

The Cruise Missile Challenge: Designing a Defense Against Asymmetric Threats

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Executive Summary

Terrorism, rogue states, and the prospect of renewed state-to-state competition comprise the security environment facing the United States and will define that environment for the foreseeable future. Potential competitors and adversaries are turning to asymmetric strategies in an effort to alter the strategic balance of power which otherwise favors the United States. Such strategies seek to exploit U.S. vulnerabilities to inflict or threaten to inflict damage to innocent people, cities and symbolic landmarks with the goals of upsetting public or allied opinion, creating terror and destruction, and possibly restricting freedom of action and/or deterring or dissuading U.S. responses. An ideal weapon for a nation or group looking to pursue such a strategy is the cruise missile.

Cruise missiles are easy to hide, adaptable, highly capable and relatively cheap. They can carry a variety of warheads, with the capacity to strike population centers, military bases, and deployed military units. In short, they are an instrument for deterring or increasing the costs of U.S. military operations, a way to hold U.S. overseas bases at risk, and a means to put the U.S. homeland at risk.

Tens of thousands of cruise missiles are available around the world and the threat is growing with time. Many states possess cruise missiles, either through indigenous development or purchase, and nearly all who have studied the issue concur with the National Air and Space Intelligence Center's conclusion that "the cruise missile threat to U.S. forces will increase over the next decade."

These weapons are no longer solely the purview of the great powers; quite the contrary, the number of states in possession of cruise missiles is large and growing, and the threat to the U.S. grows alongside this proliferation of cruise missile technology. Many countries already have cruise missiles of varying types and about twenty can manufacture their own missiles, with the others able to import them from a variety of sources, most particularly from known proliferator states.

Importantly, the greatest barriers to proliferation, namely, the detailed mapping databases and highly-sophisticated computers/memory required for accurately designating and homing in on land-targets, have all but disappeared recently with the advent of global positioning system (GPS) guidance, GPS-based maps, Google-Earth, and the latest generations of commercially-available off-the-shelf computers and memory. Accuracy of even a hundred meters is more than sufficient to serve as a terror weapon, and is tantamount to pinpoint-precision when delivering a weapon of mass destruction, especially a nuclear weapon. Further, current proliferation regimes have failed to prevent cruise-missile proliferation, as virtually all the requisite technologies can be sourced from dual-use technologies.

These concerns are no longer hypothetical. *Operation Iraqi Freedom* saw cruise missiles fired at U.S. forces for the first time. Iraq fired five modified HY-2 missiles at U.S. forces and Hezbollah used them during the recent conflict with Israel in Lebanon. National security strategists are thinking about how to respond to a cruise missile launch from a commercial container ship.

This report considers the cruise missile threat confronting the United States and, after assessing the various strategies advanced for addressing those threats, concludes that new emphasis on the development and deployment of cruise missile defense is an essential national security and homeland defense priority. The report identifies the extent to which cruise missile capabilities and technologies have proliferated and then summarizes the circumstances where cruise missiles might be used in anger against the United States.

By holding allied populations at risk, terrorists or other adversaries can threaten cruise missile attacks as a means to blackmail or coerce otherwise friendly nations to withhold or restrict support to the U.S. by denying access to bases or airspace, for example. Strategically placed systems at key geographic chokepoints, such as the Panama Canal or the Straits of Hormuz, could paralyze international commerce and raise apprehensions worldwide. Finally, their use or threatened use against the U.S. homeland is an all-too-real consideration.

The United States has four strategies it can pursue alone or in some combination to protect its citizens, cities, and deployed military forces from cruise missiles. These strategies are: (1) the denial of access to technologies and systems through the non-proliferation regime; (2) pre-emptive attacks by U.S. military forces against systems and infrastructure in hostile states or the interdiction of vessels before they get within range; (3) hardening of critical infrastructures against the impacts of a cruise missile attack domestically or abroad; or (4) constructing a robust active defense capable of destroying a hostile cruise missile *before* it reaches its target.

After the strengths and weaknesses of each approach are considered, the clear conclusion is that active defenses are necessary to secure the U.S. homeland from growing threat of cruise missiles. Active defenses complement the other three strategies and, at the same time, provide U.S. citizens with protection from a growing challenge to U.S. security. An effective cruise missile defense must have four basic elements. Those elements are:

- the capability to detect and then track a cruise missile after it is launched;
- interceptors to destroy the attacking cruise missile;
- battle management and communications network that ties the first two elements together and allows for seamless real-time engagements; and
- the ability to effectively predict and manage the consequences of a cruise missile attack.

Unfortunately, the United States presently lacks a serious and focused effort to construct a viable, wide-area defensive system. The U.S. approach to cruise missile defense has focused on the defense of particular military assets, such as warships or military bases. The systems available for those missions are superb, but are ill-suited for the wide geographic coverage and persistence needed for homeland defense. Further, the absence of a clear mandate to assume the mission of cruise missile defense clouds long-term budget decisions and program development.

While there are many competing security priorities and demands on scarce resources, the defense of U.S. citizens remains the preeminent obligation of government — one that is ignored at great peril.

Introduction

“Anybody in my opinion has the ability to make a very inexpensive cruise missile. It is not a matter of technology. It is just a matter of when it is going to happen. So, we just have to decide when (and how) we are going to be ready to deal with that situation.”

Gen. John Jumper (ret.), former Chief of Staff, U.S. Air Force¹

A relatively inexpensive and highly capable set of weapons present the United States with unique new challenges. Despite widespread acknowledgment that cruise missiles are already in the hands of a variety of real and potential adversaries, U.S. cities, its troops deployed abroad, and the citizens of friends and allies remain undefended and exposed. The day is already upon us when foes of the United States can buy or easily build cruise missiles and use them to attack the U.S. homeland, U.S. troops, or friends and allies. Iraq’s use of a modified cruise missile system during *Operation Iraqi Freedom* is the first shot of many to come. Any review of the available options leads to the inescapable conclusion that the growing likelihood of a cruise missile attack, and the untenable consequences of allowing such an attack to succeed, demands the development of a coherent and capable defense against them.

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.”² They were first introduced for use in combat by Nazi Germany against England in World War II, over sixty years ago.³ They were difficult to stop then; today, they are far more sophisticated, numerous and far-reaching. Cruise missiles draw upon every existing manner of precision-guidance and can carry every variety of destructive payload known to man, from high-explosives to chemical, biological and nuclear weapons.

The military forces of the United States or its allies, along with overseas military bases, historically were considered the main targets for cruise missiles. Throughout the Cold War, the United States struggled with the challenge posed by Soviet cruise missiles. The U.S.’s frequent use of cruise missiles since the end of the Cold War has demonstrated their effectiveness and utility and expanded demand for them. Willing suppliers of the technologies and systems in the global arms market make cruise missiles widely available today. More and more nations now possess them or have access to them, as do terrorist groups. Further increasing the attractiveness of the cruise missile is its adaptability. Cruise missiles lend themselves to creative new uses, such as a launch from a seafaring cargo container. Given that more than 75% of the U.S. population is located within 200 miles of a coastline, the consequences arising from a cruise missile attack on the homeland are not trivial. In short, dozens of countries either possess or produce them. They are flexible enough to attack anything from individual buildings to aircraft carriers and entire cities.

As Gen. John Jumper, the former Air Force Chief of Staff noted, the question faced by the U.S. military and, indeed, the U.S. public is not whether we will face a cruise missile attack, but when and what we do to try to stop these attacks in the meantime. The United States has four strategies it can pursue alone or in some combination. They are: (1) denial of access to technologies and systems through the non-proliferation regime; (2) pre-emptive attacks against deployed systems and infrastructure in hostile states or interdicting vessels before they get within range; (3) passive defense against the impacts of a cruise missile attack domestically or abroad; or (4) construction of a robust active defense.

After reviewing the capabilities of modern cruise missiles and the threats they represent, we consider the effectiveness of each of these strategies. Independently, none provides a sufficient response to the challenge of which Gen. Jumper speaks. The non-proliferation regime clearly has failed to curtail the proliferation of the necessary technologies and systems. Cruise missiles are already in the hands of those who wish harm to the U.S. A pre-emptive strategy would involve enormous political risk and consequences, domestically and internationally, and reliance on it as the chief defensive strategy against a cruise missile attack virtually ensures that some missiles will reach their targets successfully. The relative ease with which these systems may be hidden, either on land or at sea, complicates efforts to actively pre-empt their launch and places enormous challenges on our intelligence system to predict when, where, and how they might be used. Passive defenses imply capitulation and would result in considerable, and largely unnecessary, expense. Active defenses are available, but heretofore are limited, underemphasized, and underutilized for applications beyond the defense of military aircraft and naval vessels. The military systems currently employed are effective at meeting their central objective — the destruction of the attacking cruise missile — but are ill-suited for defending wide geographic areas, such as the U.S. homeland. Utilizing these assets for long-term homeland defense is unnecessarily expensive and would divert those valuable capabilities from other military missions and uses. There are systems and capabilities, which if developed and deployed for this purpose, could provide the United States with an effective defensive capability to meet today's threats.

Because cruise missiles are small, swift, low-flying and stealthy, and so extremely difficult to detect and defend against, they are an ideal weapons system for a state or group seeking to challenge the U.S. in the face of major mismatch in overall military power. The elements for effective defenses exist in the U.S. military's active inventory and in varying stages of technical development, but as Gen. Jumper stated, whether the U.S. is ready to "decide when and how we are going to be ready to deal with that situation" remains an open question.

Technical Characteristics of the Cruise Missile

Cruise missiles are precision weapons designed for use against both land and sea targets and are launched from land, air, or sea platforms. The two broad categories of cruise missiles are land-attack cruise missiles (LACMs) and anti-ship cruise missiles (ASCMs). ASCMs use radar and/or heat-seeking sensors to find and strike their targets.⁴ LACMs, however, are by far the greater worry, as they are equipped with Global Positioning System (GPS) capabilities and ground-map/terrain-following systems that enable them to fly low-altitude, terrain-following, defense-evading paths, and accurately strike land targets ranging in size from individual buildings to entire cities.⁵ While both types of cruise missiles can carry nuclear or other weapons of mass destruction (WMD) warheads, the capability of LACMs to deliver WMDs to major land targets, such as cities, is cause for particular concern.⁶

Cruise missile ranges are as little as 25 miles for the French *Exocet* anti-ship missile⁷ or as long as 2,200 miles for the Russian AS-15 *Kent*, which also can carry a 200 kiloton thermonuclear warhead.⁸ The ability to strike at a distance of 25 miles allows an attacker to sink any ship that can just be seen on the horizon. By contrast, 2,200 miles is more than enough for a cruise missile to fly from Tehran to Moscow, or for that matter, from Moscow to Paris.⁹ Further compounding the range variability is the fact that these terrain-hugging air-breathing vehicles, unlike ballistic missiles, can take circuitous routes to their targets to slip around or behind defenses, not unlike manned combat aircraft.

A LACM in Flight

"A LACM is an unmanned, armed aerial vehicle designed to attack a fixed or mobile ground-based target. It spends the majority of its mission in level flight, as it flies a preprogrammed path to a predetermined target. Propulsion is usually provided by a small jet engine."

"Because of highly accurate guidance systems that can place the missile within a few feet of the intended target, the most advanced LACMs can be used effectively against very small targets, even when armed with conventional warheads. LACM guidance usually occurs in three phases: launch, midcourse, and terminal. During the launch phase, a missile is guided using only the inertial navigation system (INS). In the midcourse phase, a missile is guided by the INS updated by one or more of the following systems: a radar-based terrain contour matching (TERCOM) system, a radar or optical scene matching system, and/or satellite navigation system such as the U.S. Global Positioning System (GPS) or the Russian Global Navigation Satellite System (GLONASS). The terminal guidance phase begins when a missile enters the target area and uses either more accurate scene matching or a terminal seeker (usually an optical or radar-based sensor)."

National Air and Space Intelligence Center, Wright-Patterson Air Force Base, Ballistic and Cruise Missile Threat (March 2006)

Employing virtually every form of guidance technology available, from inertial guidance, global positioning system (GPS), active radar, television, infra-red, imaging infra-red, terrain mapping and recognition (using either strobes or lasers) and even autonomous target-recognition, the accuracy of cruise missile systems has increased markedly in recent years. These sensors and guidance systems are described in Table 1.

