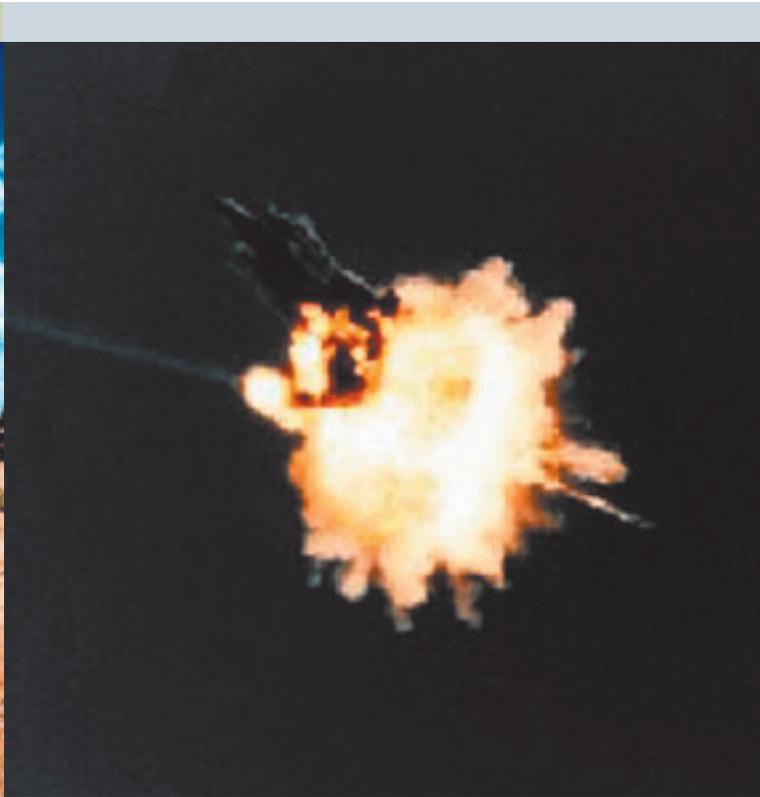


CRUISE MISSILE DEFENSE



CONNECTING THEATER CAPABILITIES TO HOMELAND NEEDS

FINDINGS IN BRIEF

Cruise missiles are flying bombs that can precisely strike distant targets after traversing circuitous, ground-hugging routes. They are capable of delivering a wide range of destructive mechanisms, including conventional high explosives, chemical agents, nuclear warheads and electromagnetic-pulse devices. Over 80 countries possess cruise missiles and 18 countries manufacture them. Most of the cruise missiles currently in world arsenals are designed for attacking ships at sea, but more countries are acquiring land-attack cruise missiles such as the U.S. Tomahawk that can strike deep into the interior of an enemy nation.

Cruise missiles have long posed a danger to U.S. forces overseas. In recent years, though, the U.S. intelligence community and independent analysts have speculated that cruise missiles could become a potent threat to the U.S. homeland. Such weapons are relatively inexpensive to build or buy, difficult to intercept in flight, and easy to conceal in a variety of launch modes (including trucks and container ships). New technologies — global positioning receivers, compact gas turbine engines, composite aerostructures — are available to virtually any state or non-state actor wishing to fashion a precise and lethal cruise missile. Analysts reason that land-attack cruise missiles might provide adversaries with a novel means of attacking the U.S. against which defense would be very difficult.

Homeland defense against cruise missiles is difficult because of the vast amount of airspace and littoral waters that must be monitored, the numerous launch modes and paths of approach that might be exploited, the min-

imal visibility of attacking weapons, and the possibility of many weapons being launched at the same time. Experts generally agree that the most effective defensive architecture is likely to be a layered system of multiple tiers that (1) effectively disseminates relevant intelligence, (2) constantly surveils potential attack corridors, (3) quickly distinguishes threatening and non-threatening vehicles, (4) continuously tracks threatening vehicles despite variations in weather and terrain, (5) effectively engages incoming weapons far from their intended targets, and (6) achieves high reliability and resilience through an integrated battle management network.

Most of the relevant assets and experience for fashioning such a system reside within the individual military services, which have developed defenses for protecting forward-deployed forces against cruise missiles. The U.S. Northern Command (NORTHCOM) and the Joint Theater Air and Missile Defense Organization (JTAMDO) are the lead agencies responsible for formulating joint doctrine and operating concepts that could support a national defense against cruise missiles. An effective national defense would require the integration of military capabilities usually dedicated to other missions with the relevant assets of various domestic agencies such as the Federal Aviation Administration and the Coast Guard.

Each military service funds programs potentially applicable to cruise missile defense of the homeland. Within the Navy, the most important programs are the Aegis Combat System, the E-2C Hawkeye surveillance plane, and

the Cooperative Engagement Capability for sharing air defense radar tracks. Key Air Force programs are the E-3 Airborne Warning and Control System (AWACS), its E-10 successor equipped with radar upgrades for tracking cruise missiles, the Global Hawk unmanned reconnaissance vehicle, and the F/A-22 fighter-interceptor. Key Army programs are the Patriot Advanced Capability Three (PAC-3) missile, the Medium Extended Air Defense System (MEADS), and the Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System (JLENS). Few of these systems were developed with homeland defense in mind, but adapting them for that purpose may be the only affordable path open for cruise missile defense, given the many other security needs the nation faces.

This study was written by Dr. Loren Thompson of the Lexington Institute staff. It was reviewed by the members of the Naval Strike Forum prior to publication.



Warfighters in the combat center of an Aegis destroyer can monitor a vast amount of airspace, precisely tracking over a hundred hostile and friendly aircraft at the same time.

