Attacking the Cruise Missile Threat

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Introduction

<u>20 March, Camp Commando Kuwait, Operation IRAQI FREEDOM</u>

Marines of the I Marine Expeditionary Force (IMEF) Headquarters are on alert in their forward-deployed position at Camp Commando Kuwait awaiting the initiation of Operation IRAQI FREEDOM (OIF). A U.S. Air Force officer attached to IMEF monitors a terminal that will alert the headquarters of any detected ballistic missile or cruise missile attacks.

Seven to nine minutes of warning are planned for a ballistic missile attack, and three to five minutes are assumed for a cruise missile attack. Once inbound missiles are detected, standard procedures are to sound the Scud alert, notify subordinate units, don nuclear-biological-chemical (NBC) protective masks and, except for watch-standers, head for underground bunkers.

Marines deployed north and east of the headquarters suddenly observe a low-flying missile passing overhead, pointed towards Kuwait in the direction of Camp Commando. IMEF's air defense computer terminals display nothing out of the ordinary, and no Scud alert is sounded. Marines in the headquarters are astonished and surprised to hear the signature of a low-flying jet engine overhead, followed by the noise and concussion from a large warhead blast.

An Iraqi Seersucker antiship cruise missile converted into a land attack role has just missed decapitating IMEF by a mere one hundred yards. The missile, launched from the Faw peninsula, flew undetected and unengaged straight through the heart of an alert and robust U.S. theater air and missile defense system. Following this attack, the U.S.

Marines maintained a Combat Air Patrol (CAP) of F/A-18s over the Faw peninsula for several days.[1]

Fortunately, the cruise missile in this instance was armed with only a conventional warhead. Because of their payload capabilities and their inherent ability to fly over large swaths of land, land attack cruise missiles (LACM) are a platform optimized for the employment of chemical or biological weapons.[2] Currently, such an attack would likely go undetected, preventing U.S. forces from donning protective equipment and taking shelter.

During OIF, five Chinese-built CSSC-3 "Seersucker" antiship cruise missiles (ASCMs) were launched by Iraq against land targets in Kuwait. The attack described above was the first. A second attack, using two Seersucker cruise missiles on 28 March, was aimed at ships at the naval base of Kuwait City. One missile homed in on a radar reflector, the other on a seafront shopping center. Two Seersuckers were also launched on 31 March—one at the port at Umm Qasr and the other at troops at Safwan.[3] Not a single one of these missiles was targeted or even detected in-flight.

Proliferation of land attack cruise missiles threatens U.S. force projection capabilities and requires joint development of a cruise missile defense system that can be integrated into and provide robustness to the combatant commander's theater air and missile defense system.

Definition

Generally speaking there are four types of cruise missiles—strategic, antiship, harassment drones, and tactical land attack. Consider just the land attack threat to the combatant commander.

> Tactical land attack missiles (TLAMs) are designed to deliver conventional warheads with accuracies of 20 meters or less. TLAMs, and their air-launched cousins, the Standoff Land Attack Missiles (SLAMs), have the capacity to complement, and in some cases replace, manned aircraft in conventional missions. Furthermore, TLAMs can be outfitted to deliver chemical and biological weapons. There are few proven defenses against land attack cruise missiles.[4]

Current and Projected Threats

Iraq's use of cruise missiles during Operations DESERT STORM and IRAQI FREEDOM, as well as the proliferation in cruise missiles, has expanded the Department of Defense's awareness of the threat and limitations in defending against it. The key to the success of cruise missiles is their stunning accuracy, ease of acquisition, and convertibility of easily obtainable technology.