Table 1 - Types of Cruise Missile Sensors and Guidance Systems

Sensor/Guidance System	Description
Inertial Navigation System (INS)	Measurement of a vehicle's acceleration in all three axes to determine its displacement from its launch point, and so to determine its position.
Global Positioning System (GPS)	Series of signal-and-timing-emitting satellites, the relative positions of which are used to determine a receiver's position in three dimensions. Can be used to determine velocity, wind, etc.
Terrain Contour Matching System (GPS)	Vehicle uses active radar to scan the ground below for comparison with an internally stored ground-map.
Digital Scene Matching Area Correlation (DSMAC)	Terminal area imagery is compared with preloaded satellite imagery to find and attack the sought-after target.
Active Radar	Vehicle emits its own radar signal, and homes in on the energy reflected off the target.
Anti-Radiation (Passive Radar)	Vehicle detects and homes in on enemy radar emissions.
Infra-Red (IR)	Vehicle homes in on heat emitted from its target.
Imaging Infra-Red (IIR)	Vehicle can recognize a heat-based image of its target.
Autonomous Target Acquisition (ATA)	Vehicle can find, recognize and attack a target completely autonomously; target is not necessarily preloaded, as with DSMAC.
<i>Source: Missile Guidance, (aerospaceweb.org, 2006), http://www.aerospaceweb.org/</i>	

As the National Air and Space Intelligence Center notes, the guidance systems of a cruise missile in flight are updated three times in the most advanced cruise missiles. This allows these systems to hit within a few feet of their targets.¹⁰ In contrast, the widely available ballistic missile, the SCUD-B, may strike from 1 to 2 kilometers from its intended target, at a much higher per missile cost.¹¹ The commercial availability of

GPS and Russian GLONASS and the future European Galileo reduces the cost and access barriers to more accurate navigational aids. One estimate suggests that widespread availability of these satellite navigation systems “has allowed Third World countries to leapfrog probably 15 years of development for long-range, fairly accurate LACMs.”¹² Integration of these capabilities into cruise missiles is done cheaply, on the order of \$50,000 to \$150,000 per missile, using technologies and products widely available on the commercial market.

Figure 1 - Silkworm Missile at an Iraqi Storage and Maintenance Facility

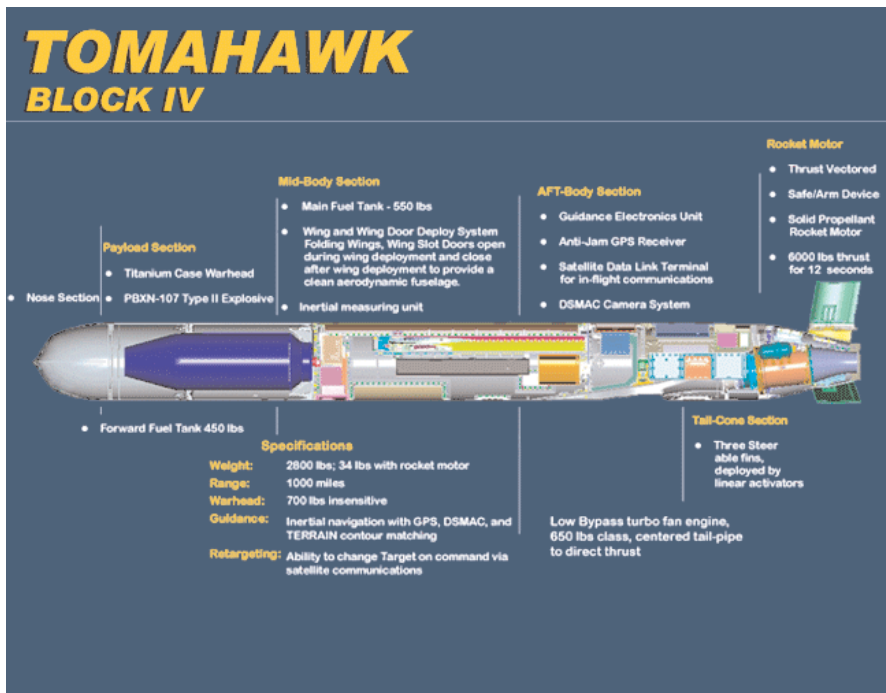


Source: http://www.nti.org/images/uav_silkworm.gif

Cruise missiles normally fly at altitudes of approximately 300 feet, but more sophisticated missiles fly at altitudes of a few tens of feet above the ground or sea through most, if not all, of their flight to their targets, making their detection and interception very difficult. Additionally, since cruise missiles are much smaller and simpler in design than manned aircraft and possess much smaller radar cross-sections, they are more difficult to detect and likelier to slip through defenses to hit their targets. Similarly, their jet engines are correspondingly smaller than those of manned aircraft and thus generate far less heat in their exhaust, making their detection more difficult for heat-seeking missiles and sensors. Indeed, it is arguably the advent of small jet engines that gave the cruise missile its deadly advantages of speed, sustained operation, range, low-altitude flight, and maneuverability. These characteristics reveal the necessity of employing sufficiently robust and sophisticated sensor, detection, and tracking capabilities when considering defensive architectures.

Over the years, cruise missiles have become smaller, faster, and capable of being launched from many platforms. Table 2 outlines the evolution of major cruise missile systems. Early generations of cruise missiles, such as the Soviet *Styx*, were the size and weight of small aircraft. These weapons and their Chinese-made copies, the *Silkworm* and *Seersucker*, have seen nearly continuous improvements to their guidance systems since their introduction. These weapons were limited to large platforms, such as bombers, ships and specially-equipped submarines. Succeeding generations of cruise missiles are much smaller and more sophisticated.

Figure 2 - Cutaway View of Tomahawk Ship-Launched Cruise Missile



Source: Staff, *Tomahawk Block IV Missile, PMA-280*, (United States Navy, March 2006), <http://www.strikenet.js.mil/pma-280/BLK4.htm>

The U.S. Air-Launched Cruise Missile (ALCM) and *Tomahawk* epitomize next-generation trends. They are carried by many more varied types of platforms, from tactical attack aircraft to small patrol boats, destroyers, cruisers, and submarines (meaning that virtually any submarine can now launch cruise missiles), as well as in much greater numbers per platform by heavy bombers such as the B-1 and B-2. As

the size decreases, they are capable of launch from smaller and thus more numerous land-launch platforms such as trucks and towed launchers.¹³ Importantly, these weapons take advantage of new generations of guidance technology, in which geographical details of the path to the target are downloaded into the memory of the missile, enabling them to fly terrain-contour-following flight paths, to hide their approach from adversaries' air-defense radars. These tactics had previously only been possible with manned strike aircraft. The Russian SS-N-21 *Sampson*¹⁴ and the U.S. *Tomahawk*¹⁵ fit into this category.

Table 2 – Cruise Missile Development Timeline

Year	Milestone	Nation
1916	First test flight of gyroscope-guided pilot-less aircraft.	U.S.
1919	'Bug' test program.	U.S.
1918-39	Experiments in pilot-less & remotely-piloted weapons.	U.S., UK, etc
1931-1934	Work on pulse-jet engine and pilot-less aircraft.	Germany
1941-1943	Development of V-1 'buzz-bomb.'	Germany
1944	Use of V-1s, world's 1st cruise missiles, in combat.	Germany
1949-1961	'Snark,' <i>Hound Dog</i> , <i>Regulus</i> cruise missile programs.	U.S.
1975-1982	<i>Harpoon</i> ASCM; SLCM, ALCM, GLCM	U.S.
1960	SS-N-2 <i>Styx</i> ASCM	USSR
1976	AS-15 <i>Kent</i> et al LACMs	USSR
1981	SS-N-22 <i>Sunburn</i> et al ASCMs	USSR
1993	SS-N-26 <i>Yakhont</i> ASCM	USSR
1975	<i>Exocet</i> ASCM	France
1968	<i>Silkworm</i> et al ASCMs	China
1975	C-802/C-802 <i>Saccade</i> et al ASCMs	China
1996	HN-2 LACM	China

Sources: Werrell, Kenneth P. *The Evolution of the Cruise Missile*. (U.S. Government Printing Office: Washington, D.C., 1985); and Duncan Lennox, (Ed.), *Jane's Strategic Weapon Systems*, (Surrey: Jane's Information Group, Issue Forty – January 2004).

The latest generation of cruise missiles from such countries as the U.S., France and Great Britain offer advanced capabilities from supersonic speeds, extended ranges, and in some cases, e.g., the latest-generation American Joint Air to Surface Standoff Missile (JASSM)¹⁶ and the European *Apache*,¹⁷ outright stealth.

Navigation and sensor systems are often combined to achieve the most effective weapon possible for the mission, target type, and the allotted unit cost. Some examples of these combinations are given in Table 3.

Table 3 – Some Representative Cruise Missiles

Name	Origin	Mission	Guidance	Homing Sensors	Range (mi)
Styx	Russia	Anti-ship	Autopilot	Active radar/IR	48
Exocet	France	Anti-ship	INS	Active radar	42
Harpoon	U.S.	Anti-ship	INS	Active radar	81
Silkworm	China	Anti-ship	Autopilot	Active radar	53
HY-4	China	Anti-ship	TBD	TBD	300 nm
Tomahawk	U.S.	Land-attack	INS, TERCOM and GPS	DSMAC (some versions)	2,200 (-A strategic version)
Krypton	Russia	Anti-ship	INS	Active/passive radar versions	120
Harpy	Israel	Anti-radar	INS	Active/passive, EO	300
JASSM	U.S.	Land-attack	INS, GPS	IIR	500
<p>List of Acronyms: EO = Electro-Optical INS = Inertial Navigation System TERCOM = Terrain Contour Matching IR = Infra Red IIR = Imaging Infra-Red GPS = Global Positioning System</p> <p>Source: Duncan Lennox, (Ed.), <i>Jane's Strategic Weapon Systems</i>, (Surrey: Jane's Information Group, Issue Forty - January 2004): 243-245; Harpy, <i>Israeli-Weapons.com</i>, 2006, http://www.israeli-weapons.com/weapons/aircraft/uav/HARPY.html.</p>					

The last and perhaps most important characteristic of note is that cruise missiles can carry a wide variety of warheads, from a few hundred pounds of high-explosive to all types of weapons of mass destruction, including chemical and biological weapons and thermonuclear warheads of up to 250 kilotons yield.¹⁸

Even with these significant capabilities, the cruise missile is an affordable weapon. The widespread availability of finished systems and components, coupled with the dual-use nature of many of the technologies involved, make for a robust market for prospective buyers. A U.S. Army estimate from the mid-1990s suggests that for an investment of \$50 million, a country could purchase at least 100 cruise missiles.¹⁹ Now more than

10 years old, this estimate has undoubtedly changed, but with the entrance of new players into the cruise missile marketplace, there is without question a robust and cost competitive marketplace for buyers, with reduced barriers to entry as the technology has proliferated.

The Three Paths of Land-Attack Cruise Missile Proliferation

Nations or terrorist groups seeking the more capable LACMs can use any of the following three paths to obtain them: (1) acquiring them, legally or illegally, from a current producer; (2) developing them indigenously; and (3) modifying existing stocks of ASCMs or UAVs.²⁰ Importantly, the greatest barriers to LACM proliferation, namely, the detailed mapping databases and highly-sophisticated computers/memory required for accurately designating and homing in on land-targets, have all but disappeared recently with the advent of GPS guidance, GPS-based maps, Google-Earth, and the latest generations of commercially-available off-the-shelf computers and memory.²¹ An accuracy of even a hundred meters is more than sufficient to serve as a terror weapon, and is tantamount to pinpoint-precision when delivering a WMD, especially a nuclear weapon.²² Further, current proliferation regimes have failed to prevent cruise-missile proliferation, as virtually all the requisite technologies can be sourced from dual-use technologies.²³

During the Cold War, only the U.S., France and Russia had the technological sophistication to produce LACMs. Now, however, the club has grown and some of the new entrants are putting them on the international marketplace. There are currently six LACM-producing nations offering them for export: China, Russia, France, the United Kingdom, South Africa, and Pakistan. Russia, in particular, has a long history of selling advanced arms to threat states, arms which have since found their way into the hands of other threat states.²⁴ Of particular note is the sale of Russian-made strategic-range *Kent* LACMs by the Ukraine to China and Iran.²⁵ Also of increasing concern is Pakistan's decision to offer its newly-deployed *Hatf-VII* LACM for export.²⁶

China also has LACMs under development,²⁷ which might very well be offered for export, as it has other missiles and other weapons technologies in the past.²⁸ Reproduction and modification of cruise missiles by capable third party producers for greater range is highly likely. Iran already has proven itself adept at reproducing and modifying ASCMs sourced from China, making the reproduction of its recently-acquired *Kents*, especially with Russian and/or Chinese assistance, likely only a matter of time.²⁹

The third route for the acquisition of LACMs, though by no means the easiest, is conversion of an ASCM. ASCMs have different, simpler guidance systems and smaller fuel capacities than their more strategically-affective LACM counterparts. The guidance systems, sensors, and main structures all require upgrading or replacement to suit the LACM mission. The task is quite easy to do. Guidance systems can be interchanged, especially if the missile was designed for this from the outset, for more sophisticated

land-attack guidance systems using modern computing technology and GPS.³⁰ The greatest difficulty is obtaining more powerful, capable and fuel-efficient jet engines to propel the extra mass and distance of a LACM compared with the original ASCM, but even these are available as dual-use items from commercial aircraft suppliers.³¹

Importantly, modern ASCMs are highly sophisticated, deadly weapons. The Russian *Club*, *Moskit*, *Yakhont*, and Russian/Indian *BrahMos* ASCMs use supersonic climb-and-dive attack tactics (and the latter three use ramjets to achieve speeds over three times the speed of sound) making them extremely difficult to defend against.³² Modification of such weapons to the land-attack role makes for a truly unsettling scenario.