AN EMERGING MISSION

The early years of the new millennium have confirmed fears that the United States faces a global landscape characterized by diverse and unpredictable dangers. While today's emerging threats do not approach the severity of the challenge posed by communist nuclear and conventional forces during the Cold War, they take so many forms that it is difficult to find a clear focus for U.S. military preparations. The Bush Administration responded by developing a defense posture based on capabilities rather than threats — a posture that stressed flexibility and versatility in the face of uncertainty.

Among the embryonic dangers that could develop fastest in the years ahead is the proliferation of cruise missiles. Cruise missiles are unmanned aircraft that can accomplish lethal attacks over long distances at relatively low cost. They are similar to the German V-1 weapons of World War Two, but have acquired much greater military potential in recent years due to advances in navigation, propulsion and airframe technology — advances available at modest cost in global commerce. Dozens of countries now possess such weapons, with the most advanced designs offering long ranges, large payloads, precise guidance and features that minimize detectability.

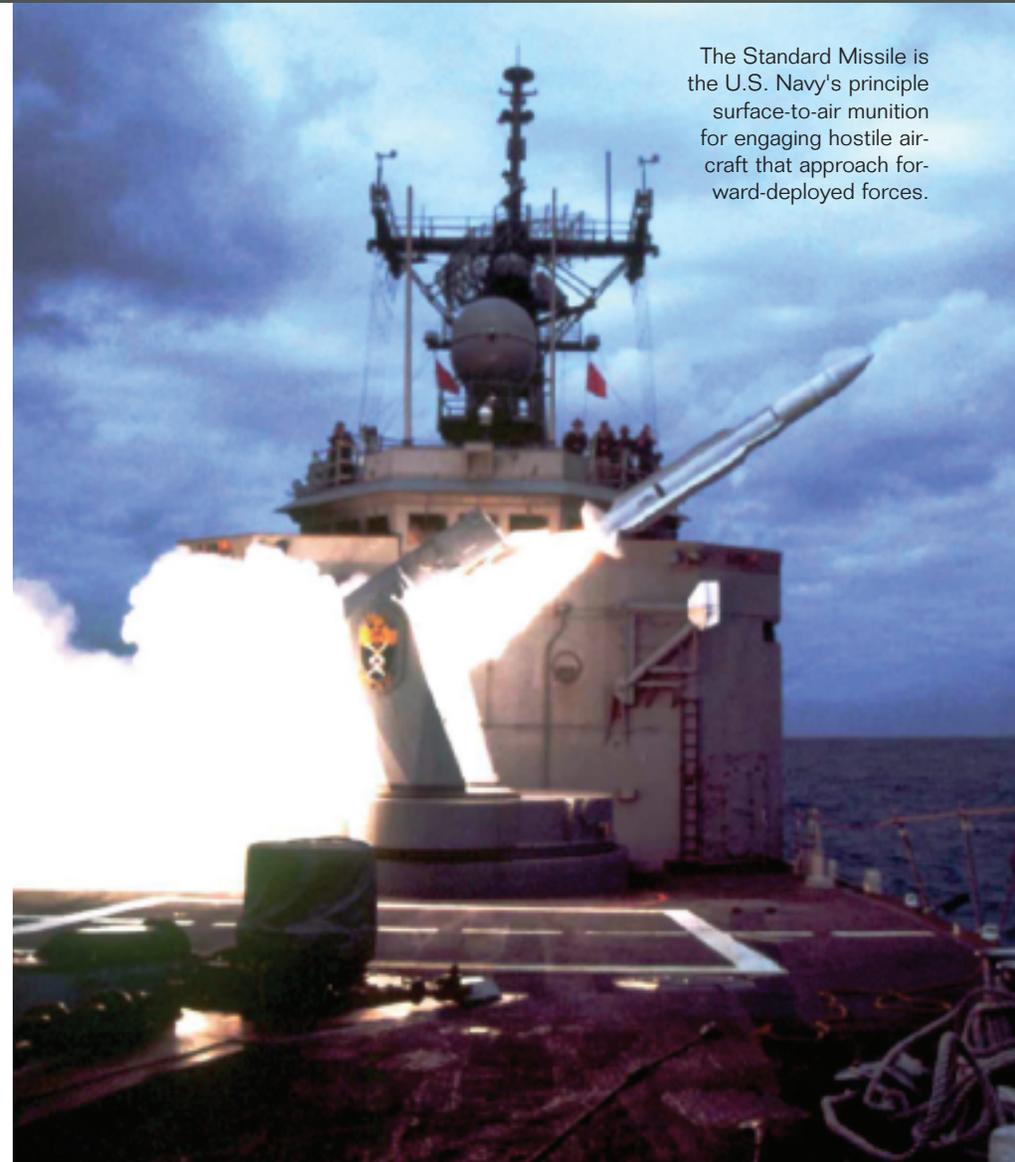
Like the threat of global terrorism, the danger posed by proliferating cruise missiles has been latent for many years. The potential of flying bombs was first explored during World War One, and there were many

subsequent hints — such as fascist “buzz bomb” and kamikaze attacks in World War Two — that airborne missiles might one day become a strategic threat to the U.S. Although ballistic missiles dominated defensive concerns during the Cold War, cruise missiles are inherently cheaper and more available to prospective adversaries. Properly equipped and utilized, they can present a difficult challenge to even the most capable defender.

Although there is no way of knowing how and when a cruise-missile threat to America's homeland may emerge in the years ahead, two things can be said with certainty. First, cruise missiles already pose a major danger to U.S. forward-deployed forces. Second, the lack of adequate preparations for defense of the homeland against cruise missiles encourages enemies to acquire such weapons. In the aftermath of the 9-11 atrocities, it is widely assumed that future adversaries will pursue “asymmetric” strategies aimed at exploiting weaknesses in U.S. military capabilities. Lack of robust cruise-missile defenses is one such area of vulnerability.

