrain Contour Matching (TERCOM), and Digital Scene Matching Correlation (DSMAC). TERCOM permits a missile to check its flight profile periodically to determine whether it is on course. It consists of a radar altimeter and a computer. Stored in the computer are digital altitude profiles of parallel strips of terrain from selected locations along the missile's flight path. As the missile reaches an approximate location on the map, the radar altimeter's returns generates a real-time altitude profile, which the computer compares to stored profiles to determine which profile the missile had just flown across.⁴⁴ Non-nuclear *Tomahawks* had their guidance supplemented by DSMAC, which compared images of the ground near the target with digital scenes in the system's memory.⁴⁵ The role of TERCOM was to deliver a cruise missile close enough to its target to allow DSMAC to sense it, perform a correlation, and provide terminal guidance.

As long as TERCOM and DSMAC represented the state of the art, there were three barriers to acquiring a LACM capability.⁴⁶ First, the systems depended upon maps derived from highly classified overhead reconnaissance systems. Second, developing a dedicated mapping infrastructure was prohibitively expensive for all but the most advanced militaries. A portfolio of targets, each with several

⁴² Carus, *Cruise Missile Proliferation in the 1990s*, p. 19.

⁴³ Werrell, *The Evolution of the Cruise Missile*, p. 135.

⁴⁴ Toomay, "Technical Characteristics," p. 37.

⁴⁵ Friedman, *Seapower and Space*, p. 269.

⁴⁶ Gormley, *Dealing with the Threat of Cruise Missiles*, p. 18.

TERCOM maps, required that over 100 million data points be gathered, analyzed, digitized, and assembled into maps.⁴⁷ Third, TERCOM and DSMAC were subject to strong export controls.

The commercial availability of signals from the GPS constellation as well as its Russian counterpart, GLONASS, has reduced considerably the barriers to entering the LACM competition and allowing cruise missiles to strike accurately at intercontinental distances. According to one estimate, the commercial availability of accurate satellite navigation data has allowed those seeking cruise missiles to shave 15 years off their development.⁴⁸ They are also relatively inexpensive. A relatively inaccurate and widely available INS costing \$50,000, combined with GPS receivers costing at most a few hundred dollars, can allow a missile to achieve navigational accuracies equivalent to those of a very sophisticated INS costing roughly \$150,000.⁴⁹ The commercial market has created integrated GPS/GLONASS receivers that are both highly accurate and resistant to US attempts to deny potential adversaries access to the GPS signal. In tests by Honeywell and Northwest Airlines, such receivers have shown positional fixes with accuracies consistently under 20 m.⁵⁰

Current LACM programs feature modular design, allowing the user to choose from a range of navigation suites and warhead options. Whereas earlier generations of ALCM had to be launched from a bomber, current models are small enough to be launched from a fighter or attack aircraft. They fly at high subsonic speeds at low altitudes and have terrain-following flight paths.⁵¹

⁴⁷ Toomay, "Technical Characteristics," p. 39.

⁴⁸ Kiziah, *Assessment of the Emerging Biocruise Threat*, p. 29.

⁴⁹ *Ibid.*, p. 29.

⁵⁰ Gormley, *Dealing with the Threat of Cruise Missiles*, p. 20.

⁵¹ National Air Intelligence Center, Ballistic and Cruise Missile Threat (Wright-Patterson AFB, OH: NAIC, September 2000) at http://www.acq.osd.mil/mda/mdalink/bcmt/lacm_7.html (accessed February 3, 2005).

LACMs: STOCKPILES AND PROGRAMS

Trends clearly point to a growing number of nations possessing LACMs. As late as 1998, only three countries – France, Russia, and the United States – possessed operational LACMs, and none had exported them.⁵² Two years later, the National Air Intelligence Center projected that at least 9 foreign countries will be involved in LACM production by the end of this decade. Several will make them available for export (see Table 1).⁵³ Demand for such weapons is high. As the then Director of Central Intelligence, George J. Tenet, testified in March 2004, “Many countries remain interested in developing or acquiring land-attack cruise missiles, which are almost always significantly more accurate than ballistic missiles and complicate missile defense systems.”⁵⁴

There are three paths to acquiring a LACM capability: purchase, indigenous development, or conversion of an ASCM, UAV, or other system. The easiest and most worrying path is for a state or terrorist group to purchase missiles from the growing ranks of LACM manufacturers. Indigenous development is the longest route to development and is unlikely to yield a modern design. And although the global inventory of ASCMs is large, only a small proportion of them are suitable for conversion into long-range systems. An easier path involves the conversion of UAVs and simple, lightweight aircraft into armed autonomous attack vehicles.

⁵² National Air Intelligence Center, Ballistic and Cruise Missile Threat, NAIC-1031-0985-98 (Wright-Patterson AFB, OH: NAIC, 1998) at <http://www.fas.org/irp/threat/missile/naic/part07.htm> (accessed February 3, 2005).

⁵³ NAIC, 2000 Ballistic and Cruise Missile Threat.

⁵⁴ Testimony of Director of Central Intelligence George J. Tenet before the Senate Armed Services Committee on “The Worldwide Threat 2004: Challenges in a Changing Global Context” (as prepared for delivery) at http://www.cia.gov/cia/public_affairs/speeches/2004/tenet_testimony_03092004.html (accessed October 15, 2004).