Similarly, modification of UAVs to LACM status requires the same sorts of upgrades as those of an ASCM, or they might simply require the emplacement of explosives, and a competent remote-operator to manually guide the UAV in to its intended target.³³ A warhead-armed UAV can be as accurate as an ASCM, but the payloads are much smaller than those of dedicated cruise missiles and their operating speeds are much lower than that of a cruise missile. This renders UAVs much more vulnerable to alert air defenses, as demonstrated by the interception of a Hezbollah UAV by the Israeli Air Force during the 2006 conflict in Lebanon.³⁴

Many states currently possess cruise missiles, either through indigenous development or via outright purchase. The threat is growing with time. The National Air and Space Intelligence Center concludes that “the cruise missile threat to U.S. forces will increase over the next decade.”

Cruise Missile-Armed Countries of Interest

Many states currently possess cruise missiles, either through indigenous development or via outright purchase. The threat is growing with time. The National Air and Space Intelligence Center concludes that “the cruise missile threat to U.S. forces will increase over the next decade.”³⁵ Even if a state ‘only’ starts with ASCMs, the inherent danger is that the expertise to build such a weapon will eventually expand from tactical ASCMs to strategic LACMs. In addition, increasing numbers of states are obtaining not only cruise missiles, but the means of producing them indigenously.

Estimates of the number of cruise missiles available worldwide vary. One estimate provided for the Congress suggests there are approximately 130 types of cruise missile types distributed between 80 nations.³⁶ The more common ASCM is in the hands of at least 70 countries, accounting for over 75,000 missiles.³⁷ It is generally agreed that 19 countries currently manufacture ASCMs and 11 export them. The countries of greatest concern on the list of exporters, Iran, China, and North Korea, tend to have older ASCMs in their inventories.³⁸ Russia is both “a world class producer” of anti-ship cruise missiles and has “a willingness” to sell or barter the technology.³⁹

The less common but more capable LACM is proliferating rapidly. In 1998, the National Air Intelligence Center stated that only three countries possessed LACMs and none were exporters.⁴⁰ *Just two years later, the estimate was raised to 9 nations involved in production of LACMs⁴¹ and the most recent estimate puts the number at twelve.⁴²*

According to officials from the U.S. Defense Intelligence Agency (DIA), in the past, ASCMs were the most widely produced cruise missile variant, but LACMs are now leading in production, based on spending trends in missile research and development. The DIA further estimates that China will have hundreds of LACMs by 2030 and that Iran, Syria and Libya will also soon have a modest number by this date.⁴³ While nascent LACM producers such as South Africa and Taiwan are not currently proliferation concern states per se,⁴⁴ it is not inconceivable that they might offer these weapons for sale, as India and Russia plan to with the *BrahMos* ASCM.⁴⁵

Table 4 – Land Attack Cruise Missiles (LACMs) of the World

Designation	Missile Inventory	Range (km)	Payload (kg)	Motors	Status
Russia					
AS-3 <i>Kangaroo</i>		650	2,300	Turbojet	
AS-15 <i>Kent</i> (Kh-65SE/Kh-101)	782	600/ 3,000	410/150	Turbo-fan	Dev't -2 vers.
AS-19 <i>Koala</i>		4,000	875		ended
<i>Alfa</i>		600			In Dev't
SS-N-21 <i>Sampson</i> ^[1]	200	2,400	410	Turbo-fan	
France					
<i>Apache/Apache</i> A1		140/ 250-400	520/400	Turbojet	

Table 4 – Land Attack Cruise Missiles (LACMs) of the World (cont.)

Designation	Missile Inventory	Range (km)	Payload (kg)	Motors	Status
<i>SCALP</i>		500-800	400		Dev't
<i>ASMP</i>		300		Rocket/ramjet	
<i>ASLP</i>		1,300		Rocket/ramjet	Dev't
<i>Teseo Mk3</i>		300	145	Turbojet	Dev't
Germany					
<i>Taurus (KEPD-350)</i>		350	500	Turbojet	Dev't
United Kingdom					
<i>Storm Shadow</i>	500-2,000	250-400	400	Turbojet	Dev't
<i>Pegasus</i>		200+	500	Turbojet	Cancelled
China					
<i>Xiong Ying?</i>		1,500 -2,000		Turbo-fan	Dev't
HN-1/-2/-3		600 (HN-1) – 3,000 (HN-3)		Turbojet/ Turbo-fan	
AS-15 <i>Kent</i> (Kh-65SE/Kh-101) ^[2]	6?	600/ 3,000	410/150	Turbo-fan	Dev't
Iran^[3]					
AS-15 <i>Kent</i> (Kh-65SE/Kh-101)	6?	600/ 3,000	410/150	Turbo-fan	Dev't
Israel					
<i>Popeye Turbo</i>		350	895	Turbojet	
<i>Delilah derivative</i>		400	450	Turbojet	Dev't
Modular Standoff Vehicle		400	675	none	Dev't
<i>Harpy^[4]</i>					
Pakistan^[5]					
<i>Hatf VII 'Babur'</i>		500		Turbojet	
<i>Babur 2</i>		1,000		Turbojet	Dev't
South Africa					
<i>Torgos</i> (multi-purpose standoff weapon)		300		Turbojet	Dev't
Taiwan					
<i>Hsiung Feng</i>			300	Turbojet	Dev't
UAE					
<i>Black Shaheen</i> (Apache variant)		140/ 250 -400	520/400	Turbojet	
Note: all systems are currently in service unless otherwise noted.					
[1] Duncan Lennox, (Ed.), <i>Jane's Strategic Weapon Systems</i> , (Surrey: Jane's Information Group, Issue Forty – January 2004)., 179					
[2] Bill Gertz, <i>Missile Sold to China and Iran</i> , (Washington: The Washington Times, April 6, 2005), http://www.washingtontimes.com/national/20050405-115803-7960r.htm					
[3] <i>Ibid.</i>					
[4] <i>Harpy</i> , (Israeli-Weapons.com 2006), http://www.israeli-weapons.com/weapons/aircraft/uav/harpy/HARPY.html					
[5] "Hatf-7, Babur Cruise Missile," <i>PakistaniDefence.com</i> , October 2005					

China

Arguably the world's greatest missile-technology proliferator, China is using a mix of imported and indigenously-developed technology to rapidly expand its cruise missile stocks. It has sold *Silkworm* and *Seersucker* knockoffs of the Soviet *Styx* for decades.⁴⁶ China also produces and exports its own second-generation cruise-missile, the C-802 *Saccade*, an *Exocet*-like high-subsonic weapon with a range of 120 km.⁴⁷ Furthermore, the pipeline of Russian-sourced missile technology remains robust. China recently acquired the Russian SS-N-22 *Sunburn* destroyer-launched⁴⁸ and SS-N-27 submarine-launched⁴⁹ supersonic-attack anti-ship cruise missiles, continuing the decades-long procure-and-replicate pattern. Disturbingly, China has also acquired the Russian-made AS-15 *Kent* thermonuclear-warhead-capable strategic land-attack cruise missile.⁵⁰ The prospect of further reverse-engineering or license-producing copies of these weapons and exporting (proliferating) them to other states, including those that are hostile to the U.S., cannot be discounted.

Figure 3 - Chinese C-802 Anti-Ship Cruise Missile



Source: "YJ-62 (C-602) Anti-Ship Cruise Missile," *Chinese Defence Today*, 2005, <http://www.sinodefence.com/navy/navalmissile/yj621.asp>

Figure 4 - Russian SS-N-27 'Club' Cruise Missile



Source: 3M-54E (SS-N-27) Anti-Ship Cruise Missile, (sinodefence.com, April 27, 2006), <http://www.bharat-rakshak.com/NAVY/Klub.html>

Russia

Russia, the heart of the former Soviet Union, has produced a great many cruise missiles, both in types and quantities over the years, from the 1960s-vintage SS-N-3 *Styx*, through the latest supersonic SS-N-22 and SS-N-27 anti-ship weapons. While Russia is no longer considered an adversary, its continued development and export of these highly-advanced weapon systems to potential or outright hostile states is worrisome. Indeed, Russia not only continues to develop cruise missiles, but its ASCMs are designed specifically to defeat U.S. naval air defenses.⁵¹ Worse, Russian-supplied weapons are routinely re-exported from the country of initial sale. For instance, Ukraine recently admitted that it sold up to a dozen copies of the ultra-long-range, thermonuclear-warhead-capable AS-15 *Kent* to both Iran and China.⁵² Cooperative development of such weapons as the joint Russian-Indian *BrahMos* supersonic anti-ship missile, which has a range of 175 miles and can be launched from a variety of land and sea-based platforms, also creates a source of concern, as both states intend to export it.⁵³ Continued work to improve the Russian arsenal will result in the availability of ever more sophisticated weapons on the international market.

Iran

Iran possesses a variety of Chinese-made cruise missiles, from the widely-proliferated *Silkworms* and *Seersuckers* to the more advanced Chinese-made *Saccade*-type weapons. Most ominously, Iran has acquired some of the same Russian-made AS-15 *Kent* thermonuclear-warhead-capable strategic cruise missiles that were illegally exported by the Ukrainian government to China.⁵⁴ Since both China and Iran are known reverse-engineering weapon proliferators, this is a strategically significant development. Iran has developed an air-launched version of the C-802 anti-ship cruise missile with Chinese help.⁵⁵ Iran also has received copies of the highly-capable Russian-made SS-N-22 *Sunburn* supersonic anti-ship missile.⁵⁶

In addition to the ASCMs mentioned above, the *Military Balance 2006* reports that the Iranians have an indigenous product line for *Noor*, *Kowsar/Kowsar-1* and *Ra'd* anti-ship cruise missiles, which would complement the aforementioned inventory of Chinese-made missiles.⁵⁷ Earlier in 2006, during war games in the Persian Gulf, the Iranians reportedly tested the *Kowsar*, which is “a land-to-sea missile designed to skim the surface of the water” that can avoid radar.⁵⁸ Finally, the *Military Balance 2006* calls attention to a dedicated cruise missile group working within the Iranian Aerospace Industries Organization (AIO).

Iran is devoting additional resources to anti-ship cruise missile development and production toward the goal of modernizing its naval forces for potential employment in possible conflicts over control of Straits of Hormuz and U.S. and western naval access to the Gulf region in general.

North Korea

North Korea possesses a number of Chinese-made anti-ship cruise missiles such as the *Silkworm* and *Seersucker*,⁵⁹ which it could use against U.S. vessels or other shipping in the Sea of Japan, constituting another coercive strategy available to that regime for use against its neighbors.