The purpose of this study is to explain how the United States can organize its military investments to deter or defeat the emerging cruise-missile threat at minimal cost. The study does not recommend major new investments in cruise-missile defense. Instead, it explores how a range of existing and planned programs can be better coordinated to provide capable defenses while at the same time accomplishing other high-prior-

ity missions. In particular, the study describes the key efforts of each military service that could, through careful planning and alignment, be integrated into an effective network for protecting both forward-deployed forces and the homeland.



The Standard Missile is the U.S. Navy's principle surface-to-air munition for engaging hostile aircraft that approach forward-deployed forces.

CRUISE MISSILE CHARACTERISTICS

Cruise missiles are small, unmanned aircraft designed to serve as long-range munitions. They have diverse methods of propulsion and guidance, and can carry a variety of destructive mechanisms ranging from conventional explosives to chemical agents to nuclear warheads to electromagnetic-pulse devices. Whatever their design characteristics may be though, all cruise missiles share three features. First, they are powered continuously throughout their flight. Second, their guidance is automatically adjusted during flight to assure accuracy. Third, their primary payload is a warhead, and thus they can only be used once.

Unlike ballistic missiles that are boosted into high-speed, arcing trajectories, cruise missiles typically traverse slower flight paths close to the ground. That makes them harder to detect and track than ballistic missiles, but easier to shoot down once found. The most advanced cruise missiles exploit stealth and maneuverability to reduce trackable “signatures,” thereby increasing their likelihood of reaching targets.

A cruise missile with adequate range and guidance can fly a circuitous, ground-hugging route to its intended target that prevents defenders from predicting the timing or direction of attack. The approaching missile often cannot be tracked with surface sensors due to interference from topographical features, and even from above — using airborne or orbital sensors — the feasibility of tracking is diminished by the missile’s small size and the complex returns generated from surrounding terrain.

Tracking difficulties are reduced over water, but the flatness of marine environments also facilitates the missile’s ability to fly very close to the surface.

A further complication in countering cruise missiles arises from the challenge of determining whether they actually are incoming weapons. Because cruise missiles often exhibit flight characteristics similar to those of manned aircraft, defenders cannot simply assume that a tracked object is hostile. The object could be a private airplane, or a friendly military aircraft. The task of determining an unknown object’s origin is referred to in military parlance as “combat identification,” and it is an especially difficult problem in the case of cruise missiles. It is not enough for defenders to establish a continuous track of an approaching body before committing weapons to its destruction — they must know what it is that they are preparing to destroy.

All of these challenges would be mitigated if cruise missiles cost as much as their ballistic brethren. But cruise missiles are much cheaper to build and operate than ballistic missiles, as German leaders discovered in developing the V-1 missile during World War Two. Dennis Gormley noted in a Carnegie Endowment study that the Germans “developed the V-1 cruise missile in one-tenth the time that it took to develop the ballistic missile at one one-hundredth of the cost, with each missile costing about one-tenth of what a V-2 ballistic missile costs.”

A similar cost differential persists today. For the price of a few ballistic missiles or fighters, a developing country can acquire dozens of cruise missiles that are easier to conceal and operate. The cruise missiles may not offer the speed of ballistic weapons or the versatility of fighters, but they do offer the security of numbers. In addition, the technologies needed to build cruise missiles are more likely to escape restrictions on arms transfers than those related to ballistic missiles and tactical aircraft.

Ground-hugging cruise missiles such as this U.S. Navy Tomahawk are able to penetrate deep into the interior of an enemy country, using evasive routes to avoid detection.



ASSESSING THE THREAT

The cruise missile threat is not new. Germany launched thousands of V-1 missiles against Britain during World War Two. The Soviet Union fielded an array of similar weapons during the Cold War, including some that were equipped with nuclear warheads. And potential adversaries such as China, Cuba, Iran, Syria and North Korea have possessed extensive inventories of antiship cruise missiles for many years, in part to deny U.S. warships access to their littoral waters. An Iraqi cruise missile crippled the *USS Stark* in 1987.

In the past, the cruise missile danger has seemed to be directed almost entirely against U.S. forward-deployed forces, which have responded by deploying sophisticated air defenses such as the Navy's Aegis warships and the Army's Patriot Advanced Capability Three (PAC-3) system. Recently, though, there have been signs that cruise missiles might become a threat to the American homeland. A National Intelligence Estimate prepared in December 2001 by the Central Intelligence Agency projected that "one to two dozen countries" would possess land-attack cruise missiles by 2015 — missiles that would primarily pose a theater-level threat, but which might be used to attack America.

Defense Secretary Donald Rumsfeld thought that evidence of increasing danger to both U.S. forces and the homeland was sufficiently persuasive that in July of 2002 he sent a classified memorandum to the White House warning of the trend. Entitled "The Growing Threat Posed by Cruise Missiles," the memo led to formation of an interagency working

group to assess how the government should organize to deter and/or defeat the danger. Rumsfeld noted three problems that collectively provided a compelling basis for concern.

First of all, the number of countries possessing cruise missiles has become quite imposing. Over 80 countries own them, and at least 18 countries are manufacturing them. The vast preponderance of the 70-80,000 cruise missiles in arsenals around the world are antiship weapons with a range of less than 100 kilometers. However, the number of countries building or buying more capable cruise missiles is growing, and there is a trend toward the acquisition of longer-range cruise missiles with the capacity to precisely attack land targets from a variety of launch platforms — aircraft, ground vehicles and ships at sea.

A second problem is the increasing availability in global markets of "dual-use" technologies suitable for building better cruise missiles. Key technologies include global positioning receivers, inertial guidance systems, compact gas turbine engines, lightweight aerostructures, and other commercial innovations with military applications. The danger posed by the spread of these technologies is threefold: they can be used by hostile states to develop more capable missiles; they can be used by hostile states to upgrade existing missiles for greater range, precision and lethality; and they can be used by non-state actors to acquire advanced military capabilities.