Table 1: Land-Attack Cruise Missile Characteristics

System	Country	Launch Mode	Warhead Type	Max Range (Mi)	IOC
New cruise missile	China	Undetermined	Conventional or nuclear	Undetermined	Undetermined
APACHE-A	France	Air	Conventional/submunitions	100+	2001+
APACHE-EG	France	Air and ship	Conventional/penetrator	300+	2002
Black Shaheen	UAE	Air	Conventional/penetrator	250+	2002+
KEPD-350	Germany/ Sweden/Italy	Air and ground	Conventional/ penetrator/submunitions	220+	2002
KEPD-150		Air and ship	Conventional/ unitary or submunitions	100+	2002
Popeye Turbo	Israel	Air	Conventional/unitary	200+	2002
AS-4	Russia	Air	Conventional or nuclear	200+	Operational
AS-15	Russia	Air	Nuclear	1,500+	Operational
SS-N-21	Russia	Submarine	Nuclear	1,500+	Operational
New Conventional cruise missile	Russia	Undetermined	Conventional/unitary or submunitions	Undetermined	Undetermined
MUPSOW	South Africa	Air and ground	Conventional/unitary or submunitions	125+	2002
TORGOS	South Africa	Air and ground	Conventional/unitary or submunitions	185+	2004+
Storm Shadow	United Kingdom	Air	Conventional/penetrator	300+	2002

Source: National Air Intelligence Center, Ballistic and Cruise Missile Threat (Wright-Patterson AFB, OH: NAIC, September 2000) at http://www.acq.osd.mil/mda/mdalink/bcmt/lacm_8.html (accessed February 3, 2005).

Purchase

Some countries will seek to purchase LACMs from suppliers. Russia, for example, began marketing LACMs at the 1992 Moscow Air Show, when it offered a shorter-range version of the Kh-55 *Granat*/AS-15 *Kent*, which has a range of 3,000 km (1,860 miles) and was designed to carry a nuclear warhead. The missile was advertised with a range of 500 km, a payload of 410 kg, and a TERCOM-like guidance system with GLONASS updates for a promised accuracy of 20m. At the International Defense Exposition (IDEX) arms show the following year in Abu Dhabi, the Russians displayed the Kh-65E, a scaled-down AS-15 with a range of 280 km.⁵⁵ Recent reports suggest that Ukraine may have exported the AS-15 to both China and Iran.⁵⁶

The prospect of LACM proliferation is not confined to the traditional producers. For example, South Africa is offering the TORGOS air-launched LACM for export. The turbojet-powered missile has an advertised range of 300 km, payload of 500 kg, and accuracy of 2 m. The missile appears to have several advanced features, including an imaging infrared terminal seeker, a digital data link for guidance and control, automatic target recognition, and an optional low-light television sensor.⁵⁷

European states are another emerging source of LACMs. France's *Apache* family, which entered development in 1989, exists in several forms, but all share the same basic airframe, which has a stealthy aerodynamic shape and incorporates low-observable materials and infrared signature reduction. The shortest range system is the *Apache*, which carries a 520 kg payload of anti-runway submunitions 140 km. The *Storm Shadow*, employed in combat by the Royal Air Force during Operation IRAQI FREEDOM, has a range of 300-400 km. An even longer range variant is the French SCALP EG.⁵⁸ Moreover, such weapons are proliferating: Italy and Greece have

⁵⁵ Gormley, *Dealing with the Threat of Cruise Missiles*, p. 37.

⁵⁶ Tom Warner, "Ukraine 'Sold Cruise Missiles to Iran, China,'" *Financial Times*, February 3, 2005, p. 1; Associated Press, "Lawmaker Accuses Ukraine's Former Regime of Selling Cruise Missiles to Iran and China," February 2, 2005.

⁵⁷ NAIC, 2000 Ballistic and Cruise Missile Threat.

⁵⁸ Gormley, *Dealing with the Threat of Cruise Missiles*, p. 39.

purchased the SCALP EG, and Britain and France have sold a variation of the missile, the *Black Shaheen*, to the United Arab Emirates.

Indigenous Development

Indigenous development takes longer and is limited by a state's domestic infrastructure. Still, it remains an attractive option to many. China, for example, is reportedly developing two types of LACMs to complement its growing force of approximately 500 short-range ballistic missiles based opposite Taiwan: an ALCM and a longer-range LACM. Both are likely to become operational within the next 5 to 10 years.⁵⁹

First, China is expected to field the 400-500 km range *Ying Ji* (YJ-63) ALCM within the next few years. Second, last October it test-fired the *Dong Hai-10* (DH-10) ground-launched LACM, which reportedly has a range of more than 1,500 km. Press reports credit the missile, which reportedly uses a combination of INS and GPS for guidance, with a circular error probable (CEP) of 10 meters.⁶⁰

Despite the commercial availability of the components of a highly accurate guidance system, integrating them remains a challenge, even for the technologically proficient. Although China, for example, possesses a mature infrastructure for missile production, the difficulty of producing a guidance system has slowed its LACM program.⁶¹

Taiwan, for its part, is reportedly pursuing the *Hsiung Feng 2E* LACM to strike targets along China's coastline. Based upon the *Hsiung Feng 2* ASCM, the missile reportedly has a range of 1,000-1,500 km.⁶²

⁵⁹ FY04 Report to Congress on PRC Military Power Pursuant to the FY2000 National Defense Authorization Act, pp. 37, 49.

⁶⁰ Wendell Minnick, "China Tests New Land-Attack Cruise Missile," *Jane's Missiles and Rockets*, October 1, 2004.

⁶¹ You Ji in Goldman and Mahnken, p. 111.

⁶² Wendell Minnick, "Taiwan Has Ambitious Plans," *Jane's Missiles and Rockets*, April 1, 2004.

To show just how easy it would be for “almost any person or small group of persons with the necessary knowledge and skills” to build a cheap cruise missile, an engineer in New Zealand, Bruce Simpson, began building one in his garage with materials purchased over the Internet for under \$5,000, documenting his project on his website.⁶³ He was able to build and test a pulsejet engine for the missile before being put out of business by local authorities, ostensibly for tax evasion.

Converting an ASCM

Another path to acquiring a LACM would be to convert an ASCM into a LACM. Such an approach is hardly without precedent. As noted above, the *Tomahawk* cruise missile was originally developed as an anti-ship missile, the TASM. The program was only later expanded to include a nuclear land-attack variant (the BGM-109A *Tomahawk* Land Attack Missile—Nuclear, or TLAM-N) and several conventional LACMs.⁶⁴ The United States has similarly fielded a LACM variant of the AGM-84 *Harpoon*, the Short-Range Land Attack Missile, or AGM-84E SLAM.