In the Gulf War, the Al-Hussein-modified Soviet SS-1C "Scud B" missiles experienced a circular error probable (CEP) of 1,000 meters, meaning that half of the missiles fired landed within one kilometer of the target.[5] By comparison, the Tomahawk Land Attack Cruise Missile reportedly has a CEP of less than six meters. Cruise missiles can be seen as more dangerous than ballistic missiles for their accuracy and attack profile. During the Falklands conflict in 1983, three French-made Exocet antiship cruise missiles hit British Navy ships, killing 45.[6] In 1987, 37 U.S. servicemembers were killed when a French-built Iraqi Exocet antiship missile slammed into the hull of the USS *Stark*.[7] As noted earlier, the Iraqi cruise missile threat during OIF demonstrated the capability of the missile as well as the limitations of U.S. defense against that threat.

Of increasing concern is the ease of acquisition and proliferation of the cruise missile technology and capability in states sponsoring terrorism, terrorists, and belligerent nonstate actors. Obtaining cruise missiles will be a major strategic goal of Third World countries over the next ten years—it now seems inevitable that Third World countries will acquire land attack cruise missiles in the 21st century.[8] The CIA's unclassified December 2001 National Intelligence Estimate on missile threats facing the United States up to 2015 states that "one to two dozen countries probably will possess land-attack cruise missiles by 2015 posing primarily a theater-level threat—but with sufficient range to be forward-deployed on air- or sea-launch platforms."[9]

The third element behind the increasing threat from cruise missiles is the relative ease with which the technology can be converted. The ability of third world countries to acquire such products from a number of sources, including indigenous development, conversion or reverse engineering, and open purchase, all lead to the dangerous proliferation of LACMs. Conversion accounts for most third world sourcing, running neck and neck with open purchase; nevertheless, most open purchase systems are conversions. Compared to ballistic missiles, the scientific know-how required to design and build cruise missiles is "less advanced and generally available to countries with a light aircraft manufacturing capability.[10] Because the technology is familiar and less difficult to master, Third World countries can save millions of dollars in research and development costs by opting for cruise missiles.[11] At least nine Third World nations have civilian aerospace manufacturing programs that can be converted to produce land attack missiles.[12] Currently, ten countries are suspected to be manufacturing remotely piloted vehicles, with cruise missile potential, and another ten countries have military cruise missile production capability.[13]

The world remains a very complex, dynamic and dangerous environment permeated throughout with uncertainty. Considering current global instabilities and the volatility of an uncertain future, expectations are that the requirement for U.S. intervention in the affairs of evolving nation states will increase at an equal or greater pace than in the past two decades. Moreover the Global War on Terrorism will demand that the United States employ its military might to shore up porous security apparatuses in less-developed regions. Looking to the future, the Secretary of Defense in the Quadrennial Defense Review Report noted, "Future adversaries will seek to avoid U.S. strengths and attack U.S. vulnerabilities, using asymmetric approaches such as terrorism, information operations, and ballistic and cruise missile attacks."[14] Cruise missiles in the hands of bad actors in volatile regions portend unintended casualties given the limited U.S. defensive capabilities.

Although 70 percent of the 140 known types of cruise missiles today are shorter range, antiship systems,[15] about half of the 120 systems under development for future deployment will be land attack systems.[16] A cruise missile in this case is defined as an unmanned, self-propelled, guided vehicle that sustains flight through aerodynamic lift for most of its flight path and whose primary mission is to place an ordnance or special payload on a target.[17]

While the combatant commander needs to be aware of the total threat picture, which includes strategic as well as antiship cruise missiles, the cruise missile threat discussed here focuses on the land attack cruise missile. Although such missiles can be used to target national strategic assets such as population centers, government installations, and infrastructure, tactical land attack cruise missiles are primarily designed to deliver conventional weapons munitions against tactical targets such as tactical operations centers, tactical headquarters, bivouacked fielded forces, and logistics hubs.