A third problem is the difficulty of policing access to relevant technologies through arms control agreements. Unlike in the case of ballistic missiles and tactical aircraft, where some critical technologies are uniquely military in character, there is little on a cruise missile other than the warhead that does not have definite commercial uses. Indeed, many of the most important technologies are increasingly prosaic, “commodity” items. Even if it were feasible to capture these technologies in arms control regimes, half the countries that make cruise missiles — countries like Brazil, China, India, Iran, Israel and North Korea — are not party to the key agreements. So the danger is likely to grow.



The carrier-based E-2C Hawkeye early warning and battle management aircraft is being equipped to track low-flying cruise missiles over both water and the land.

DEFENSIVE REQUIREMENTS

Congressional committees and military advisory panels have been calling for more focus on cruise missile defense since the mid-1990's. A Defense Science Board task force warned in 1995 that the threat could develop rapidly in the years ahead, and the National Defense Authorization Act for fiscal 1996 directed the military services to accelerate defensive efforts. Three years later, the Senate Armed Services Committee complained that too little progress had been made in integrating the relevant programs from each military service. The absence of an urgent threat apparently undercut military interest in the mission.

Even now, years after the 9-11 attacks, the federal government is still in the preliminary stages of developing an effective national defense against cruise missiles. An August 2004 report by Ravi Hichkad and Christopher Bolkom of the Congressional Research Service found that the level of funding requested by the Defense Department for cruise missile defense in fiscal 2005 was less than five percent of the amount sought for defense against ballistic missiles. Given this disparity, many experts feel that the fastest way to field a first-generation defense of the homeland against cruise missiles would be by more closely coordinating and adapting air defense programs already underway in the military services.

Most of the military's knowledge concerning cruise missile defense derives from two sources: the network of radars and interceptor bases built to counter Soviet bomber attacks during the Cold War, and the more

recent investments in theater air defenses for forward-deployed forces. Neither set of experiences is precisely relevant. Bombers typically fly much higher and are easier to track than cruise missiles, while forward air defenses usually are configured for point defense rather than area defense. Nonetheless, there is general agreement on the capabilities that any effective air defense network must have, and these can be summarized in a series of sequential tasks.

- First, defenders need an **intelligence system** able to uncover enemy preparations for an attack. Ideally, this system would provide strategic warning of danger long before tactical intelligence indicates that military action is imminent.
- Second, defenders need a long-range **surveillance system** capable of reliably monitoring all approaches to national airspace. The surveillance system must be sufficiently sensitive and resilient so that it can detect stealthy air vehicles hundreds of kilometers away, despite efforts by attackers to evade or degrade defensive sensors.
- Third, defenders need a **combat identification system** to firmly establish that detected objects are hostile. That means quickly differentiating incoming weapons from other objects that look similar but pose no danger.

- Fourth, defenders need a **tracking system** that can continuously fix the location of cruise missiles until they are engaged. A robust tracking system would be able to maintain contact with hostile vehicles regardless of time of day, weather conditions, changes in terrain or enemy countermeasures.
- Fifth, defenders need an **engagement system** to intercept and destroy hostile aircraft. The kill mechanisms traditionally employed in air defense are surface-to-air missiles fired from the ground and air-to-air missiles fired from fighters, but directed energy now offers another option.
- Finally, defenders need a **battle management system** that can integrate all facets of intelligence, surveillance, tracking, identification and engagement to assure effective use of defensive assets. Among other things, managers should be able to quickly assess whether attempted intercepts have been successful.



Aerostats enable defenders to deploy surveillance and tracking sensors on station for weeks at a time, and are difficult to disable in a preemptive attack.

KEY DEFICIENCIES

The generic requirements of cruise missile defense are thus fairly straightforward. However, when the peculiar characteristics of cruise missiles are combined with the demands of defending a whole country, the mission becomes hugely challenging. The challenge is increased further by the fact that current threat levels do not justify a massive expenditure of new funds. Somehow, the federal government must accomplish a mission it has never attempted before at relatively modest cost.

Fortunately, there are many programs within the military services and defense agencies that can be readily adapted to cruise missile defense of the homeland. Some new investments will be needed, particularly in the areas of persistent surveillance, intelligence fusion and battle management. But these efforts will make a minimal claim on the defense budget — well below one percent of total funding — as long as they exploit activities already under way for other purposes. It should be noted that virtually all of the new expenditures required to fashion a national defense against cruise missiles will also support other missions such as counterterrorism, drug interdiction, border control and force protection.

The most immediate need in closing current defensive gaps is to formulate joint doctrine for the integration of relevant service efforts. It probably is not useful to reorganize military and domestic agencies so that they can better support what is today a secondary mission, just as it does not make sense to dedicate sizable funding to the mission. But there must

be some formal statement of expectations as to what will be the responsibilities of each organization with a role in cruise missile defense. Without authoritative guidance directing goals for cooperation and interoperability, a unified effort cannot emerge.

Once doctrine is formulated and organizational relationships clarified, planners will need to address several technical deficiencies currently precluding effective defense against cruise missiles. The first of these is that the U.S. lacks a resilient surveillance network for finding and tracking low-flying aircraft. There are major gaps in coverage of the airspace both around and within the nation — gaps that are especially pronounced at the low altitudes where cruise missiles operate due to the limited horizon of ground-based radars. The only practical way to resolve these deficiencies is to provide continuous surveillance from above, either from manned and unmanned aircraft or from aerostats (balloons). Whatever constellation of airborne sensors is acquired, it must be able to combine the inputs from many sources into an integrated picture and withstand the efforts of adversaries to destroy it in a surprise attack.