Many ASCMs are, however, unsuitable to conversion to a LACM. They either lack the propulsion system or payload characteristic of long-range LACMs. On the other hand, the roominess and simplicity of design of the Chinese HY-4 make it an ideal candidate for conversion to a LACM. It is the only *Styx* variant that possesses a turbojet engine; others would require a new propulsion system. As currently configured, the HY-4 has a range of 150 km, a payload of 500 kg, and a cruising speed of Mach 0.8. Replacing the missile’s bulky autopilot and avionics system with an integrated INS/GPS guidance package would increase the missile’s accuracy to less than

⁶³ “A DIY Cruise Missile,” at <http://www.interestingprojects.com/cruisemissile/> (accessed October 14, 2004). See also Bruce Simpson, “The Low Cost Cruise Missile: A Looming Threat?” at <http://aardvark.co.nz/pjet/cruise.shtml> (accessed October 14, 2004).

⁶⁴ On the development of the Tomahawk, see Robert J. Art and Stephen E. Ockenden, “The Domestic Politics of Cruise Missile Development, 1970-1980” in Richard K. Betts, ed., *Cruise Missiles: Technology, Strategy, Politics* (Washington, DC: Brookings, 1981).

100 meters and free up internal volume for fuel to increase the missile's range. With the addition of two short fuel plugs, the missile's range could be increased to 700 km.⁶⁵

Under Saddam Hussein, Iraq undertook two cruise missile programs. The first, dubbed *Al Faw*, used modifications to the HY-2's propulsion system, together with components from C601 and C-611 ASCMs to extend its range from about 100 to 150 km.⁶⁶ In late 2001, Baghdad inaugurated the *Jinin* project, an attempt to convert the HY-2 into a 1,000-km LACM. The project envisioned modifying the missile's flight computers and replacing its rocket engine with a turbojet.⁶⁷

There are two major barriers to converting an ASCM such as the HY-4 to a LACM. The most formidable would be obtaining a suitable navigation system. An Intel 486-class chip equipped with 16 MB of RAM and a 1 GB hard drive would be sufficient to act as the missile's flight management computer, the heart of its navigational system. Although the components of such a system are available off the shelf, integrating them is difficult. The user would also have to write some basic software to control the system. The most daunting challenge would be integrating the system's complex subsystems. According to one estimate, with modest foreign technical and engineering assistance, Iran could convert its Silkworms to LACMs in six to ten years. With more substantial help, that time could conceivably be cut in half.⁶⁸

The other major barrier would be incorporating a suitable turbojet engine. It remains difficult for regional powers to manufacture or acquire gas turbine engines for LACMs with ranges above 300 km. China manufactures the WP-11 engine for its HY-4 ASCM, but has to rely on Russian assistance to produce advanced turbofan designs. Although India, Israel, South Africa and Taiwan are currently developing small turbojet engines that could conceivably

⁶⁵ Lum, "China's Cruise Missile Program," p. 71.

⁶⁶ *Comprehensive Report of the Special Advisor to the DCI on Iraq's WMD*, volume 2 (Washington, DC: GPO, September 30, 2004), p. 37.

⁶⁷ *Ibid.*, pp. 39, 41.

⁶⁸ Gormley, *Dealing with the Threat of Cruise Missiles*, p. 32-33.

support cruise missiles capable of ranges up to 1,000 km, for the foreseeable future the manufacture of highly advanced turbofan designs is likely to remain limited to the United States and Russia.⁶⁹

Converting Unmanned Aerial Vehicles and Kit Aircraft

Estimates of the world inventory of UAVs are much less precise than those of ASCMs and LACMs. According to one recent study, at least 40 countries have produced more than 600 different types of UAVs, nearly 80 percent of which have ranges of over 300 km, 65 percent beyond 500 km, and 36 percent beyond 1,000 km.⁷⁰ Of these, only 22 producers are members of the Missile Technology Control Regime and therefore bound by its export constraints.

Nearly two-thirds of current UAVs are propelled by reciprocating engines and fly at less than 160 km/hr.⁷¹ Such a feature is actually an advantage as advanced air defense systems are designed to detect high-performance aircraft at high speeds and ignore slow ones. Look-down radars eliminate slow-moving targets on or near the ground to prevent their data processing and display systems from being overwhelmed. As a result, large numbers of propeller-driven UAVs flying at low speed could easily be ignored as potential targets.⁷²

The steps needed to modify a UAV into a LACM are much the same as those needed to convert an ASCM. Some UAVs already have GPS/INS guidance or fire-control systems that can be used to fly pre-programmed paths. In these cases, conversion is relatively straightforward. In other cases it would be necessary to equip the UAV

⁶⁹ Ibid., p. 21-22.

⁷⁰ Ibid., p. 34.

⁷¹ Dennis M. Gormley, "New Developments in Unmanned Air Vehicles and Land-Attack Cruise Missiles" in *SIPRI Yearbook 2003: Armaments, Disarmament and International Security* (Oxford: Oxford University Press, 2003), p. 411.

⁷² John Stillion and David T. Orletsky, *Airbase Vulnerability to Conventional Cruise-Missile and Ballistic-Missile Attacks* (Santa Monica: RAND, 1999), p. 17; Gormley, *Dealing with the Threat of Cruise Missiles*, p. 11.

with a guidance package consisting of a GPS receiver and radar altimeter and replace its sensors and data links with a warhead and extra fuel.⁷³

A number of states have weaponized UAV programs. China, for example, has obtained the Israeli *Harpy* attack drone. Moreover, China also has co-developed with TAAS Industries of Israel the air-launched *Delilah* anti-radiation cruise missile, a weapon with a 54-kg payload and 400-km range.⁷⁴ India's Defense Research and Development Organization is reportedly planning a LACM based upon the design of the *Lakshya* target drone. The missile will reportedly carry a 450 kg payload to a range of 600 km, guided by a combined INS/GPS system and a radar or infrared terminal seeker.⁷⁵ In addition, there has been speculation in the Indian press that New Delhi may convert the *Nishant* UAV into a short-range cruise missile like the *Harpy*.⁷⁶

At least one terrorist group has also demonstrated a UAV capability. On November 7, 2004, a UAV operated by Hezbollah entered Israeli airspace from Lebanon and spent nearly half an hour over Israeli territory. Hezbollah later released footage of the UAV. Although the group claimed that the vehicle, called the *Mirsad-1*, was an indigenous design, others have speculated that it may have been obtained from Iran.⁷⁷

Another option would be to convert a simple, cheap airplane kit into a weapons-carrying vehicle. Converting a kit aircraft would be cheaper, would require less skill, and would take fewer steps. Nearly 500 such designs are available, many with a range of 1,000 km and a

⁷³ Stillion and Orletsky, *Airbase Vulnerability*, p. 15; Gormley, *Dealing with the Threat of Cruise Missiles*, p. 33

⁷⁴ Lum, "China's Cruise Missile Program," p. 69.