Pakistan

Pakistan is a regular customer of Chinese and North Korean ballistic missile and nuclear technologies. As a result, Pakistan is believed to have an arsenal of some 30 to 50 nuclear weapons deliverable via ballistic missile.⁶⁰ Recently, Pakistan also tested its Hatf VII *Babur* LACM, with a range of 500 km, which it touts as being equivalent to the U.S.'s own *Tomahawk*. The *Babur* is capable of delivering both conventional and nuclear warheads.⁶¹

India

Long a client for Soviet weapon systems, India has several Russian-made cruise missiles in its inventory, such as the SS-N-25 *Switchblade* and SS-N-27 *Club* anti-ship cruise missiles.⁶² India also has partnered with Russia to jointly develop and produce the *BrahMos* ASCM,⁶³ a high-supersonic anti-ship cruise missile closely patterned after Russia's own SS-N-26 *Yakhont*, for both domestic use and for joint export. The *BrahMos/Yakhont* family of weapons is a formidable one. Use of a ramjet for propulsion gives it a maximum speed of nearly three times the speed of sound, which reduces a defending warship's warning time by a similar factor and makes the attacking missile much more difficult to track and shoot down.⁶⁴

Israel

Israel began anti-ship cruise missile production soon after its losses to Soviet-made ASCMs in the Six-Day War. Israel's first such product, the *Gabriel* ASCM, was produced in the late 1960s and had a range of 25 miles. By contrast, the latest, third-generation version of the *Gabriel* has a range of 200 km.⁶⁵ Israel also produces the *Harpy* anti-radiation UAV, a battlefield-loitering weapon that it calls a UAV, but which is, in fact, a radar-ground-station-hunting cruise missile.⁶⁶ Significantly, copies of the *Harpy* that were sold to China were the subject of an international incident involving Israel, China, and the U.S. over the latter's concerns about the missiles' refurbishment. In the end, the weapons were retained by Israel as a result of demands from the U.S., an action that infuriated the Chinese government.⁶⁷ Such weapons exports to China represent enormous potential cruise missile proliferation threats to the U.S., if they should copy or even simply use Israeli-made weapons such as the *Harpy*.

France

France is also a prominent exporter of cruise missiles. It is said that nothing succeeds like success in combat. There is perhaps no better proof of this than in the export success of France's own *Exocet* ASCM, the weapon that was so lethal against the Royal Navy in the 1982 Falklands war. The *Exocet* has since been sold to nearly three dozen countries, in both air and ground-launched versions, to such notable states as Saddam-era Iraq, Libya, Venezuela, and, of course, Argentina.⁶⁸ Of even greater concern is the Anglo-French *Apache/Scalp/Storm Shadow* LACM, also known as the *Black Shaheen* in the version exported to the United Arab Emirates. This state-of-the-art LACM is a stealthy, submunition-dispensing weapon, with versions having ranges from 140 km to 600 km, and uses GPS, TERCOM, and Imaging Infra-Red guidance systems.⁶⁹

The Attractiveness of Cruise Missiles: Anywhere, Anytime

Cruise missiles are easily stored, mounted and transported and are capable of being fired from wide variety of platforms and vehicles. They can extend the range of combat aircraft well beyond the reach of enemy air defenses, radically improving the survivability and combat-effectiveness of manned aircraft. These same force-multiplier factors apply to surface warships and submarines that use cruise missiles.

These weapons are no longer solely the purview of the great powers; quite the contrary, the number of states in possession of cruise missiles is large and growing. The concomitant threat to the U.S. homeland grows alongside this proliferation of cruise missile technology. As the preceding section showed, many countries already have cruise missiles of varying types, and about twenty can manufacture their own missiles, with the others able to import them from a variety of sources, most particularly from known proliferator states.

This section reviews how cruise missiles have been used in combat operations and discusses how they might be employed against the United States in the future.

Cruise Missile Use by the United States

Modern electronics, sensors, and jet engines enabled the development of cruise missiles during the Cold War. During the Cold War, the Soviets deployed anti-ship cruise missiles with its navy, as a substitute for the naval air-arm they did not possess. They were the Soviet Union's answer to American naval airpower, particularly against U.S. aircraft-carrier-based battle groups.⁷⁰ By contrast, the U.S. designed its cruise missiles to extend the range, survivability, and destructive power of their manned strategic forces.

Operation Iraqi Freedom also saw the first time cruise missiles were used against the U.S. when Iraq fired 5 modified HY-2 missiles at U.S. forces

Modern cruise missiles first showed their potential as precision-guided weapons in the 1967 Six-Day War, in which Israel lost several naval vessels to Soviet-made *Styx* missiles in the hands of the Egyptian navy.⁷¹ Most Soviet cruise missiles of that era were little more than small, pilot-less jet aircraft with internal navigation and terminal-phase radar-homing systems, but even then, their effectiveness as substitute airpower tools was clear.

Western Europe and the U.S. developed advanced, second-generation cruise missiles with greater precision, smaller size, extended range and even some measure of stealthiness. These characteristics reflected the West's lead in electronics. Western cruise missile technology first proved effective in the hands of the Argentine Air Force, which used French-made *Exocet* missiles so effectively against the British Royal Navy in the 1982 Falklands War.⁷²

Cruise missiles really came of age in modern land warfare in the hands of the U.S. armed forces during the first Persian Gulf War in 1991, when then-latest generation *Tomahawk* cruise missiles were used to attack strategic targets deep inside heavily-defended Iraqi territory.⁷³ These were conventionally-armed counterparts to strategic weapons developed by the U.S. during the Cold War. Despite being little larger than naval torpedoes, *Tomahawks* possessed the ability to fly over 1,500 miles and still strike to an accuracy of within 30 feet of their intended targets.⁷⁴

So effective are these weapons in breaching enemy defenses and destroying their targets that the U.S. has used them in virtually every major military operation since 1991, from Bosnia, Kosovo, Serbia, Sudan, and Afghanistan, and up through *Operation Iraqi Freedom* in 2003.⁷⁵ Cruise missiles provided an attractive option for responding to terrorist attacks during the 1990s as well, such as when then-President Clinton ordered cruise missile strikes on targets in Taliban-controlled Afghanistan and in the Sudan, in retaliation for the 1998 bombings of the U.S. embassies in Kenya and Tanzania.⁷⁶ *Operation Iraqi Freedom* also saw the first time cruise missiles were used against the U.S. when Iraq fired 5 modified HY-2 missiles at U.S. forces.⁷⁷

Incentives to Acquire Cruise Missiles

The frequency of U.S. use, which clearly demonstrated the effectiveness and utility of the cruise missile, also has encouraged other states to acquire similar capabilities.⁷⁸ The incentives to acquire cruise missiles emerge from the unique qualities of the weapon, the relative immaturity and limited availability of defenses against them, and their low relative cost.

Cruise missiles were originally created to provide a precision-air-strike function that can be described as that of disposable attack aircraft, a continuation of the defense-bypassing, highly mobile, bombardment, disruption, destruction and defeat function of airpower itself. For states today, constructing and maintaining airpower is expensive and difficult. Cruise missiles offer an affordable and effective alternative to supporting an air force. As Lt. Col. David Nicholls, USAF, states,

“For decades, military theorists have argued that the fundamental value of airpower is its ability to destroy the key nodes in a state’s economy or military that would cripple the opposing force and prevent it from fighting effectively.... It is unlikely that any nation will have aircraft that are capable of achieving air

superiority against U.S. military forces in the foreseeable future, and thus could not mount a strategic bombing campaign. However, cruise missiles are so inexpensive and expendable that a state could mount a strategic bombing campaign with cruise missiles, and thus avoid the need to achieve air superiority.⁷⁷⁹

Cruise missiles are also capable of inflicting significant damage on their targets, civilian or military. They can carry conventional warheads or weapons of mass destruction. The destructive power is certainly below the threshold of a ballistic missile, but a nuclear detonation of any kind is an outcome worth avoiding. Cruise missiles are particularly well-suited as delivery vehicles for chemical or biological weapons. The flat flight path of a cruise missile is much more efficient for disseminating a chemical or biological agent than a ballistic missile.⁸⁰ Further, given that likely adversaries of the United States will not be looking to engage in a full-scale war, but instead, induce terror at home or restrain movements of U.S. forces abroad, the high accuracy of a cruise missile enables an adversary to strike precise targets.

In light of the preponderance of U.S. military power, potential competitors and adversaries are looking to utilize asymmetric strategies.⁸¹ These strategies seek to exploit U.S. vulnerabilities to alter the strategic environment by upsetting public or allied opinion, thereby restricting freedom of action. Asymmetric strategies also may succeed by showing the ability to (or actually doing it) inflict unacceptable damage on U.S. or allied forces or civilian populations with the objective of deterring or dissuading further U.S. actions. Cruise missiles are an effective means for accomplishing these goals.⁸² Because they are hard to detect, adaptable, highly capable, with the ability to carry a variety of warheads, and strike population centers, military bases, and actively deployed military units, they are a means to deter U.S. intervention in a region,⁸³ hold U.S. overseas bases at risk,⁸⁴ and place the U.S. homeland at risk.⁸⁵

The defense of military forces from cruise missiles was the focus of past U.S. thinking and is reflected in the suite of available defensive options to be reviewed shortly. The U.S. principally saw the cruise missile threat as one that would manifest itself against its naval and ground forces and be directed against those forces on a battlefield. As cruise missiles become viewed as instruments of coercion and terror, other political or military considerations come into play.

By holding allied populations at risk, terrorists or other adversaries can use the threat of cruise missile attacks as a means to blackmail or coerce otherwise friendly nations to withhold or restrict support to the U.S. by denying access to bases or airspace, for example. Strategically placed systems at key geographic chokepoints, such as the Panama Canal or the Straits of Hormuz, could paralyze international commerce and raise apprehensions worldwide. Finally, the use or threatened use against the U.S. homeland or overseas military bases is an all-too-real consideration, which may limit options available to U.S. leaders in responding to future crises.⁸⁶

Cruise Missile Threats to the U.S. Homeland

Is there a cruise missile threat to the U.S. homeland? The possibility of a terrorist group or other non-state actor acquiring cruise missiles is no longer discountable. That such groups, particularly terrorist groups, might fire those missiles at targets within the U.S. as instruments of terror is obvious. It has long been argued that states would not risk U.S. retaliation by firing cruise or ballistic missiles. However, even assuming that deterrence actually works against states, it is doubtful whether such a strategy will work against terrorists who lack a state to retaliate against. Today's terrorists appear more likely to use these kinds of weapons than any other adversary faced by the United States. Many are willing to commit suicide in pursuit of their goals and can be expected to suffer retaliatory blows willingly. The seemingly intractable problem of locating where to strike works to the terrorists' advantage. With 'no return address' to go after, a successful terrorist leadership cadre could launch a cruise missile from a container ship at an American city and successfully evade U.S. efforts to capture them, as Osama Bin Laden and other senior Al Qaeda leaders have. The questions are whether terrorists can or will acquire cruise missiles, and what the impact of such use might be.

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The acquisition of these systems by terrorist groups or their supporting states is inevitable. Indeed, this is already a reality, as proven by Hezbollah's use of anti-ship cruise missiles in the July 2006 Lebanon war.⁸⁷ The proliferation trends described previously show that these systems have already made their way into the hands of states hostile to U.S. interests, are readily available on the international arms market, and can be improved through the acquisition of commercial navi-

gational aids and other technology. Of further concern is the growing store of public knowledge that provides instructions for constructing simple cruise missiles.⁸⁸ In short, the prospect of groups attaining the basic knowledge needed to begin indigenous production of a "simple, autonomous, self-guided cruise missile with a significant payload has reached a new and dangerous level."⁸⁹

The use of commercial vessels to serve as launch platforms for cruise missiles against U.S. targets is a widely discussed threat. Cargo vessels equipped with cruise missile launchers hidden inside standard shipping containers or from within the cargo hold itself, are considered possible by the intelligence community.⁹⁰ In 2002, then-Defense Secretary Rumsfeld warned of the possibility of terrorists using a rudimentary cruise missile against homeland targets.⁹¹ A 2004 Defense Science Board study examining the roles of the Defense Department in homeland security concluded that "ocean

vessels, cruise missiles, and low-flying aircraft are credible delivery systems available to adversaries” and urged the DOD to undertake defensive efforts to counter those threats.⁹² In 2006, the Air Force issued a request for information to address “high priority capability gaps” including how to respond to “a rogue maritime platform” that fires a cruise missile off the coast of Maryland “targeting a major metropolitan area.”⁹³ As a corollary, the successful ballistic missile tests by North Korea in July 2006 involved several missiles that also would fit onto many merchant container ships. The ballistic missile launch from a cargo ship is one that many national security planners are concerned about as well.