A second technical deficiency is that the U.S. lacks a system for quickly determining the identity of unknown objects approaching or traversing its national airspace. This is a serious problem, because despite the best efforts of intelligence agencies to provide strategic warning, military planners have to assume that a cruise missile attack would occur

unexpectedly. That means thousands of friendly aircraft — civil and military — are likely to be airborne in the same airspace cruise missiles are transiting. The present practice of visually inspecting unidentified aircraft to determine whether they are hostile won't work in coping with a cruise missile attack. The attack might unfold at night or in inclement weather, when visibility is limited. There may be many incoming weapons and very little time to scrutinize each one. Thus, some sort of automated system for rapidly and reliably sorting out threatening objects from non-threatening ones is essential — not only to minimize noncombatant deaths but also to assure that scarce engagement assets are applied effectively.

The third major technical deficiency is the absence of a system for integrated fire control of engagement systems. Because the military services have developed their air defense capabilities largely in isolation from each other, they aren't accustomed to operating as a unified team. Even if all the various sensor inputs can be fused into a complete picture of the relevant airspace and hostile aircraft reliably identified, there is still a need to assign each available defensive weapon to the optimum target. Some defensive weapons will need to be used at ranges far beyond the operating radius of their organic sensors, necessitating quick transfers of information and precise battle management against pressing timelines. Shooting down cruise missiles isn't hard if defenders can detect, track, identify and approach them, but when large areas are being protected the task of using diverse engagement assets efficiently is daunting.

The Aegis combat system is being netted together with all of the other sensors and weapons in the fleet to provide a fully integrated defense against hostile aircraft.



LEAD ORGANIZATIONS

As with other military missions, most of the money and manpower related to cruise missile defense is found in the individual services. The three sections following this one describe the key programs in each military department that could be brought to bear on the cruise missile challenge. However, an integrated defense of the homeland is unlikely to arise from the uncoordinated exertions of the services, which typically are more concerned with their defensive needs in forward areas. Coherent defense of the homeland requires joint management within the Department of Defense, and interagency coordination across the rest of the federal government.

Within the Department of Defense, the lead agency for cruise missile defense of the homeland is the U.S. Northern Command (NORTHCOM). NORTHCOM is the unified command assigned primary responsibility for homeland security, and it is the U.S. component of the North American Aerospace Defense Command (NORAD), the binational command first established in the 1950's to guard North American airspace.

Since its establishment in 2002, NORTHCOM has been working through NORAD to define the operational requirements for effective cruise missile defense. Its efforts are mainly directed to understanding the threat, enhancing sensor assets in a layered defensive architecture, establishing operational linkages among the assets of the military ser-

vices, and determining battle management requirements for tracking and intercepting land-attack cruise missiles. These activities overlap with other NORTHCOM missions, but impose special demands in terms of sensor precision, weapons flexibility and so on. They also create a need for close coordination with domestic agencies, such as the Federal Aviation Administration that operates interior airspace radars and the Coast Guard that monitors maritime traffic potentially carrying cruise missiles.

A second organization that plays a central role in developing cruise missile defenses is the Joint Theater Air and Missile Defense Organization (JTAMDO). JTAMDO was established in 1997 with the mission of coordinating defensive efforts against ballistic and air-breathing threats. As the result of October 2001 direction from the Joint Staff, JTAMDO currently is responsible for developing both the operational concept and the technical architecture underpinning an integrated air defense of the U.S. homeland. In addition to supporting NORTHCOM in augmenting North American air defenses, JTAMDO also assists the U.S. Strategic Command (STRATCOM) in developing and deploying global defenses against ballistic missile attack.

From its headquarters in northern Virginia near the Pentagon, JTAMDO funds a range of programs related to cruise missile defense. For example, it is responsible for developing a joint approach to combat identification of cruise missiles. But its most important role is broader: to

forge a common framework within which military services and defense agencies can cooperate as seamlessly as possible to accomplish a shared mission. That makes JTAMDO the principle planning body for thinking through joint relationships with regard to cruise missile defense over the longer term.

Other Pentagon agencies that play a department-wide role in cruise missile defense include the Assistant Secretary of Defense for Homeland Defense, the Joint Forces Command, the Defense Advanced Research Projects Agency and the Defense Intelligence Agency. Organizations outside the Department of Defense playing an important role include the Central Intelligence Agency, the Department of Homeland Security (especially the Coast Guard), the Department of Transportation (especially the Federal Aviation Administration), and the Department of Justice. The need to involve domestic agencies arises from the fact that much of the activity required to counter cruise missile attacks and their perpetrators might unfold within U.S. borders or in littoral waters.



Although protected by a dedicated air defense zone, the nation's capital is highly vulnerable to attack from the sea by enemies employing cruise missiles.

NAVY PROGRAMS

The U.S. Navy has more experience with defending against low-flying aircraft and missiles than any other military organization in the world. Because of its longstanding practice of operating carrier battle groups and amphibious ready groups in close proximity to littoral countries possessing antiship cruise missiles, the Navy has had to think through all of the technology requirements and operating concepts for an integrated defense against such weapons. The result is a layered architecture consisting of multiple tiers of defensive sensors and engagement systems, each of which must be successfully penetrated before a sea-skimming cruise missile can reach its intended target.

The Navy's air defense architecture has many pieces, but three components stand out as being particularly relevant to cruise missile defense of the homeland: the Aegis Combat System, the E-2C Hawkeye surveillance plane, and the Cooperative Engagement Capability (CEC). Collectively, these three systems and subsidiary elements such as the Standard Missile comprise a pillar of current Navy force structure called Sea Shield, which the Chief of Naval Operations has stated, "extends homeland security to the fullest extent with forward deployed forces, buying time and space for the detection and tracking of threats headed toward our country."

The Aegis Combat System provides the core combat capability of

Arleigh Burke-class destroyers and *Ticonderoga*-class cruisers. It consists of an omnidirectional phased array radar, a weapons control system, and a command element that are continuously upgraded to track and destroy the most sophisticated airborne threats. In recent years, Aegis air defense upgrades have been aimed at enhancing detection and tracking of sea-skimming cruise missiles, eliminating extraneous radar returns, and countering any electronic measures attackers might use to mask their movements. In addition, the system has been modified to provide defense against ballistic missiles. The huge search volume of the four-face, four-megawatt Aegis radar, combined with its ability to simultaneously monitor over 100 aircraft and quickly discriminate threats, make it an obvious candidate for deployment to U.S. littoral areas in the event of an urgent cruise missile threat against coastal cities.