⁷⁵ Isby, "India to Develop Land-Attack Cruise Missiles,," Gormley, *Dealing with the Threat of Cruise Missiles*, pp. 25-26.

⁷⁶ Isby, "India to Develop Land-Attack Cruise Missiles."

⁷⁷ Eugene Miasnikov, "Terrorists Develop UAVs" at <http://www.armscontrol.ru/UAV/mirsad1.htm> (accessed February 14, 2005).

payload of 200 kg. According to one estimate, a kit aircraft could be converted into a weapon for roughly \$60,000.⁷⁸

⁷⁸ Gormley, "Missile Defense Myopia," p. 74.

III. Military Significance of Cruise Missile Proliferation

ASCMs will continue to threaten both merchant vessels and naval combatants, particularly when operating in coastal waters or narrow seas. Moreover, the threat to even advanced surface combatants will grow as modern ASCMs continue to proliferate.

Although ASCMs have played a significant role in war at sea for the past four decades, the 2003 Iraq War marked the first time LACMs targeted US forces.⁷⁹ By contrast, America's enemies have used ballistic missiles against US forces and facilities on three different occasions.⁸⁰

In part, this is because the handful of countries that possessed LACMs did not proliferate them. There was, in other words, no cruise missile equivalent for the ubiquitous *Scud* short-range ballistic missile. The United States has only sold the TLAM to one country,

⁷⁹ During the Iran-Iraq War, Iran fired at least six *Silkworm* missiles at Kuwaiti shipping and oil processing facilities.

⁸⁰ Libya fired *Scuds* at a US facility on Lampedusa Island off Italy in 1986. Iraq launched *Scud*, *Al-Hussein*, and *Al-Abbas* ballistic missiles against US forces in Bahrain and Saudi Arabia during the 1991 Gulf War. Iraq launched 19 *Ababil-100* and *Al Samoud II* missiles against US forces during the 2003 Iraq War.

Great Britain, but not until 1998. Similarly, until recently the barriers to producing accurate LACMs indigenously were substantial.

ADVANTAGES AND DISADVANTAGES

Cruise missiles have a number of desirable characteristics. First, their small size makes them easy to hide and more mobile than ballistic missiles. For example, according to the US Army's 32nd Army Air Missile Defense Command, 11 of Iraq's 15 *Ababil-100* ballistic missile launchers were destroyed by combat operations; the remainder of them were secured after the capture of Baghdad. Similarly, 7 of Iraq's 11 *Al Samoud II* ballistic missile launchers were destroyed in combat. By contrast, one week into Operation IRAQI FREEDOM, soldiers of Iraq's coastal defense cruise missile battery managed to set up firing positions on the Al Faw peninsula and fire two *Seersuckers* at Kuwait, even though the peninsula had been occupied by British Royal Marines a week earlier. Three days later they managed to fire another pair of missiles from positions north of Basrah.⁸¹

It is also easier to field accurate cruise missiles than ballistic missiles. Ballistic missiles based upon the *Scud B* have a CEP of between 1 and 2 km. Without extensive modification involving the development of maneuvering reentry vehicles, they can only utilize GPS signals for navigation updates before main engine cutoff. As a result, GPS updates would be expected to improve accuracy by at most 20 percent. Advanced ballistic missiles with a separating payload section can expect CEP improvements from GPS of about 70 percent. Further improvements would require the integration of sophisticated technology, such as the map-matching guidance used in the *Pershing II* ballistic missile. While such technology is within reach of a country like China, it is difficult and expensive. The relative ease of achieving high accuracy with cruise missiles makes them more attractive.⁸²

Cruise missiles can also be developed at a substantially lower cost than comparable ballistic missiles. According to one US Army

⁸¹ Tim Ripley, "Iraqi Missile Forces Failed to Impact on Iraqi Freedom," *Jane's Intelligence Review* (April 2004).

⁸² Gormley, *Dealing with the Threat of Cruise Missiles*, p. 46.

estimate, a developing nation could acquire at least 100 cruise missiles for \$50 million. The same investment would buy only 15 short-range ballistic missiles and three transporter-erector-launchers.⁸³ Although some of the most capable cruise missiles, such as the TLAM, tend to cost more than \$1 million per copy, a number of missiles, such as the *Switchblade*, can be had for less than \$400,000. Others, such as the HY-2 series, cost \$250,000 or less. Many, if not most, UAVs cost even less. By comparison, the *Scud B* reportedly sells for between \$500,000 and \$1 million per missile, and Chinese ballistic missiles have reportedly been offered for between \$1 million (for the M-11) and \$2 million (for the M-9)⁸⁴ The fact that ballistic missiles require extensive support equipment for movement, command and control, launch, and resupply further adds to their cost. By contrast, cruise missiles can be launched from aircraft and surface vessels and can use more austere missile transporter/erector/launchers (TELS).

Roles and Missions

Like any weapon, cruise missiles are better suited to some roles than others. At sea, cruise missiles pose the primary long-range threat to surface combatants. They are also better at avoiding air defenses than ballistic missiles. While ballistic missiles follow a predictable trajectory, modern cruise missiles can fly at low altitudes to stay below the enemy's radar horizon and—in some cases—hide behind terrain features. Moreover, like aircraft they can approach and attack targets from different directions to overwhelm defenses. They can also use circuitous routes to avoid air defense radars.⁸⁵

Cruise missiles have inherently low visual, infrared, and radar signatures; newer models incorporate stealth features to reduce their radar and infrared signatures. Some developmental systems may also

⁸³ *Ibid.*, p. 53.