The United States has more than 12,000 miles of coastline, including Alaska and the Great Lakes. Within 200 miles of these coasts more than 75% of the U.S. population resides, about 80% of the economic wealth of the country is generated, and three quarters of the military bases are located. For a group seeking to incite terror or a state looking to inflict harm, there are ample targets to choose from. The concern is not academic. Two former National Security Council staff wrote of such a scenario in 2003, noting that Al Qaeda is reported to have 15 freighters at its disposal for use as possible launch platforms.⁹⁴

The weapon of choice today probably would be the widely available Chinese-made *Silkworm*,⁹⁵ although use of larger missiles is also possible. Conversion of the *Silkworm* from an ASCM to a LACM is accomplished with “relative ease” and its range extended from 90 miles to more than 310 miles.⁹⁶ Territorial waters extend to 200 miles, implying that *an adversary may never even have to enter U.S. waters to launch their missile against a U.S. city or, if they entered U.S. waters and neared shore, the missile could reach cities or other targets hundreds of miles inland.*

Cruise missiles can be stowed inside a standard cargo container, as evidenced in Table 5. ISO standard cargo containers measure 20-40 feet in length, are 8 feet wide, and 8.5 feet tall. The brief sampling of dimensions of various cruise missiles shows they would fit within those parameters. Further, storing a cruise missile in such a container protects it from the elements and obviously aids its concealment from detection.

Table 5 – Comparison of Dimensions of Cargo Containers vs. Cruise Missiles

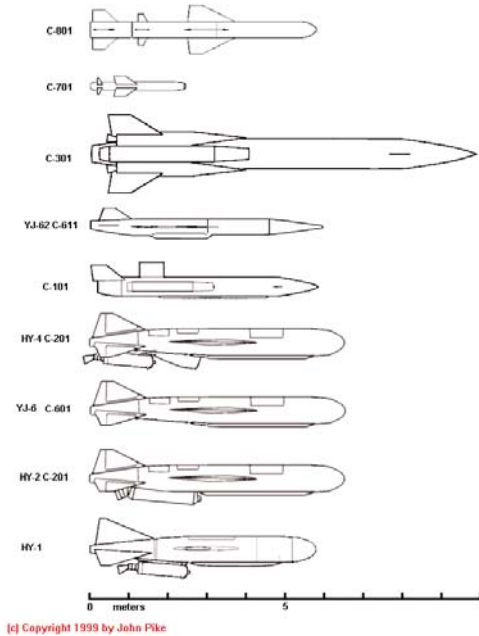
Object	Length (ft.)	Width (ft.)	Height (ft.)
ISO Shipping Cargo Container ^[1]	20.0/40.0	8.5	8.5
HY-1 <i>Silkworm</i> ^[2]	19.0	7.9	2.5
C-802 ^[3]	21.0	4.0	2.5
AS-15 <i>Kent</i>	29.2	2.5	2.5

[1] Staff, *Container Dimensions and Capacity*, Export911.com, — last accessed June 21, 2006, <http://www.export911.com/e911/ship/dimen.htm>

[2] Duncan Lennox, (Ed.), *Jane’s Strategic Weapon Systems*, (Surrey: Jane’s Information Group, Issue Forty – January 2004). 53-54

[3] Ibid: 65-67

Figure 5 - Comparison of Chinese Cruise Missiles to Std. 40ft. Shipping Container



Source: John Pike, *Chinese Cruise Missiles in Plan View and to Scale, Chinese Conventional Missiles*, 10 August, 1999, <http://www.fas.org/man/dod-101/sys/misile/row/prc.htm>; and *Container Dimensions and Capacity*, Export911.com, - last accessed June 21, 2006, <http://www.export911.com/e911/ship/dimen.htm>

Even if the missile were not hidden, finding a ship carrying a cruise missile is a daunting task. With over 125,000 merchant vessels in use worldwide, and some 90,000 of these at sea at any time, the scope of a search for such equipment is problematic.⁹⁷ Locating a vessel 500 nautical miles off the U.S. coast requires searching three million square miles of ocean.⁹⁸ Use of ever more capable cruise missiles will further extend these ranges, increasing the search challenge substantially. Many ports outside the U.S. do not have the detection capabilities or inspection regimes available in the U.S. Certainly, the U.S. relies heavily on its intelligence capabilities to narrow the search dimensions, but the craftiness of adversaries to adapt to these new circumstances should not be discounted.

Terrorist organizations desire WMDs and unconventional delivery systems. Hezbollah, well-known for its state backing from Iran and Syria,⁹⁹ has an arsenal of over ten thousand artillery rockets and battlefield ballistic missiles and is reportedly in possession of chemical weapons.¹⁰⁰ Hezbollah used an Iranian-made UAV to overfly and reconnoiter military positions in northern Israel in 2005,¹⁰¹ which is a technology that could also be converted for use as a cruise missile.¹⁰² Hezbollah also fired two Chinese-made C-802-class anti-ship cruise missiles against the Israeli missile-corvette, the *Hanit*, in the July 2006 Lebanon war.¹⁰³ Similarly, Al Qaeda's use of airplanes as weapons, access to merchant vessels, and interest in WMDs are all indicators of the desire to inflict terror on the United States and its allies. *The precedents are all in place to realize the nightmare scenario of strategic weapons, i.e., WMD-armed, de facto cruise missiles in the hands of a terrorist organization.*

While there is currently relatively little state-to-state armed conflict in the international environment and the prospect of another state launching an attack on the U.S. homeland is remote today, should the international system become destabilized or a hostile power seek to inflict harm on the United States, cruise missiles would be a weapon of choice. Submarine fleets or long-range bombers, reminiscent of the Cold War, could be used to deliver cruise missiles close enough to strike U.S. cities. Indeed, that was why the Soviet Navy presented such a threat to the U.S. Navy during the Cold War.¹⁰⁴ It is also why there are growing concerns about the Chinese naval and maritime air forces' increasing development and/or acquisition of both indigenous and Russian-sourced ASCMs.¹⁰⁵ China is also fitting long-range LACMs on its existing fleet of bomber aircraft.¹⁰⁶ More likely, cruise missiles would be used to deny U.S. access to areas in a theater of conflict or against the population centers of allies.

Cruise Missiles as WMD Delivery Systems

The implications and the effects of cruise missile use are ominous. A nuclear-armed cruise missile would inflict tens of thousands of casualties, billions of dollars in damage, and incalculable psychological impact. As Abt explains, a 10-20 kiloton-yield nuclear weapon would have the following effects:

“The catastrophic... priority targets are the major U.S. population, commercial, government, and transportation centers. The top three are New York, Washington DC, and Los Angeles, as has been repeatedly demonstrated in the last decade before 9/11/2001. Clearly the centers of American economy, government, and urban society are targeted by the terrorists for strategic bombardment and destruction, and are likely to continue to be their targets for the foreseeable future...a successful attack would create disruption of U.S. trade valued at \$100-200 billion, property damage of \$50-500 billion, and 50,000 to 1,000,000 lives.”¹⁰⁷

It should be remembered that there are cruise missiles in both American and Russian inventories that can carry 200 kiloton to 250 kiloton warheads, respectively. In particular, the AS-15s now in the hands of China and Iran are capable of carrying 200 kiloton warheads. Use of these or similar systems would have enormous impact.

Heidenrich and Murray provide appropriate context for evaluating the nuclear cruise missile challenge:

“A mere half-kiloton blast, less than one/twenty-fifth of what destroyed Hiroshima in 1945, is still equivalent to the explosive force of 500 tons of TNT. On September 11, 2001, the World Trade Center collapsed after massive fires from two airliner impacts weakened the Twin Towers — and not before an estimated 30,000 occupants were evacuated. However, if a half-kiloton warhead had exploded at the WTC’s base, the Twin Towers would have fallen immediately, and diagonally, hitting other buildings in a giant domino effect on lower Manhattan. The death toll would have been catastrophic. And most nuclear weapons have yields much higher than half-kiloton.”¹⁰⁸

The cruise missile is particularly well-suited as a biological or chemical weapon delivery device.¹⁰⁹ A relatively flat flight trajectory and ability to make precise turns allows for much more precise dispensing of the biological or chemical agents. The chem-biocruise

The implications and the effects of cruise missile use are ominous. A nuclear-armed cruise missile would inflict tens of thousand casualties, billions of dollars in damage, and incalculable psychological impact.

threat is limited by the challenge of creating warheads suitable for cruise missiles, but intelligence reports suggest some nations and groups are looking at the possibilities.¹¹⁰ The number of casualties and illnesses arising from such attacks is hard to estimate and influenced by population

density, weather patterns, and efficiency of the dispersal.¹¹¹ One impact is clear — a chemical or biological attack on the United States or any ally would have devastating psychological effects on the population.

Even if a cruise missile were armed with conventional munitions, the potential effects of a strike on the U.S. homeland are substantial. Destruction of the World Trade Center cost thousands of lives directly, cost the City of New York \$95 billion,¹¹² and served as a key motivator for the U.S. military response in Afghanistan and Iraq, with their associated lives lost and financial costs. A conventional strike with a cruise missile on a U.S. city may or may not create equivalent results to the September 11th attacks, but they are not costs that any U.S. citizen or the U.S. government should bear.

A further consideration is the response the U.S. government or any friendly or allied government would have if a terrorist group or hostile state threatened to use cruise missiles in the manners described. How the U.S. will respond to WMD blackmail and coercion remains to be seen. Certainly, these capabilities in the hands of hostile powers intent on using them or threatening to use them will severely restrict U.S. freedom of action and may result in disadvantageous agreements.

The Four Components of Cruise Missile Defense

Given the strategic value of cruise missiles to future adversaries and as instruments of terror, the need for an effective strategy against them is obvious. With the tens of thousands of cruise missiles in world military inventories today, the growing numbers and possessors of these weapons, and the rising numbers of states capable of producing these weapons indigenously, the risk of the U.S. being attacked with these weapons, for which defensive preparations are minimal, is great and rising, and with it, the risks of heavy losses and even defeat in combat. This risk also extends to friends and allies, who may themselves face these threats, and either be forced to respond in kind, or else might draw the U.S. into a conflict to help support them. U.S. homeland defenses, in particular, are minimal with nothing in place beyond existing military bases and a limited number of fighters ready to scramble to intercept them. As Gen. Jumper is quoted at the outset, the issue is what the U.S. will do in the face of these facts.

Four options define the approaches for defending against a cruise missile threat attack. These are nonproliferation, pre-emption, passive defenses, and active defenses. Each is considered for its strengths and limitations.

Non-Proliferation Regime

Of the four methods of protecting against attacks with cruise missiles, preventing the spread of the capabilities has obvious benefits. If the international community could successfully prevent states and organizations from ever obtaining completed cruise missiles, component technology, or the expertise to produce them, then the threats facing the U.S. and its allies would be minimized. Unfortunately, the multilateral arms-control process has proven unable to preclude the proliferation of these systems and the underlying knowledge base needed to construct them. In today's world, cruise missile technology is ubiquitous and the non-proliferation regime cannot roll capabilities back from those who already possess it.

The three international regimes aimed at preventing the spread of cruise missile technologies are the Missile Technology Control Regime (MTCR),¹¹³ the U.S.-led and recently implemented Proliferation Security Initiative (PSI),¹¹⁴ and the Wassenaar Arrangement on Dual-Use Export Controls.¹¹⁵ The MTCR is a set of guidelines and restrictions agreed upon by 33 states, restricting the flow of missile technologies that enable missiles to have greater than 500kg payloads and 300km ranges. It also includes enforcement rules.¹¹⁶ The PSI permits interdiction of shipments worldwide as part of the effort to prevent proliferation.¹¹⁷ The Wassenaar Arrangement is a voluntary organization of nations seeking to control the flow of dual-use technologies to nations of concern. It is the successor arrangement to the Coordinating Committee on Multilateral Export Controls (COCOM,) a Cold-War-era organization that was aimed at restricting the flow of dual-use technologies to the Warsaw Pact.¹¹⁸

To the extent that cruise missiles and related technologies are being kept out of the reach of states of concern and non-state actors, these regimes are necessary and irreplaceable. However, non-proliferation measures have already proven insufficient to prevent the spread of a variety of weapons technologies. The number of states possessing cruise missiles of all types has grown and the number of states capable of manufacturing completed systems is on the rise. The export market for cruise missiles is active and a number of states of concern to the U.S., such as Iran and North Korea, are active sellers. The widespread availability of dual-use components, such as navigational aids, enables the easy upgrading of older systems. This does not mean that non-proliferation programs and activities should be abandoned; quite the contrary, they remain necessary and essential to slowing the ongoing spread of weapons technologies. Nevertheless, the non-proliferation regime alone is no longer sufficient as the primary response to the task of protecting U.S. interests from cruise missile proliferation.