Approximately 70 nations currently possess cruise missile technology, with a worldwide inventory of over 75,000 cruise missile variants available to allies, threat countries, terrorists, and belligerents. Of these, only about 12 highly developed nations possess sophisticated land attack cruise missiles like the Navy's Tomahawks that were recently used against targets in Iraq.[18] Nevertheless, approximately 40 developing nations have acquired various shorter-range antiship cruise missiles.[19] Cruise missiles are inexpensive, easy-to-build weapons that can be used to devastating effect by nation states, terrorists, or belligerent groups to achieve significant battlefield success considered in light of limited U.S. defense capabilities.

While the cruise missile serves as an excellent conventional delivery vehicle, perhaps more important is its WMD threat potential. The cruise missile's aerodynamic stability makes it an inherently easier and cheaper platform from which to deliver and disperse chemical and biological agents, giving it a lethality factor more than 10 times greater than that of a ballistic missile for a given amount of biological agent.[20]

When all aspects are considered, producing and deploying cruise missiles is cheaper and less complicated than establishing and maintaining a force of modern combat aircraft.[21] Cruise missiles are more concealable than aircraft, more effective in penetrating defenses, and, potentially at least, more accurate.[22] Cruise missiles can be launched from any angle, from the air, sea, or ground, and are proven to be more difficult to shoot down. A cruise missile attack would offer little warning before a strike. Cruise missiles such as Silkworm and Exocet are designed to fly at "sea-skimming" levels only a few feet above the surface to avoid radar contact.

The genesis of today's most prolific cruise missile dates back to the late 1950s when the Former Soviet Union introduced the SS-N-2 Styx missile, a surface-to-surface antiship cruise missile. Most variants of modern cruise missiles are conversions of the Styx—the Silkworm, Seersucker, Sardine, and Saccade were all derived from a re-engineered Styx. On 1 April 2003 at Ash Shuaybah Airport, British forces captured a number of Soviet built SS-N-2 Styxes that had been dismounted from boats.[23]

The Silkworm, the predominant of these variants, is the "Scud" of cruise missiles, available globally, manufactured regionally (Iran, Egypt, North Korea), with a range that has been extended to 400 km.[24] Egypt, Iraq, Iran, Pakistan, and North Korea have Silk-worms and Seersuckers, a version of which North Korea now manufactures.[25] The Silk-worm is 7.36 metres long, weighs 2,988 kilograms and can deliver a 513-kilogram payload.[26] It can be launched from semimobile (towed) launchers or from ships. The Silkworm is the weapon of choice because of its range potential and simplicity of trans-formation.[27] The highly proliferated, less sophisticated Chinese variant of the Silkworm antiship cruise missile, can be modified for land attack missions with an extended range of up to 300 kilometers and improved guidance and navigation systems that are based on commercially available technology.[28] The Silkworm gained fame in the 1980s when it was used by both sides in the Iran-Iraq War; both countries were supplied by China.[29]

China has exported several types of cruise missile systems to Iran, Iraq, and Libya, including long-range C-802 Silkworm missiles and shorter-range C-801 Sardine missiles. China also recently test-fired a 200-kilometer-range C-803 cruise missile.[30] Intelligence estimates offer foundation for the belief that the Silkworm or some variant will be the cruise missile of choice for either a nation state or lone group or actor seeking to conduct an attack against U.S. forces responding to instabilities in one of the emerging volatile regions in the world, or while meeting the challenges of the Global War of Terrorism.

Current Legacy Systems LACM Defense

Defense Secretary Donald H. Rumsfeld sent a classified memo to the White House in 2002 that highlighted his concern over the proliferation of cruise missiles among hostile nations and urged an intensified government-wide effort to defend against them.[31] It goes without saying that cruise missile defense has become a top-level defense concern for the United States and its allies. Cruise missile detection is complicated because its radar signatures can be similar to those of friendly forces. The Pentagon relies on a patchwork of surveillance systems and an assortment of interceptors fired from land, sea, or air platforms for defense from cruise missile attack.[32]

Land-based Defense Systems

The U.S. Army owns the majority of the land-based air defense systems that are its principal deterrent against the cruise missile threat. Although the following analysis looks at commonly used land-based systems and missiles, the list is not all-inclusive.