⁸⁴ Christopher Bolkcom, Analyst in National Defense, Congressional Research Service, testimony before the Senate Governmental Affairs Committee, June 11, 2002, p. 2; Gormley, *Dealing with the Threat of Cruise Missiles*, pp. 53-54.

⁸⁵ NAIC, 2000 Ballistic and Cruise Missile Threat.

incorporate chaff and decoys.⁸⁶ These features contribute to their survivability.

As Dennis Gormley has noted, the success of the *Patriot* theater ballistic missile defense system in the Iraq War, coupled with the difficulties the US-led coalition encountered in preventing Iraqi cruise missile attacks, increases the incentives of future adversaries to integrate cruise missiles into their operational plans. The low purchase and operational costs of cruise missiles further increases their attractiveness. Potential adversaries may also see an operational advantage in combining ballistic and cruise missile attacks. The most worrisome scenario is one in which an adversary would employ a large number of cheap cruise missiles, a smaller number of more sophisticated, stealthy cruise missiles, and ballistic missiles.⁸⁷

Finally, cruise missiles are much better suited to delivering chemical and biological weapons than ballistic missiles. A cruise missile's steady horizontal flight permits the release and spraying of chemical or biological agent at right angles to the wind direction and upwind of the target area, greatly increasing dissemination efficiency.⁸⁸ Although there are a number of technological hurdles to disseminating chemical—and especially biological—agents,⁸⁹ it is worth remembering that the US Army Chemical Corps overcame them more than forty years ago.⁹⁰ Such a capability is within the reach of a range of states. Disseminating either chemical or biological agent from a rapidly descending ballistic missile is both less efficient and more technologically challenging.

Cruise missiles also have disadvantages relative to other strike means. They are, for example, less efficient than ballistic missiles at destroying certain types of targets. For example, one recent study estimated that one GPS-guided ballistic missile armed with conventional submunitions could severely damage or destroy almost

⁸⁶ Ibid.

⁸⁷ Gormley, "Missile Defense Myopia," pp. 62, 74.

⁸⁸ Ibid., p. 72.

⁸⁹ These include: (1) the effective dissemination of the agent; (2) maintaining viability of the agent; and (3) selecting an appropriate delivery system.

⁹⁰ Kiziah, *Assessment of the Emerging Biocruise Threat*, p. 17.

an entire fighter wing parked in the open. It would take almost a dozen cruise missiles with submunitions to do the same damage.⁹¹

Cruise missiles in general—and LACMs in particular—are less effective than manned aircraft at striking moving targets. Most cruise missiles are autonomous and lack the ability to be re-targeted once launched. Similarly, most cannot track moving objects. Mobility will thus continue to provide protection against cruise missile attack.

Cruise missiles are also generally less effective than air-launched precision-guided munitions (PGMs) at attacking hardened targets. Hard-target penetrating PGMs employ high velocity and special warheads to destroy hardened targets. Precise ballistic missiles also can be used against hardened targets. The *Pershing II*, for example, was designed to destroy hardened targets with a nuclear warhead. Most cruise missiles, however, lack the high velocity and payload to be able to threaten such targets.

PLAUSIBLE SCENARIOS FOR CRUISE MISSILE USE

A diagnostic assessment of the cruise missile challenge should also include an exploration of plausible scenarios in which cruise missiles could be used against the United States, highlighting particular challenges to the United States, its forces, and allies. A representative range of scenarios should examine the employment of different types of cruise missiles (i.e., both anti-ship and land-attack missiles). It should also cover a range of threats, from small numbers of relatively unsophisticated missiles to larger, more sophisticated integrated attacks including not just cruise missiles but other attack means. It should examine the use of cruise missiles by both states and non-state actors, such as terrorist groups. Finally, it should highlight particular challenges to US national security, including the ability of potential adversaries to deny the United States access to key areas, or to threaten the US homeland.

⁹¹ Stillion and Orletsky, *Airbase Vulnerability to Conventional Cruise-Missile and Ballistic-Missile Attacks*, p. 13.

Cruise missiles are likely to be increasingly attractive to US adversaries. The success of the US air forces has made competing head-to-head with the United States in the air a singularly unattractive prospect. Moreover, the demonstrated effectiveness of US theater ballistic missile defense units may divert some competitors away from investment in ballistic missiles. As the Chief of Staff of the 32nd Army Air and Missile Defense Command commented regarding Iraq's cruise missile force, "this was a glimpse of future threats. It's a poor man's air force. A thinking enemy will use uncommon means such as cruise missiles and unmanned aerial vehicles on multiple fronts."⁹²

THE PERSIAN GULF

The Defense Department has stipulated the need for forces that can, among other things, protect "critical bases of operations, including the US homeland, forces abroad, allies, and friends, and defeating weapons of mass destruction and their means of delivery."⁹³ Cruise missiles already pose a threat to US bases. One recent analysis determined that less than a dozen cruise missiles equipped with submunition warheads could severely damage or destroy almost an entire fighter wing parked in the open.⁹⁴ ASCMs similarly threaten US ships, particularly in chokepoints and littoral waters.

Iran could use a combination of ASCMs, LACMs, and ballistic missiles to deny the United States access to the region in a future conflict. One recent study, for example, explored a combined ballistic and cruise missile attack on four Persian Gulf air bases: Dhahran,

⁹² Gormley, "Missile Defense Myopia," p. 62.

⁹³ Donald H. Rumsfeld, *Transformation Planning Guidance* (Washington, DC: Department of Defense, June 2003), p. 10; *Quadrennial Defense Review Report* (Washington, DC: Department of Defense, 30 September 2001), p. 30.

⁹⁴ One GPS-equipped ballistic missile armed with conventional submunitions could do the same damage. See Stillion and Orletsky, *Airbase Vulnerability to Conventional Cruise-Missile and Ballistic-Missile Attacks*, p. 13.