Pre-Emption

Pre-emptive attack operations against cruise missiles involve launching air and ground strikes against launchers, storage facilities, military bases, roads and railways.¹¹⁹ Aircraft and surface-ship or submarine-launched strikes could be carried out against cruise-missile-armed ships (both military and possibly civilian, or asymmetric launch platforms.) Anti-submarine warfare (ASW) operations could also be conducted to sink cruise-missile-carrying submarines.

There is no guarantee that air, ground, surface and subsurface attacks will find and destroy all the threat launchers; there are simply too many different types and routes of cruise-missile launch platforms to find and destroy. Recall that cruise missiles are easily disguised and transported in trucks, cargo containers, and railroad cars and with more than nine million containers seeking to enter the United States annually, finding the right one is a large, demanding task. A successful pre-emption strategy would demand detailed intelligence and nearly real-time response for success against a state, a highly unlikely combination of events. Acting against a terrorist cell or other non-state actor, where reliable intelligence is already suspect, raises the probability of error even more.

As historical evidence to this point, neither the V-weapon hunt that was *Operation Crossbow* in 1944 nor the Scud ballistic-missile hunts of *Operation Desert Storm* in 1991 were anywhere near 100% effective in finding and destroying all the missile-launch facilities of their respective eras.¹²⁰ Pre-emptive attack operations cannot by themselves guarantee full protection against cruise missile attacks.

Passive Defenses

Passive defenses are measures taken to avoid or withstand the effects of attacks. These include bunkering, deep burial, dispersal, concealment, and placement of assets far behind front lines or far inland from shores and borders.¹²¹ This approach does nothing to prevent the attacks themselves or the damage caused. Instead, passive defense simply tries to prevent or minimize the damage to critical assets or infrastructure. The harm to non-strategic targets like people and homes could be extensive, especially if WMDs are used. Cruise missile strikes against the U.S. homeland are most likely intended for cities and other high-value, non-military targets.

Nonproliferation, preemption and passive defense each have limitations that significantly diminish their independent abilities to defend U.S. interests. Even together, none can prevent a cruise missile attack from doing damage if the missiles are launched and strike their targets.

The passive defense strategy clearly has benefits for overseas or domestic military bases and other elements of U.S. critical infrastructure as it improves the probability of survival. Such approaches are of little value for homeland defense, where sheer size and expense precludes serious contemplation of their application. Furthermore, the passive defense strategy still allows the missiles to hit their targets. It is neither an effective defensive option for homeland defense nor an optimal one for protecting military forces abroad.

Active Defenses

Nonproliferation, preemption and passive defense each have limitations that significantly diminish their independent abilities to defend U.S. interests. Even together, none can prevent a cruise missile attack from doing damage if the missiles are launched and strike their targets. With the proliferation of capabilities and strong incentives for use, active and effective defenses are needed to detect and destroy cruise missiles before they reach their intended targets.

Active defenses against cruise missiles require that the defending system have both the means of detecting and tracking incoming threats, as well as the means of physically destroying the threats. Options for defending against cruise missile attacks are considered in the next section.

Cruise Missile Defense Efforts and Options

Concerns within the military about cruise missile defense resulted in the fielding of service-oriented defensive systems, such as the Army's *Patriot* ground-based air defense, the Navy's *Aegis* ship-based missile defense, and the Air Force's surveillance and tactical combat aircraft.¹²² As a consequence of these investments, the U.S. military has developed fairly effective point defenses, that is, the defense of a very limited geographic space. However, neither the existing systems nor the current approach to cruise missile defense offer the kind of wide area coverage perceived as needed in the face of the growing threat and diverse challenges faced today and into the future.

Before evaluating the defensive options available, criteria for assessing the effectiveness of a cruise missile defense are offered for context. These principles were originally offered as a way to evaluate military systems generally, and offer a base framework for evaluating cruise missile defense options broadly. They are that:

1. The system must be militarily effective in all circumstances that might arise.
2. The system should have a cost-exchange advantage at the margin in the worst case; that is to say, the unit of defense must always be cheaper than whatever the offense could do at the margin, so that the attacker could not possibly scale his way out of the challenge posed to the attacker by the defender.
3. The system has to be robust in all plausible military environments.¹²³

However, neither the existing systems nor the current approach to cruise missile defense offer the kind of wide area coverage perceived as needed in the face the growing threat and diverse challenges faced today and into the future.

A cruise missile defense can be designed to meet the first and third criteria. The second presents major challenges, as the cost of cruise missiles are so low. When assessing this cost-exchange criterion in light of homeland defense concerns and the rise of asymmetric warfare, the cost trade-off between a defensive system compared to the value of the defended asset must also be considered. Preventing the destruction of American lives and property in light of an increasing threat places a premium on the development of defensive capabilities. The criterion has most applicability when comparing equally effective defensive options during the process of selecting which combination of capabilities are best suited to protect

against particular threats. Another factor implicit in comparing cost-exchange ratios is the relative buying power of the defender compared with that of the attacker, though this is subsumed in the value of the target being defended. Considering the consequences of failing to construct a defense, more favorable application of the criteria against proposed cruise missile defenses is possible.

The time horizon for desired deployment will require trade-offs in cost and capability. If the threat posed by cruise missiles is so acute that the U.S. seeks a deployed defense within the next two years, the resulting system will not be an optimal one; it will be an expeditious one based on available systems and capabilities reoriented toward this new mission. Future refinements and capability enhancements through the development of new systems will improve the performance and cost-effectiveness of cruise missile defenses. Also driving the development of more comprehensive cruise missile defenses is the increasing threat to the U.S. and its interests, as cruise missiles themselves continue to proliferate and grow in sophistication. For this reason, available options for cruise missile defense also are evaluated for their near-term and longer-term applications.

An effective cruise missile defense must have four basic elements. Those elements are:

- the capability to detect and then track a cruise missile after it is launched;
- interceptors to destroy the attacking cruise missile;
- a battle management and communications network that ties the first two elements together and allows for seamless real-time engagements; and
- the ability to effectively predict and manage the consequences of a cruise missile attack.

Detection

The greatest challenge for a cruise missile defense is the detection and tracking of the missile early enough to engage it before it reaches its target. A viable cruise missile defense will have as its goal the earliest possible detection of a missile after its launch. Sensor detection capabilities should be pushed out to as far a distance as possible from the areas defended to allow as much time as possible to track and intercept the missile. Also, in homeland defense, intercepting the attacking missile out over the ocean lessens the consequence management implications than over populated areas on land. Achieving this requires the ability to detect and launch an interceptor quickly so as to extend intercept ranges to the farthest point possible.

Cruise missile flight paths make detection a particularly challenging undertaking. Shorter range missiles offer little reaction time. The missiles fly close to the Earth's surface, and advanced systems are programmed to use topography (valleys, hills, and mountains) and the Earth's curvature to mask their approach from detection by the defender.

Traditional approaches to CMD were specific, i.e., the defense of a particular point such as a naval vessel or military base, and relied on radar to fulfill the detection mission. By virtue of their size and design, cruise missiles present small radar cross sections (RCS) during head-on intercept, which is the method employed by most point defenses.¹²⁴ Generally, low-flying objects are difficult to detect against other ground objects and sea-backgrounds. The radar must locate a faint cruise missile signal against "the hundreds of thousands of echoed returns from signals created by ground

clutter.”¹²⁵ Ground-based radars have gaps in their field of coverage that allow low-flying objects, like cruise missiles, to exploit the curvature of the Earth. Defense of wider areas requires complementing the ground-based radar with air- or space-borne assets to provide more time to detect and track and result in more opportunities for interception.

Satellite assets have difficulty detecting cruise missiles through dense cloud cover.¹²⁶ Unlike ballistic missiles, which break through the highest bands of clouds, the low-flying nature of cruise missiles enables them to use the cloud deck as cover from space-based detection. The lack of persistence of orbiting platforms over any given stretch of ground makes them less than optimal platforms with which to provide the continuous coverage necessary for surveillance against short-duration threats. Satellites are costly platforms with numerous responsibilities. Tasking existing satellite capacity for the homeland cruise missile defense mission may divert their use from other priority areas. The deployment of a dedicated satellite constellation for those purposes would be prohibitively costly. Consequently, space-based sensors will likely serve complementary roles to ground- and air-based assets.

The optimal sensor platform for cruise missile detection, therefore, will be air-based. By looking down on the Earth, elevated sensors can spot a cruise missile from many angles, unlike ground-based radars which may only see the nose. Even more importantly, air-based sensors can see over any obstructing terrain that might otherwise be used to conceal a cruise missile’s flight path. An air-based sensor platform can also survey a wider area than a ground system, since it can see farther over the Earth’s horizon than is possible from ground-level surveillance platforms. Distinguishing the cruise missile from ground clutter will remain a task for air sensors, but the ability to see more of the weapon in flight should provide stronger signals for analysis against items on the ground.

In sum, the cruise missile surveillance mission is best accomplished with look-down, ground-clutter-filtering radar augmented by imaging infra-red sensors, mounted on an aerial platform that is as persistent as possible, with the lowest possible operating costs.

There are a number of systems and programs currently available to the U.S. to serve this mission. Both the Air Force’s E-3 Sentry Airborne Warning and Control System (AWACS)¹²⁷ and the Navy’s E-2 Hawkeye¹²⁸ Airborne Early Warning (AEW) aircraft are tasked with detecting and tracking airborne threats at the greatest possible distances, and with directing combat aircraft and anti-air batteries to deal with these air threats. The great advantage of these AEW aircraft is that they are already capable against cruise missiles, an ability that only grows with time and upgrades.

The greatest advantage of aircraft-based AEW systems is also the source of their greatest limitation for sustained cruise missile defense, especially for the homeland. They are few in number and have high procurement and operating costs. They require bases and infrastructure which add to those costs. The wear-and-tear on the aircraft from the nearly constant operations inherent in a homeland defense mission would

result in rapid depreciation of a very valuable asset. Further, as with combat aircraft and surface warships developed for Cold War cruise missile defense needs, these systems are designed for their primary missions of Command, Control, Communications, Computing, Intelligence, Surveillance, and Reconnaissance (C4ISR) and AEW combat-support operations, not for homeland security. Providing round-the-clock coverage of the entire eastern seaboard of the United States with E-3s, for instance, would be prohibitively expensive and divert a scarce resource from other missions and duties.

The Navy's *Aegis* radar-equipped warships also have an ongoing role to play in cruise missile defense. Originally designed with a primary role in defending the fleet against Soviet cruise-missile threats, the *Aegis* system is comprised of ship-borne radars, missiles, and C2BMCs.¹²⁹ Naval radars have the advantages of an unobstructed view out to the horizon at sea, ship's-superstructure-mounted height (offering greater range to the horizon) and the mobility and persistence of an ocean-going vessel. This mobility is useful in extending homeland defense surveillance far out to sea, an important advantage in extending the probability of detection and the warning time of an offshore-launched cruise missile attack, precisely the sort of attack that *Aegis* ships were designed to defend against. The *Aegis* also serves as an interceptor platform for cruise missile defense, which is considered later.

The U.S. military is also developing or proposing several platforms that offer even more effective long-term options for cruise missile detection. The Joint Land Attack Cruise Missile Defense Elevated Netted Sensor (JLENS) is a longer-term option for stationary airborne sensor missions.¹³⁰ JLENS is an unpiloted, lighter-than-air vehicle, essentially an unpowered, tethered balloon, used as an at-altitude radar observation platform. Operating at 10,000 to 15,000 feet, the JLENS can look down over the horizon and down into otherwise-hidden terrain, to scan for cruise missiles. Its greater detection range can provide greater warning time for defensive systems. JLENS is designed to be 'net-centric' and share data in real-time with other components of a cruise missile defense. Since it is unmanned and lighter-than-air, it can remain on-station 24 hours a day for up to 30 days at a stretch. Importantly, there are actually two JLENS variants needed, one for surveillance, and another for tracking.¹³¹ Concerns have been raised about the all-weather viability of JLENS. Its relatively low-altitude operations render it vulnerable to adverse weather conditions. In addition, it is not due for deployment until 2010 at the earliest.¹³²

Until recently, the U.S. Air Force had been developing the E-10 Multi-sensor Command and Control Aircraft (MC2A) as a next-generation replacement for the E-8 JSTARS airborne ground-target surveillance and command-post aircraft, as well as the E-3 Sentry AWACS aircraft.¹³³ The E-10 was to be capable of detecting low-flying cruise missiles using its MP-RTIP AESA (Active Electronically-Scanned Array) radar system, capable of highly detailed, long-range, rapid scanning of surveilled territory to find and track multiple targets.¹³⁴ The Defense Department terminated the E-10 program during FY 2007.