The main drawback of the Aegis Combat System is that its primary sensor is surface-based. Even on a flat ocean surface, it loses radar horizon with distance due to the curvature of the earth. Nearby terrain features exacerbate the problem. In order to assure that all airborne threats are detected in a timely fashion, the Navy operates a carrier-based radar plane designated the E-2C Hawkeye. Hawkeye's radar monitors six million cubic miles of airspace, including areas below the horizon of surface sensors. Its on-board computers can simultaneously track over 2,000 aircraft, and it can direct intercepts of up to 20 hostile airframes at the same time. The Navy is currently upgrading

Hawkeye's radar to enable better tracking of low-flying cruise missiles over land, a task that requires rapid filtering of extraneous radar returns from ground objects.

Hawkeye is already closely linked to the Aegis system so that surface sensors and weapons can be cued for action at the first sign of airborne threats. This linkage dramatically extends the effective range of the Standard Missile. Programmed upgrades to Hawkeye will further expand its connectivity so that it can communicate with air defense assets across the joint force, including Air Force radar planes and Army surface-to-air missile batteries. Hawkeye's combination of huge search volume, precise target discrimination, and comprehensive connectivity suggests that it could become a central node in future joint architectures for cruise missile defense.

Like the Air Force, the Navy is equipping its next-generation fighters with sensors and communications links suited to the conduct of networked warfare. The Active Electronically Scanned Array (AESA) radar to be installed on carrier-based F/A-18's and F-35's will enable engagement of hostile air vehicles far beyond the pilot's field of view. When this improved tracking and engagement capability is linked to the surveillance and battle management features of Advanced Hawkeye, it will facilitate the integration of sea-based fighters into a layered defensive architecture for countering cruise missiles.

The most important networking initiative underway within the Navy that bears upon cruise missile defense is called the Cooperative Engagement Capability (CEC). CEC is being installed on Aegis warships, Hawkeye surveillance planes and other platforms to permit the instantaneous merging of radar tracks from many locations. The result is a composite picture of airspace far more detailed than any one sensor could provide. Because all members of a battle group have access to the same air picture, defensive weapons can be employed faster and further than would be feasible depending solely on local sensors. In other words, an engagement can be accomplished long before the platform from which the defensive weapon originates can see the attacking missile. Cooperative engagement is likely to be a key feature of any integrated defense against cruise missiles, so efforts are under way to determine how CEC might figure in a joint architecture.

AIR FORCE PROGRAMS

The Air Force traditionally has been the lead service for providing air defenses of the U.S. homeland. During the early Cold War period, it deployed thousands of fighter-interceptors in support of the continental air defense mission and took the lead in constructing three lines of surveillance radars across Canada and the northern U.S. to guard against bomber attack. The first computerized air defense system, called the Semi-Automatic Ground Environment (SAGE), was developed under Air Force auspices. Although interest in air defense waned after the advent of intercontinental ballistic missiles, the service has continued to maintain an integrated air defense of North America in cooperation with the Canadian Air Force through NORAD.

The current Air Force architecture for national air defense consists of surface and airborne sensors linked through command centers to fighters armed with air-to-air missiles. Much of this infrastructure resides in the Air National Guard, but in wartime it could be quickly augmented with assets drawn from the regular Air Force. The two most important combat systems in the existing architecture are the F-15 fighter and the Airborne Warning and Control System (AWACS) aircraft. Equipped with the Advanced Medium Range Air-to-Air Missile (AMRAAM) and electronically-steered fire control radars, the F-15 remains the most effective fighter-interceptor in the world despite its advanced age. When teamed with AWACS, it can provide a flexible and survivable defense

against existing air threats.

AWACS is a radar plane based on the Boeing 707 and 767 commercial transports that can provide surveillance of low-flying aircraft to a range of over 300 kilometers (and further in the case of higher-flying objects). When potential threats are detected, it uses an on-board combat identification system to ascertain their origin. If tracked objects are deemed to be real dangers, AWACS battle managers can direct fighters to intercept them, simultaneously managing many different engagements. The AWACS sensor and related subsystems are currently in the midst of a “Radar System Improvement Program” that will increase their capacity to track targets with reduced signatures, such as cruise missiles. The improvement program will also enhance countermeasures against electronic jamming and deception, and bring various configurations of the plane up to a standard level of performance.

The Air Force recognizes that its current air defense architecture is not well-suited to dealing with large and/or sophisticated cruise missile assaults on the homeland. Primary sensors lack the persistence, reach, sensitivity and survivability to cope with potential threats. Engagement systems are aging fast, but even if they were new they would not have the endurance and agility needed to counter a well-planned cruise missile attack. The service’s top two modernization priorities — the F/A-22 fighter and the E-10 electronic aircraft — are both expected to play an important role in addressing these deficiencies.

The E-10 is envisioned as a successor to the AWACS and JSTARS radar aircraft that would be part of a comprehensive constellation of airborne, orbital and surface sensors. The first variant (or “spiral”) of E-10 will host a sophisticated sensor and software package called the Multi-Platform Radar Technology Insertion Program that provides unprecedented capacity for tracking low-flying, stealthy aircraft. Originally described as an upgrade of the JSTARS ground surveillance system, the Air Force now acknowledges that the package is also one in a series of initiatives to improve defensive capabilities against cruise missiles. A scaled-down version of the package will be carried on the Air Force’s long-endurance unmanned aerial vehicle called Global Hawk. E-10 and Global Hawk therefore are likely to operate in tandem in any future defensive architecture.