Doha, Riyadh Military, and Al Kharj.⁹⁵ These bases together comprise 14 parking areas totaling around 13.5 million square feet.⁹⁶

This scenario posits a conflict between Iran and the United States. Iran's strategy is to allow US forces to deploy to the region, then attack their basing infrastructure with conventionally armed cruise and ballistic missiles. According to modeling by researchers at the RAND Corporation, an attack by less than 100 missiles—60 GPS-guided ballistic missiles and 38 slow-flying UAVs converted into rudimentary cruise missiles—could achieve a 90% probability of destroying all aircraft parked in the open. Attacks on tent cities housing support personnel and missile defense radars would require an additional 40 ballistic missiles and 8 converted UAVs.

In this scenario, the Iranian missile force draws its effectiveness from the combination of precision (from GPS guidance) and highly lethal submunition warheads against aircraft in the open. Even more lethal scenarios are plausible, however. For example, if the Iranians used converted kit aircraft, they could have delivered a larger payload of submunitions at one-quarter to one-sixth of the cost. If they used more advanced cruise missiles, coordinated ballistic and cruise missile strikes would prove much easier to effect.⁹⁷

The use of chemical or biological weapons by cruise missiles would further complicate US air operations. According to one study, it is possible to degrade operations at 11 air bases in the Persian Gulf region by delivering between 500 and 2,000 kg of Sarin or VX nerve agent. Moreover, only 5 to 10 kg of anthrax would be required to cover most of an air base.⁹⁸ Cruise missiles are well suited to disseminating such agents.

⁹⁵ These bases were selected because all have been used in the past and are within 1,100 km of Iran. Basing US short-range air assets outside this range would greatly increase the number of tanker sorties needed to support air operations.

⁹⁶ This scenario is documented in Stillion and Orletsky, *Airbase Vulnerability to Conventional Cruise-Missile and Ballistic-Missile Attacks*, ch. 3.

⁹⁷ Gormley, *Dealing with the Threat of Cruise Missiles*, p. 49.

⁹⁸ Cited in *Ibid.*, p. 50.

ASCMs would also figure into an Iranian effort to deny the United States access to the region. Iran could use land-based ASCMs to raise the cost of operations in the confined waters of the Persian Gulf and North Arabian Gulf. The Iranian leadership would calculate that the possibility of missile strikes would force the US Navy to keep a healthy distance, thereby substantially reducing its effectiveness.

A War Across the Taiwan Strait

Cruise missiles would likely feature in a future war across the Taiwan Strait. On the one hand, China's missile capability is growing significantly. On the other, Taiwan concentrates its military aircraft at three of its eight major air bases. Such concentration makes a missile attack lucrative.

A cruise missile strike is well tailored to pinning down Taiwanese air defense fighters. An attack by 75 cruise missiles equipped with runway-cratering submunitions would be sufficient to provide a 90 percent probability of temporarily closing the main runways and parallel taxiways at Taiwan's three primary air bases as well as the one that houses Taiwan's airborne surveillance aircraft. An additional 10 or so cruise missiles could disable Taiwan's *Patriot* air defense radars.⁹⁹ The 1,500 km range attributed to China's DH-10 cruise missile would permit it to fly circuitous flight paths and strike targets from all azimuths, greatly complicating the task of defense.

Having pinned down Taiwanese air defenses, China could follow up with strikes by GPS-aided ballistic missiles on other air base targets, early warning and air defense radars, and command and control targets.¹⁰⁰ These strikes would create a much more permissive environment for Chinese attack aircraft.

The key to Chinese success in in such a conflict would lie in deterring, delaying, or interfering with US intervention on Taiwan's behalf. ASCMs would likely figure in this equation. While ASCM-armed surface ships are less of a concern, ASCM-armed submarines

⁹⁹ Gormley, *Dealing with the Threat of Cruise Missiles*, p. 52.

¹⁰⁰ *Ibid.*, p. 52.

operating in littoral waters and ALCM-equipped bombers operating over Chinese territory could prove more worrisome. As with the Iranians, the Chinese might calculate that the risk to US forces from cruise missiles would hold US forces at arm's length.

Taiwan's missile programs are another factor to consider. Ballistic and cruise missiles, together with information warfare, offer Taiwan its best opportunity to deter or retaliate against Chinese missile strikes. Taiwanese strikes on the Chinese homeland could complicate a future conflict.

Terrorist Use

Another potential threat would be the use of cruise missiles by terrorist groups. According to a recent unclassified National Intelligence Estimate on missile proliferation, "A commercial surface vessel, covertly equipped to launch cruise missiles, would be a plausible alternative for a forward-based launch platform. This method would provide a large and potentially inconspicuous platform to launch a cruise missile while providing at least some cover for launch deniability."¹⁰¹

The world's merchant fleet is huge, with more than 100,000 ships worldwide.¹⁰² Moreover, it is a relatively simple matter to change the name, flag, paint scheme, and even appearance of a vessel to disguise it. Even the relatively large *Seersucker* can be hidden and launched from a standard 12-meter shipping container complete with a small internal erector for launching.¹⁰³ Should a container ship containing such a cruise missile be able to approach to within 500 nm

¹⁰¹ National Intelligence Council, *Foreign Missile Developments and the Ballistic Missile Threat to the United States Through 2015* (Washington, DC: Central Intelligence Agency, 1999), p. 12.

¹⁰² Defense Science Board 2003 Summer Study on DoD Roles and Missions in Homeland Security, Volume II-A: Supporting Reports (Washington, DC: Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, May 2004), p. 65.