The MP-RTIP and its potential for improved surveillance capabilities, including low-RCS cruise missile detection, were showcased on the *Proteus*, a manned surrogate of the *Global Hawk* UAV. The first test flight of the *Proteus* was completed on September 30, 2006, as part of risk reduction work.¹³⁵ The resultant system is to be deployed operationally in the *Global Hawk*. The President's FY 2008 budget supports the development of MP-RTIP capabilities on 40 *Global Hawk* platforms.

The JLENS, E-10, and other air-based radar surveillance systems, are often seen as competitors with each other. E-10 advocates claimed the aircraft could be deployed quicker and would be more mobile than the tethered JLENS, and that the latter was also impacted by adverse weather. JLENS supporters counter that the system is designed to withstand wind speeds of up to 100 knots and point to its superior loitering capability as an asset, although these claims are hotly contested.¹³⁶

Both sets of criticism have merit, but in the end both systems could make contributions in providing improved future cruise missile defense mission. JLENS's ability to loiter in place offers attractive qualities for designing a homeland or wide-area defense. Assigning an aircraft to that mission is an expensive and inefficient use of that asset. By contrast, the E-10 or its equivalents have mobility and speed of deployment and wider-area patrol/surveillance capabilities unmatched by aerostats, and therefore are extremely desirable for responding to crisis and combat situations.

The High Altitude Airship (HAA) was another emerging-technology program under consideration for the wide-area surveillance and defense mission. This 500ft long, 150ft wide, lighter-than-air, fully-autonomous airship-cum-UAV was intended to remain

The decision to stop supporting the HAA may make sense in the context of ballistic missile defense priorities, where competing sensor platforms are available, but it leaves one to wonder whether the challenge of defending the homeland from cruise missiles is receiving the attention it deserves.

on-station at altitudes of up to 70,000ft, for periods of weeks to six or seven months. Unlike the JLENS, the HAA would be unencumbered by any tethers, would be solar-powered, enabling it to operate entirely on electricity using electric motor-driven propellers, avionics, and radars. As a result, the fuel, range or time-on-station limitations are virtually unlimited. The HAA was also to have a payload capacity of 10,000-12,000 lbs at 60,000 feet.¹³⁷ It was to give the lighter-than-air surveillance-platform

concept full tether-free autonomy and self-propelled mobility, with its greater operating altitude enabling it to see farther while maintaining equal or greater persistence. Also of note, a complete suite of sensors, from radars to EO and IIR, could be carried on a

single HAA, unlike JLENS, which can only carry a single, limited payload. This factor drives the need for two different versions of JLENS in any given deployment. The HAA is intended to give its operators “capabilities on par with satellites at a fraction of the cost. In position, an airship would survey a 600-mile diameter area and millions of cubic miles of airspace.”¹³⁸ Indeed, an argument can be made that the HAA is the optimal solution for wider-area, cruise and ballistic missile defense missions, including the homeland.

Yet, despite this promising application, the HAA program was terminated in the FY 2008 presidential budget request due to “funding constraints.”¹³⁹ The decision to stop supporting the HAA may make sense in the context of ballistic missile defense priorities, where competing sensor platforms are available, but it suggests that the challenge of defending the homeland from cruise missiles is not receiving the attention it deserves.

The potential use of near-space for aircraft operations opens the door for other, ground-breaking possibilities. HAA would have been a near-term achievable platform, had the development been allowed to proceed. A potentially superior platform for this mission is ISIS (Integrated Sensor Is Structure), in which the Defense Advanced Research Projects Agency (DARPA) plans to integrate the AESA radar sensor components into the structure of the airship itself, maximizing the size of the antenna, alongside its attendant detection power.¹⁴⁰

Any future sensor system for cruise missile defense must fulfill two missions. One is for combat operations, where U.S. troops are deployed forward, or in response to crisis or elevated threat situations. The other is the more static and continuous surveillance needs for homeland or area defense. Ground- and sea-based radars will form the backbone of any sensor strategy, coupled with use of space-based or near-space-based assets as available. For the first mission, aircraft systems offer the the optimal and most cost-effective solution. For the second mission, homeland defense, ground- and sea-based assets offer immediate options for the policymaker concerned about cruise missile defense. They can be complemented during times of crisis with aircraft, aerostats, or even UAVs as circumstances warrant. Continuing concerns about the long-term threat posed by cruise missiles warrant consideration of permanent deployment of tethered or other aerial assets, such as near-space systems like the HAA.

Interceptors

Once an attacking cruise missile is located, the next major challenge is to shoot it down. Combat aircraft and ship-borne defense systems are the two principal means currently at the U.S.’s disposal to down cruise missiles. The *Patriot* PAC-3 missile defense system offers the most viable option for deployment in the near-term of a cost-effective wide area defense.

Some key factors when evaluating interceptors for cruise missile defense are their relative cost, the speed of the interceptor, and how well integrated they are with the sensor systems. Coloring the considerations which affect the character and number of interceptors to be deployed are judgments about the value of the asset being defended. In the cases considered here, the value of American or allied population centers is quite high.

All current U.S. front-line fighters since the Navy's F-14A *Tomcat* have been equipped with look-down, shoot-down, pulse-Doppler radar. This radar technology was designed from the outset to "see" and direct air-to-air missiles against airborne targets flying at low altitudes against ground clutter. Indeed, the F-14A was designed specifically with fleet air-defense and particularly with cruise missile defense as its primary mission.¹⁴¹ The latest versions of the F/A-18 *Hornet* and *Super-Hornet*,¹⁴² the F-16 *Fighting Falcon*,¹⁴³ as well as the F-15 *Eagle* (from its inception)¹⁴⁴ all are equipped with this technology. All front-line U.S. fighter aircraft can carry the AMRAAM active-radar-homing air-to-air missile, with a range of up to 110 km, one that was designed from the outset to be effective against low-flying targets, such as cruise missiles.¹⁴⁵ Similarly, all front-line fighters carry various versions of the *Sidewinder* heat-seeking air-to-air missile, though its range is much less than that of the AMRAAM, at a maximum of 18km.¹⁴⁶ The newly deployed F-22 *Raptor* air-dominance fighter is also said to have improved cruise missile defense capabilities.¹⁴⁷ Compared to other fighters, the loiter time of the F-22 is longer and the aircraft employs active electronically scanned array radar (AESA), which is capable of detecting smaller targets at greater range and with greater precision. These capabilities have yet to be tested in an end-to-end test, but the potential is there, and the Air Force is building in cruise missile defense as a mission for the F-22.¹⁴⁸ The F-22 is both an immediate and improving longer-term potential platform for detecting and downing cruise missiles.

An interesting development along these lines, and an addition to the suite of improved future defenses against cruise missiles, is the new Air-Launched Hit-To-Kill (ALHTK) program. This is part of the Missile Defense Agency's (MDA) "Quick Reaction Special Projects" program to derive air-based defenses against boost-phase ballistic missiles, using existing defense missiles such as the *Patriot* and AMRAAM.¹⁴⁹ Recently funded by the MDA, this program involves mounting *Patriot* PAC-3 interceptors on F-15s. Basing a PAC-3 on a jet fighter would greatly extend the missile's reach as well as its range. This new version of the PAC-3 is to have increased performance and maneuverability with a more powerful motor and larger fins to enable it to engage boost-phase ballistic missiles, as well as cruise missiles, in addition to its current suite of airborne and missile targets. Other potential platforms for the ALHTK include the F-16, F-22, and F-35.¹⁵⁰ These weapons would then be carried by aircraft flying Combat Air Patrols to provide area defense against all aerial threats.

While front-line combat aircraft are profoundly capable assets, they are not optimal resources on which to base an effective and cost-effective continuous defense against cruise missiles. Fighters are expensive to operate and maintain and have very limited on-station endurance, regardless of whether they are based on land or aircraft carriers.

Costs to operate a fleet of aircraft of sufficient size to patrol both U.S. coasts are prohibitive, in terms of materiel and especially in exhaustion of aircrews and support personnel, as was seen in the post-9/11 defensive Combat Air Patrols (CAPs).¹⁵¹ For instance, the CAPs maintained over Washington and New York in the wake of 9/11 cost the Air Force and Air National Guard (ANG) some \$30 million a week, “wreaking havoc on units.”¹⁵² CAPs can provide defenses against cruise missiles during times of high threat, but not on a permanent, sustained basis. Further, interception times and basing locations may not permit the timely interception of cruise missiles on short notice as might well be the result of surprise launches of cruise missiles from offshore cargo ships or submarines. Combat aircraft are best employed in in-theater warfighting, which is their primary function.

However, front-line combat aircraft are extremely useful assets for crisis situations. This applies to both surveillance and fighter aircraft. If circumstances near the homeland warrant their use, these aircraft can fill that complementary mission. In areas where military forces are forward deployed or in times of combat, these aircraft will assume the role of primary defense for U.S. troops or others.

The U.S. Navy’s warships are also equipped with a variety of anti-aircraft defense systems capable of defeating cruise missiles. *Standard* SM-2 Block IV-series surface-to-air missiles guided by *Aegis* shipboard radar systems,¹⁵³ *Vulcan Phalanx CIWS* gun systems,¹⁵⁴ and RIM-116 *RAM* short-range heat-seeking missiles¹⁵⁵ all provide U.S. warships with a wide array of self-defense capabilities against cruise-missiles as well as aircraft. U.S. naval air-defense weapon systems were designed to defend against Soviet cruise missiles, and they retain those capabilities today.¹⁵⁶

While naval surface warships can provide more persistent area defense against cruise missiles than combat aircraft can (up to weeks at a time), these warships’ primary missions of global power projection and fleet defense would be curtailed or eliminated with long-term coastal defense missions. Further, warships are expensive to maintain on-station and the numbers of vessels required to fully defend the U.S. homeland against cruise missiles might well strain available resources.

A distinction is necessary for the *Aegis* missile defense vessels. The United States is committing a number of *Aegis* cruisers to ballistic missile defense missions, outfitting those vessels with sensor and interceptor capabilities specifically designed for that function. While oriented toward ballistic missile defense, the Navy plainly sees roles for these vessels beyond fleet defense. Increasing the number of these vessels and assigning them to homeland defense missions enhances both the sensor and interceptor elements for cruise and ballistic missile defense of the United States.

Aegis aside, the use of naval vessels and combat aircraft for continuous homeland defense against cruise missiles represents an expensive and inefficient use of resources. These systems have clear combat defense roles, but their use for homeland or large area defense is not a preferred solution. They simply cannot provide the reliable, always-on interceptor capability needed to protect American cities from cruise missile

attack. The same is true for large area defense missions abroad. They offer important complementary capabilities for crisis situations and, in those times, the cruise missile defense should utilize them.

Another means of providing continuous defense against cruise missiles is, perforce, ground-based air-defenses. One such system is the Surface-Launched Advanced Medium-Range Air-to-Air Missile, or SLAMRAAM, a ground-based variant of the U.S. Air Force's highly-successful AMRAAM. The SLAMRAAM is adapted for defense against low-flying cruise-missiles. As with the AMRAAM, SLAMRAAM is a self-guided, day/night, all-weather anti-air weapon capable against of downing cruise missiles as well as aircraft. It is also intended to provide some protection against ballistic missiles and UAVs at beyond-visual ranges and can engage multiple targets simultaneously. A SLAMRAAM battery includes an integral radar and fire-control unit, but is also fully net-centric and can link up with other weapons platforms and sensors to provide or obtain target data in real-time, including the JLENS systems described previously.¹⁵⁷

Development of a new version of the AMRAAM is underway. Called the Network Centric Airborne Defense Element (NCADE), it is designed to intercept boosting ballistic missiles, possibly in addition to its existing anti-air tasks, including cruise missiles.¹⁵⁸

Given the thousands of miles of U.S. coastline to defend, and the large numbers of cruise missiles to defend against, an effective defense requires an affordable array of always-on-station sensors and interceptor missiles.

These surface-to-air options have important drawbacks, in that they have limited range, are expensive, and are tasked with theater combat ground-based air-defense. Another disadvantage of the SLAMRAAM is that its range is significantly less than that of its airborne cousin, the AMRAAM, which itself has a nominal range of 110 km.¹⁵⁹ This short range may also result in debris from an interception falling on populated areas. These systems provide

important complementary functions, but longer range interception options clearly are preferred.