The F/A-22 is a multirole replacement of the F-15 that offers substantially greater endurance, agility, connectivity and sensing capacity than the existing fighter. Among the many missions it is designed to accomplish is cruise missile defense of forward-deployed forces and the homeland. One advantage F/A-22 will have over F-15 is a fuel-efficient “supercruise” mode of flight that enables it to dash to the vicinity of incoming missiles and take multiple shots before requiring refueling. Another advantage is the F/A-22’s extensive array of on-board sensors and computers for tracking, identifying and targeting reduced-signature airframes. The Air Force is developing tactics that can fully leverage these capabilities against cruise missiles, such as intercepting missiles in an aspect where their stealth features are likely to be least effective.



The Air Force's multirole F/A-22 fighter has performance features and on-board equipment that make it uniquely suited to effective cruise missile defense.

ARMY PROGRAMS

When the Army and Air Force became separate services after World War Two, the Army retained control of anti-aircraft artillery. Over time, that responsibility evolved to make the Army lead service for the development of ground-based defenses against aircraft and missiles — including cruise missiles. As a result, Army systems are likely to provide the core of any close-in defensive capability as the government develops a layered architecture for countering cruise missiles. Navy systems such as Aegis and the E-2C Hawkeye would probably be deployed to the homeland in an emergency, but Army systems are more likely to be permanently stationed near key national assets.

The Army's main weapon today for defending against cruise missiles is the Patriot air defense system. Patriot has been in use for many years, but is being upgraded with a more versatile surface-to-air missile called the Patriot Advanced Capability Three (PAC-3) that can intercept manned aircraft, cruise missiles and tactical ballistic missiles. Following a very successful development program that included tests against cruise missiles, PAC-3 became operational in 2003 and saw action in the Iraq war. The PAC-3 design combines a millimeter-wave seeker and command link to remote controllers that enable it to achieve kinetic (impact) kill of cruise missiles without using an explosive warhead. The weapon is much smaller than the earlier PAC-2, allowing a launcher to carry sixteen missiles rather than four.

An extended-range version of PAC-3 is in development that would double

the weapon's range against cruise missiles. Called the "missile segment extension," the new version will provide the engagement mechanism for a multi-nation program called the Medium Extended Air Defense System (MEADS). MEADS is a joint undertaking of the U.S., German and Italian militaries intended to eventually replace Patriot, Hawk and other aging anti-aircraft weapons. The new system will feature omnidirectional surveillance and tracking against the full range of airborne and ballistic threats, rapid surface mobility, and a distributed architecture similar to the Navy's Cooperative Engagement Capability that networks all coalition sensors and weapons in an integrated defense.

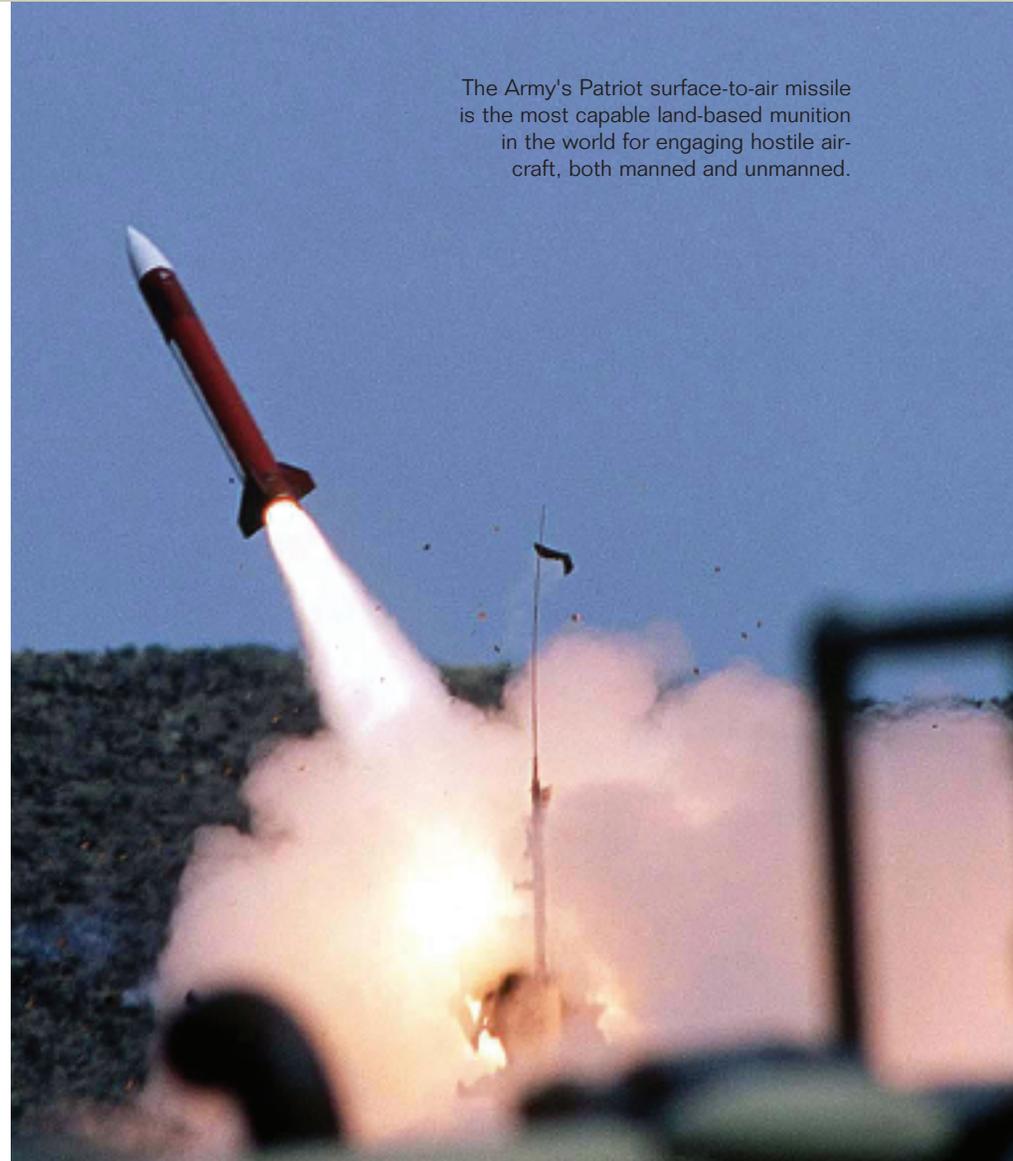
Although MEADS will not be operational until the next decade, Army leaders say they will try to assimilate some of its technology into existing air defenses as advances become available. For example, a new lightweight launcher and improved battle management package could be deployed in the current decade. More generally, the Army is pursuing improved connectivity among its air defense systems and those of the other services to promote early emergence of a joint architecture. Following direction from the Joint Staff, the Army is leading efforts to create a "single integrated air picture" fusing the surveillance and tracking inputs of all services.