¹⁰³ Gormley, "Missile Defense Myopia," p. 75.

of the East Coast, its weapon would be able to reach targets from Raleigh, North Carolina to Augusta, Maine within an hour.¹⁰⁴

A terrorist cruise missile could be used to dispense chemical or biological weapons or deliver a radiological weapon, a so-called “dirty bomb” composed of a mixture of explosive and radioactive material. If a dirty bomb were detonated in a densely populated area, it could result in tens of deaths, hundreds of possible deaths, thousands of cases of radiation sickness, and widespread contamination.¹⁰⁵

Finding such a ship would be a daunting task. Locating a vessel 500 nm off the coast of the United States would require searching three million square miles of ocean. Even if the launch platform were to be located, intercepting and destroying its cruise missiles during their relatively short flights would be even more difficult. Further complicating the task would be the fact that defense against wind-dispersed chemical and biological warfare agents would require the destruction of the missile about 100 km out to sea, further shortening reaction time.¹⁰⁶ The 2004 Defense Science Board Summer Study on Defense Department Roles and Missions for Homeland Security concluded that “ocean vessels, cruise missiles, and low-flying aircraft are credible delivery systems available to adversaries. DoD needs to take steps to counter these threats as a complement to ongoing initiatives to defend against ballistic missiles.”¹⁰⁷

¹⁰⁴ “Theater Missile Defense: The Cruise Missile Threat,” p. 19.

¹⁰⁵ *Ibid.*, p. 21.

¹⁰⁶ DSB 2003 Summer Study, p. 65.

¹⁰⁷ *Ibid.*

IV. Implications for the Defense Department

The cruise missile threat is best understood as a subset of the growing spectrum of threats to forward-deployed land and naval forces as well as the US homeland. Over the next ten to twenty years, US forces abroad and the United States itself face a diverse range of threats from ballistic missiles, cruise missiles, manned aircraft, and unconventional attacks by terrorist groups.

Within this context, the cruise missile challenge is real and growing. As the recent Defense Science Board Summer Study concluded, the threat “is quite serious and will probably get more serious in the future.”¹⁰⁸ Three specific challenges stand out. The first is the growing threat that highly capable ASCMs, such as the SS-N-22 *Sunburn* as well as more modern systems like the *Klub* family, will pose to forward-based naval forces. These missiles contribute to the considerable advantage the offense enjoys over the defense in naval warfare, an edge that appears to be growing. There is currently no effective active defense against such low-flying, fast weapons; the best hope of protecting naval combatants lies in destroying launch platforms before they launch their missiles or in fielding effective decoys or countermeasures. If purchased in sufficient numbers by

¹⁰⁸ Ibid., p. 67.

countries of concern, they would raise considerably the cost of littoral naval operations.

While these missiles may prove lethal at short ranges, few of the countries that possess ASCMs have an ability to locate targets over the horizon. Until they do, US naval forces will be at greatest risk when they operate close to hostile shores. Moreover, the sensor reach and long-range strike capability of advanced navies may allow them to “outrange” most cruise missile threats. In the longer term, however, the Defense Department must watch closely the development of an over the horizon targeting capability by potential adversaries and develop appropriate responses.

The second challenge is to forward-based ground forces and the US homeland from commercially available modern LACMs. Purchasing LACMs will likely continue to be the most reliable and inexpensive route to acquiring a long-range strike capability. The demonstrated effectiveness of US cruise missiles and the existence of multiple suppliers are likely to increase demand, spur innovation and reduce the cost of such systems.

On the other end of the spectrum, one finds the “low-technology cruise missile”, particularly converted UAVs or kit aircraft. While a growing threat to US forces operating overseas, their ubiquitousness, simplicity, and low cost may also make them attractive to terrorist groups seeking to threaten the US homeland.

The balance between cruise missiles and defenses currently favors the offense. If nothing else, the experience of the 2003 Iraq War shows that current US air and ballistic missile defense systems have difficulty identifying, tracking and engaging even older LACMs. It will be even more difficult to defend against more modern missiles. Cruise missiles approach their targets from different azimuths than ballistic missiles. While short-range ballistic missiles have apogees of hundreds of kilometers, cruise missiles hug the ground. Many ground-based radars supporting modern air defenses attempt to reduce ground clutter by lifting their search beams above the ground, increasing the chance that cruise missiles will approach undetected. Moreover, the detection range of surface-based radars is limited by the curvature of the earth’s surface. For example, ground-based radars would only be able to detect a cruise missile flying at 50 m above the ground at a distance of 35 km or less. The ASCM’s low flight altitude also

complicates airborne surveillance due to ground clutter, which results in high noise rates and insufficient signals to detect the target.

Most modern ASCMs and LACMs also have sleek aerodynamic designs that make them difficult to detect. Their reduced radar cross section means that missile defenses will find detection more difficult, further reducing reaction time.¹⁰⁹ With proliferation, this feature will become increasingly common in the ASCM inventories of hostile states (and perhaps nonstate groups). As this occurs, it will raise the cost of cruise missile defense dramatically.¹¹⁰

On the other hand, the Defense Department has a number of programs aimed at defending against cruise missiles. Some are aimed at protecting forward-deployed troops. For example:

- The E-10A Multi-Sensor Command and Control Aircraft is designed to provide cruise missile defense and advanced airborne ground surveillance and targeting. It will include the Multi-Platform Radar Technology Insertion Program (MP-RTIP) radar and an advanced battle management command and control system on a Boeing 767-400ER aircraft.
- The RTIP radar will also be retrofitted onto five E-8 Joint STARS aircraft. Its increased resolution will provide an improved ability to detect, track, and identify both stationary and moving ground targets.

¹⁰⁹ For example, the E-3 *Sentry* AWACS can detect enemy aircraft with a 7 m² radar cross-section (RCS) traveling at 800 km/hr at a distance of 370 km, providing 28 minutes to react. However, detection distance and reaction time both fall as the object's RCS falls. The same AWACs could detect a cruise missile with a 0.1 m² RCS traveling the same speed at a distance of only 130 km, leaving only 10 minutes of reaction time. Cruise missiles with a RCS of 0.0001 m² are conceivable in the near future. The AWACS would detect such a missile traveling at the same speed at less than 25 km, leaving less than 2 minutes to react. See Gormley, *Dealing with the Threat of Cruise Missiles*, p. 62.

¹¹⁰ Dennis M. Gormley, "New Developments in Unmanned Air Vehicles and Land-Attack Cruise Missiles" in *SIPRI Yearbook 2003: Armaments, Disarmament and International Security* (Oxford: Oxford University Press, 2003), p. 411.