Given the thousands of miles of U.S. coastline to defend, and the large numbers of cruise missiles to defend against, an effective defense requires an affordable array of always-on-station sensors and interceptor missiles. Such missions could be undertaken today by deployments of *Patriot* PAC-3 missiles and their associated radars. PAC-3 has a demonstrated capability to intercept cruise missiles.¹⁶⁰ While the PAC-3 was designed for terminal area defense against ballistic missiles, with intercept ranges of approximately 15-45 km,¹⁶¹ its application for cruise missile defense provides new opportunities for use in combat operations, as well as for area and homeland defense.

Figure 6 - Patriot PAC-3 Launch



Source: *Patriot PAC-3*, (Missile Defense Agency, February 5, 2000), <http://www.mda.mil/mdalink/images/dt5i102.jpg>

The PAC-3 offers a cost-effective option compared to other available alternatives. It is a well-developed weapon system, with proven capabilities against both ballistic and cruise missiles. It is capable of great acceleration to reach its Mach 5 top speed, which it then uses to achieve its hit-to-kill efficacy.¹⁶² Indeed, it is arguably the most effective surface-to-air defense system in the world today. And, being a ground-based system, it can be kept on alert for extended periods of time. Overall, it is likely the most effective and cost-effective interceptor weapon available for homeland U.S. cruise missile defense for the near term.

From an acquisition cost perspective, the PAC-3 also offers the most cost-effective option among the available near-term interceptor choices if an expanded cruise missile defense is the goal. In FY 2006, the U.S. Army purchased 108 PAC-3 missiles at a

cost of roughly \$560 million.¹⁶³ In contrast, an *Aegis* warship costs about a billion dollars to construct and more to outfit for missile defense purposes.¹⁶⁴ Similarly, the F-22 costs about \$168 million per aircraft; the FY 2006 budget funded the purchase of 25 aircraft at \$4.2 billion.¹⁶⁵

For the future, several programs offer interesting alternatives. One option is the outfitting of a long-loitering UAV with interceptor capabilities, as was envisioned for the *Raptor-Talon* program for ballistic missile defense in the early 1990s. Such a system has the advantage of long loitering capabilities, long-range sensing and increased weapon ranges.¹⁶⁶ The *Talon* missiles were never built or flown before the program was cancelled in 1993, but the *Raptor* high-altitude, long-endurance UAV flew as part of other Scaled Composites and NASA programs. This is another option for consideration if cruise missile defense of the homeland becomes a persistent mission. Significantly, a weapon system very closely matching this configuration has recently been revealed to be under advanced development by Israel.¹⁶⁷ Designed primarily for boost-phase defense against ballistic missiles such as Iran's *Shahab-3*, this new BMD UAV could have applications to future cruise missile and homeland defense architectures.

A critical factor differentiating the homeland defense mission from other air-defense operations is that airborne targets must be visually identified and confirmed as threats before they can be engaged.¹⁶⁸ One way to solve this problem is the Advanced Extended Range Attack Munition (AERAM) surface-to-air missile proposed by the Army's Space and Missile Defense Command. Essentially a melding of a UAV with a heat-seeking missile, this proposed weapon would fly out as far as 100 km to intercept and fly in close formation with an airborne threat, then use its Imaging Infra-Red (IIR) sensor to positively identify the target. If the target is deemed a threat, the AERAM would destroy it; otherwise, the AERAM ditches into a predetermined "safe" area.¹⁶⁹

Several directed energy (DE) weapons technologies are emerging with the potential for cruise missile defense applications in the longer term. DE represents a breakthrough in weapons technologies, firing a destructive 'round' that travels in a straight trajectory at the speed of light, costs much less per round compared with a kinetic/explosive-energy guided weapon and needs little or no flight calculation beyond merely "pointing" directly at the target.¹⁷⁰

High-powered microwaves (HPM), which are best produced using the latest generation of "Active Electronically Scanned Array" (AESA) radar antenna technology, focus electromagnetic power on a target with extreme precision. By generating a large pulse of electrical current to flow through the guidance system electronics of a target missile or the avionics of an enemy aircraft, the critical avionics are destroyed.¹⁷¹ Future aircraft, such as the F-22, F-35 and EASA-upgraded fighter aircraft, will have built-in anti-missile electromagnetic weapons capability.¹⁷²

Figure 7 - U.S. Raptor-Talon BMD UAV



Source: Greg Goebel, *The BMDO Raptor Talon UAVS*, (In the Public Domain, 1 April 2006), http://www.vectorsite.net/twuav_15.html

Another DE option is the High Energy Laser (HEL). Powered with either chemicals or electricity, the HEL shares the speed-of-light, multi-shot, line-of-sight efficiencies of HPM with a greater physically-destructive effect against less electronically “smart” targets, as well as missiles. Indeed, the Tactical High Energy Laser (THEL) project successfully shot down artillery rockets, tactical ballistic missiles, artillery shells, and even mortar rounds, both singly and in volleys, in a multitude of tests dating back to 1996.¹⁷³ These accomplishments bode well for the efficacy of laser weapons for point defense against cruise missiles. THEL was cancelled by the U.S. Army in 2005 in anticipation of much better future progress in solid-state lasers.¹⁷⁴

It must be noted that none of the posited DE weapon systems are yet operational and it may be years before any of these are fully prepared for use in combat. Another limiting feature is that these weapons are by their nature line-of-sight only, which curtails their effectiveness against low-flying cruise missiles. Finally, DE systems are likely to be expensive to operate and maintain, like their other, more established military combat system platform counterparts, such as combat aircraft and naval vessels.

For the immediate future, the best interceptor choices for wide-area cruise missile defense are PAC-3 and combinations of tactical aircraft and ship-borne missiles.

These prospective systems represent options for defense planners and policy makers as they consider the future interceptor architectures for cruise missile defense. As they mature, some may alter the cost-benefit calculations and represent efficient and effective ways to achieve cruise missile defense. For the immediate future, the best interceptor choices for wide-area cruise missile defense are PAC-3 and combinations of tactical aircraft and ship-borne missiles. For area and home-

land defense missions, the PAC-3 offers the most cost-effective choice to serve as the base interceptor. The Aegis can play an equally important role as PAC-3 to cruise missile defense. The cruise missile defense architecture for homeland and area defense missions should define roles for the other systems to provide on-station support during times of crisis.

Real-time Integrated Battle Management Systems for Cruise Missile Defense

The final, and in some ways the most important, but least understood element of a cruise missile defense system is the battle management and command and control system. This information grid connecting all of the sensors and interceptors with the command structures must be seamless and highly capable of transmitting required data in real-time in formats understandable to the recipients, and in such a way as to facilitate rapid decision-making. Further, inclusion of all sensors, weapon platforms, and relevant decision-making facilities in both pre-planned and dynamic, as-it-happens fashion is required. This characteristic is the very essence of Net-Centric Warfare¹⁷⁵ and is arguably the most critical brains-and-nervous-system turning a myriad of weapons and sensors into an integrated, efficient fighting system that can obtain and use full situational awareness to maximize the use of limited combat resources to defend against cruise missiles. All of these systems must be capable of interconnecting and sharing data seamlessly and in real time. A profound advantage of these systems lies not only in sharing and exchanging information, but in sharing the ability to process and to “fuse” the data from all various sensors into one big picture, and to simultaneously manage the tracking, engagement, and destruction of all targets as they arise.¹⁷⁶

Such capabilities are by no means new, having first been developed by the U.S. military during the Cold War, in the form of the Link-16 real-time target-data-sharing capability for AWACS, E-2 and fighter aircraft. Link-16 was since integrated into various land, sea and air defense platforms of 19 different countries.¹⁷⁷ However, Link-16 is something of a legacy system, and lacks the ultimate real-time data-sharing capacity required for true net-centric operations. Other, higher-data-capacity, more sophisticated information processing and distribution networks are needed.

Arguably the best way to develop a real-time-datalink command-and-control network that is optimized for cruise missile defense is to use a network that is already being tailor-made for the missile-defense mission. Fortunately, one such network is already operational; namely, the MDA's Command, Control Battle Management and Communications (C2BMC) network. C2BMC integrates all of the disparate and oftentimes globally separated missile detection, engagement and command and control facilities operated by the various Services, and increasingly, U.S. allies. It enables planning and in-situ training of defenses, real-time data-sharing into a single integrated picture, and all-important battle-management in a secure and expandable network. Its basic network capabilities were completed in 2005, with the full implementation scheduled for 2009.¹⁷⁸ For the sake of overlapping threat and mission types, as well as built-in tailoring to handle missile threats, this is perhaps the best network within which to implement C2BMC for homeland cruise missile defense.

Another prospective contributor to this mission is the Navy's Cooperative Engagement Capability (CEC). This architecture was intended to be "a sensor network with integrated fire control that provides a means by which data from existing sensor and fire control systems can be combined and distributed to each element of a networked force."¹⁷⁹ Similarly, the Single Integrated Air Picture (SIAP) is a joint program to provide a shared, graphical depiction of the battlespace.¹⁸⁰ Under development by the Joint SIAP System Engineering Organization (JSSEO), the SIAP will integrate and display information from the Navy's CEC, the Joint Tactical Information Data System (JTIDS), and Identification Friend or Foe (IFF) signals from aircraft in the area.¹⁸¹

Conclusion

How will the United States address the cruise missile defense challenge? This challenge is present today and growing more acute. More nations have operational cruise missiles than ever before, the capabilities for indigenous production outside the scope of the non-proliferation regime to control are expanding, and many critical technologies are available freely on the commercial market. When Iraq fired cruise missiles at U.S. forces during *Operation Iraqi Freedom*, it marked the first time cruise missiles have been fired at U.S. forces and it will not be the last. Cruise missiles are a particularly attractive weapons system for prospective adversaries of the United States. They are relatively cheap, readily accessible, easy to conceal, mobile, and hard to defend against. Their ability to carry weapons of mass destruction as well as conventional munitions warheads makes them strategically attractive. Undoubtedly, they are a major challenge for the U.S. military in the coming decades.

The prospect of their use against civilians is real as well. National security planners believe cruise missiles fired from commercial container ships off the coasts of the U.S. is a scenario that can no longer be ignored. Similar risks are faced by cities in friends and allies of the U.S. as well. The real costs, in terms of lives lost and economic damage, of a cruise missile strike armed with a weapon of mass destruction, or even a conventional warhead, are significant.

The risks of all those can be lessened by investment and deployment of cruise missile defenses as part of the combined strategy against cruise missile proliferation. Certainly the United States should continue to vigorously enforce the non-proliferation rules and encourage other states to control the spread of both cruise missile technology and weapons of mass destruction. That system is not without flaws and imperfections, particularly as it concerns cruise missile technology. They are available and they have been and will be used against the U.S. The U.S. will certainly consider pre-emptive action against hostile states or terrorist groups if the circumstances became dire enough. Ensuring that those strikes destroy all of the cruise missile inventories and launch capabilities is difficult to guarantee, and the sheer fact of striking preemptively may provoke international condemnation and criticism. Still, the option of pre-emption remains a component of the strategy, but one that should be employed at last resort. Passive defense, the hardening and strengthening of critical infrastructure and other key assets, will help ensure survivability of those items, but the strategy is small consolation to the cities, homes, citizens, and soldiers left unprotected. The U.S. may decide that certain facilities demand additional protection to survive a cruise missile attack, as was done for the threat of nuclear attack throughout the Cold War.

Only the construction of an active defense ensures the ability to intercept and destroy cruise missiles after they have been launched. Only an active defense deployed on a wide-area scale can defend the U.S. homeland, U.S. troops abroad, and the cities of friends and allies.

Such a defense requires the ability to detect cruise missiles as soon as they are launched and at far distances to provide the greatest amount of time for the interceptors, whether they are missiles fired by a PAC-3 battery, off an Aegis warship, or from a combat aircraft, to reach and destroy the attacking cruise missile. Such a defense also demands a highly capable information backbone to connect all these systems and ensure they communicate seamlessly with each other. In the future, other capabilities may be developed to further refine or improve the capacity and reliability of a cruise missile defense.

These capabilities lie within our grasp today. We must not allow the pursuit of the perfect to become the enemy of the good. Instead, the Administration, Congress, and the public must come to recognize the need to invest time and resources into the design and deployment of effective, wide-area cruise missile defenses. The United States government and the American public need only decide to act and a viable defense could come together in several years' time. One hopes that the decision is made before another cruise missile is fired at the U.S. in anger.

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