One particularly promising air defense initiative that the Army is managing is the Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System, referred to as JLENS. JLENS is an aerostat that would host surveillance and fire control radars for tracking low-flying aircraft. At its specified altitude of 15,000 feet, it would have the same cruise missile detec-

tion range as AWACS, about 300 kilometers. JLENS would help close the gap in persistent surveillance by fielding a low cost, highly survivable sensor system that can remain on station for 30 days. In its operational configuration it would be untethered to permit easy repositioning, and would be continuously linked to the Navy's Cooperative Engagement Capability and Air Force Joint Tactical Information Distribution System for cross-service sharing of tracking data. Other aerostat concepts are being considered that would operate at higher altitudes to achieve greater detection ranges.

In recent years, the Army has shown greater receptivity to air defense operating concepts and technologies drawn from other services. Not only is it moving to rely more heavily on the Air Force for theater air defense, but it plans to adopt a surface-launched version of that service's AMRAAM missile as a next-generation defensive weapon. Most of the Army's relevant programs, such as PAC-3 and JLENS, were developed primarily for use in defense of forward-deployed forces, but their versatility and mobility make them readily applicable to homeland defense. Policymakers are also considering proposals to supplement or replace the Navy's Standard air defense missile with a version of the Army PAC-3, a move that would reduce the cost and enhance the interoperability of joint defenses against cruise missiles.

The Army's Patriot surface-to-air missile is the most capable land-based munition in the world for engaging hostile aircraft, both manned and unmanned.



DESIGN PRINCIPLES

The Defense Department is sometimes criticized for spending too much money on ballistic missile defense while neglecting the far more common threat of cruise missiles. However, the preceding pages demonstrate that the military services have numerous programs in production or development that can be readily applied to the challenge of cruise missile defense. Some of these programs, such as JLENS and the radar upgrades of the E-2C Hawkeye, were initiated with the explicit purpose of countering cruise missiles. The problem is that nearly all of them were conceived to protect forward-deployed forces, a mission markedly different from homeland defense.

To develop an effective defense of the U.S. homeland against land-attack cruise missiles, designers will have to apply some different principles. The following considerations are likely to influence the design of any defensive network.

1. Land-attack cruise missiles are one among many asymmetric threats that could arise in the current period of diverse security challenges. Because the danger to the homeland from cruise missiles is neither urgent nor well-defined, it is unrealistic to assume the availability of extensive funding for addressing that danger. Whatever defensive efforts the nation undertakes will mainly involve the realignment of programs and relationships already in place for other purposes.

2. Cruise missile defense of the homeland is thus an opportunity to apply some of the guiding precepts of military transformation, such as joint cooperation and networked warfare. By integrating existing resources and programs in imaginative ways, policymakers can satisfy most of the requirements for a coherent defensive architecture. It will not be enough simply to link existing programs together — some gaps in surveillance, identification and fire control will still exist — but for the most part, better defense against cruise missiles demands more integration, not more investment.
3. The need for more integration rather than more investment is especially clear in the case of doctrine and intelligence. Until the military has developed detailed joint doctrine addressing cruise missile defense, it will be difficult to formulate a suitable defensive architecture or investment plan. In addition, there must be an understanding of what existing intelligence-collection capabilities can contribute to defense against cruise missiles before the services embark on investment in new indication and warning systems.
4. The principle of layered protection already observed in designing theater air defenses and ballistic missile defenses is equally important in the case of cruise missile defense of the homeland. Layered protection enables a system of multiple, imperfect tiers to provide nearly impermeable defense. However, designers can't

simply import the framework of carrier battle group defense into the context of homeland security because the operational environment is so different. All of the relevant operating concepts, from combat identification to rules of engagement, will have to be adjusted to reflect the pervasive presence of noncombatants.

5. The problem of operating under pressing timelines in close proximity to civilians will be exacerbated by the need to rely heavily on forces usually deployed in different environments. If the nation cannot afford a robust and dedicated defense of its territory against cruise missile attack, then in times of heightened danger it will need to draw home air defense assets configured for foreign combat. Networking concepts such as the Navy's Cooperative Engagement Capability can resolve many of the technical challenges in quickly reconfiguring the force, but whether operators can repeatedly make the mental adjustment is another matter.

Like other forms of asymmetric warfare, the prospect of cruise missile attacks on the homeland presents military planners with novel problems. Not the least of these is the possibility that defenders might do more damage to the homeland than the weapons they seek to counter. But with overseas adversaries of every stripe increasingly gaining access to mechanisms of mass murder — mechanisms that could be delivered by cruise missiles — the dilemmas of defending America against such weapons probably cannot be avoided for much longer.



Test drones such as those shown here are routinely used by the Navy to assess whether sea-based air defenses are functioning effectively.



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