- A number of Air Force F-15C Eagle aircraft have been upgraded with the AN/APG-63(v)2 Active Electronically Scanned Array (AESA) radar, which gives aircraft an improved capability to track and target cruise missiles. Both the F/A-22 Raptor and F-35 feature AESA radars as well.
- The Joint Land-attack Cruise Missile Defense Elevated Netted Sensor (JLENS) system envisions using low-cost aerostats to detect and track cruise missiles.
- The US Patriot Advanced Capability 3 (PAC-3) and the multi-nation Medium Extended Air Defense System (MEADS) air defense systems both are designed to be able to engage cruise missiles.

These programs will offer increased capability to both detect and destroy LACMs. Similarly, the Navy has a series of programs aimed at improving defenses against ASCMs. These include:

- Upgrades to the E-2C Hawkeye and Aegis Weapon System to detect and track cruise missiles.
- Upgrades to the Navy's Cooperative Engagement Capability (CEC) system, which is designed to share situational information throughout a naval battle group.
- Deployment of the RIM-116 Rolling Airframe Missile (RAM), a short-range quick-reaction missile designed to destroy anti-ship missiles. The RAM, a joint program with Germany, is deployed, or planned for installation, on 78 US Navy ships.
- The Rearchitected NATO Sea Sparrow Surface Missile System, which is also designed to engage cruise missiles.
- The Phalanx Close-In Weapon System (CIWS), an air defense system deployed on most US naval vessels.

While the Defense Department has numerous programs to address threats to forward-deployed ground and naval forces, it has devoted much less attention to cruise missile threats to the homeland. A number of the above programs, such as JLENS, could clearly be

applied to homeland defense. Plans to do so, however, remain embryonic.

Success in countering the cruise missile threat would seem to depend both on the ability of the United States to field such systems before the threat matures as well as the ability to integrate disparate systems into a unified architecture. Unless the United States fields such an architecture, it is likely that its air and missile defenses will become increasingly ineffective.

It appears that a sustained investment in cruise missile defense can pay dividends. The case of theater ballistic missile defense is illuminating. During the 1991 Gulf War, US missile defenses were at best marginally effective. The General Accounting Office estimated that only 9 percent of *Patriot* PAC-2 missiles actually hit their targets, while the Israelis reported that *Patriots* intercepted no more than 1 of 39 Iraqi *Scud* variants aimed at Israel. Following the war, the United States invested \$3 billion in upgrading *Patriot*, and, as noted above, the results in 2003 were far different: *Patriot* units successfully intercepted all 9 of the Iraqi ballistic missiles that threatened targets in Kuwait.¹¹¹

The success of ballistic missile defense in the Iraq War was partially the result of an easier threat—a smaller number of shorter-range missiles that were slower and easier to intercept than the missiles that Iraq used in 1991. But substantial credit must be given to the integration of ballistic missile defenses into a joint architecture. *Patriots* were able to use cueing data from the Defense Support Program satellites, an AEGIS cruiser, and the COBRA JUDY sea-based radar. This, combined with improvements to the *Patriot* itself, made defenses much more effective.¹¹²

Of course, active defense is but one element of defending against cruise missiles. Even more desirable is destroying the missile while it is still on its launcher. This not only prevents the missile from being launched, it also denies adversaries the use of the launcher. The Iraq War also demonstrated that the US armed forces' ability to identify, target, and destroy, mobile, time-sensitive targets is increasing.

¹¹¹ Gormley, "Missile Defense Myopia," p. 63.

¹¹² *Ibid.*, p. 63.

During the 1991 Gulf War, fixed-wing aircraft failed to destroy a single *Scud* launcher despite roughly 1,500 strikes against Iraq's missile infrastructure.¹¹³ As noted above, US forces fared much better in the Iraq War. Still, there is room for improvement.

The cruise missile threat is real and growing, but not unmanageable. The United States clearly has the wherewithal to improve greatly its defenses against both ASCMs and LACMs. What is needed is a holistic approach to the problem.

¹¹³ Thomas A. Keaney and Eliot A. Cohen, *Gulf War Air Power Survey Summary Report* (Washington, DC: Government Printing Office, 1993), pp. 79, 83.

The Cruise Missile Challenge. January 2005. Authors
This research examines the effect of cruise missile possession on state behavior. Specifically, it seeks to determine if countries who possess cruise missiles are more likely to initiate a military threat, display, or use of force than countries who do not possess cruise missiles. Traditional International Relations theory suggests that, all else being equal, a state with an asymmetrical military advantage should enjoy concessions from target states, decreasing the likelihood of armed conflict. Accordingly, coercion theory warns the use of armed force to change adversarial behavior should be exercised sparingly. A cruise missile is a guided missile used against terrestrial targets, that remains in the atmosphere and flies the major portion of its flight path at approximately constant speed. Cruise missiles are designed to deliver a large warhead over long distances with high precision. Modern cruise missiles are capable of travelling at supersonic or high subsonic speeds, are self-navigating, and are able to fly on a non-ballistic, extremely low-altitude trajectory. Ramjet powered cruise missiles like the Bomarc need a solid fuel booster to get the missile up to c. Continue Reading. A supersonic cruise missile will have some heating issues, but since it's a one shot weapon you can use aluminum structure and skin: you will have to limit the cruise speed to Mach 2.5. Go Mach three and the air friction becomes excessive and you have to use Titanium, which is usually cost prohibitive. The most important challenge when building a supersonic vehicle (car, jet, missile, etc) is the heat and resistive force produced by air friction. First of all you need to have an ultra quality ceramic alloy that can withstand the heat, then a very powerful engine that can produce the necessary thrust to propell it at such high speeds. Cruise missiles (and related systems). The United States can destroy cruise missiles that have been detected, but it faces a significant challenge detecting the missile early enough to mount an effective defense and target the missile over the horizon. Cruise missile development activity reportedly is occurring in a number of potentially hostile states, but analysts disagree on the speed with which such a threat is evolving. The key issue in this debate centers on land-attack ...