The Stinger is the Army's short-range air defense (SHORAD) missile for use in brigade, division, and corps areas against cruise missiles, unmanned aerial vehicles, low-flying fixed-wing aircraft, and helicopters. The Stinger is an infrared missile system that can be fired from the ground or from rotary-wing platforms. The missile homes in on the engine heat generated by the target of opportunity. The Stinger is fielded in multiple configurations—man-portable air defense systems, on the Avenger, on the Kiowa Warrior and Black Hawk helicopters, on the Bradley Linebacker, and on the U.S. Marine Corps light armored vehicle air-defense system. The Stinger's Block 1 upgrade improved accuracy and resistance to countermeasures; it is effective against both unmanned aerial vehicles and cruise missiles, as well as against standoff helicopters in clutter.[33] Stinger's primary defense limitations include lack of connectivity to overhead surveillance platforms and inability for radar to see over the horizon, both of which severely limit its effectiveness against cruise missiles.

The first air defense system to consider is the Avenger, a lightweight, highly mobile surface-to-air missile and gun weapon system mounted on a Humvee. Avenger has a crew of two and is configured with two missile-launcher pods containing four Stinger missiles each. There is a forward-looking infrared receiver (FLIR), a laser rangefinder, an identification friend or foe (IFF) system, and a very high rate of fire .50-caliber machine gun (1,100 rpm). The Avenger is an all-weather, shoot-on-the-move system, which can be remotely operated from a protected position up to 50 meters from the unit. An A1 upgrade integration permits the firing of the new Stinger Block 1 missile. The A2 upgrade adds a digital slew-to-cue (STC) capability and an upgraded fire-control computer. The STC capability accepts and displays aerial tracks from external radar sources and forms the foundation for future incorporation of a beyond-visual-range engagement capability.[34] Like the basic Stinger, the Avenger system's defense limitations are primarily an absence of connection with overhead surveillance platforms and an inability for radar to see over the horizon.

Another air defense system is Sentinel AN/MPQ-64, used in conjunction with the Army's Forward Air Defense Command and control (FAADC2) system to perform critical air surveillance of the forward area. Sentinel is the key air surveillance and target acquisition/tracking sensor for SHORAD weapons systems, capable of searching for and tracking fixed-wing and rotary-wing aircraft. The system is transportable via the M1097A1 Humvee group, and the antenna transceiver group is mounted on a 1-ton wide-track trailer, as are the identification friend or foe (IFF) capability and FAADC2 interfaces. The sensor has a 40-km radar range with 360 degrees azimuth coverage; targets can be hovering to fast moving. The Sentinel system achieved first unit-equipped status in June 1997. It was deployed to heavy, light and special divisions (six each), National Guard Avenger battalions (six each), and armored cavalry regiments (two each). Sentinel offers advance detection and tracking capabilities and interoperability with other Army air defense systems.[35] However, Sentinel lacks joint overhead surveillance connectivity, has limited radar range, and lacks ability to see over the horizon, all of which are required for effective cruise missile defense.

The Patriot Missile Defense System is a long-range, high-altitude, all-weather system designed to counter tactical ballistic missiles, cruise missiles, and advanced aircraft. In addition to the United States, Germany, Israel, Japan, Kuwait, the Netherlands, Saudi Arabia, and Taiwan all have the Patriot in service. One Middle Eastern ally, Egypt, has been cleared to procure the missile.[36] The Patriot missile guidance system allows midcourse corrections to be transmitted from the mobile Engagement Control Centre. The target acquisition system on board the Patriot acquires the target in the terminal phase of flight; the data is down-linked to the Engagement Control Station for final course correction calculations. The Patriot missile range is 70km and maximum altitude is greater than 24km.

In 1990, the Patriot Advanced Capability version two (PAC-2) missile was hurriedly taken out of a testing program and placed into production for the Gulf War. The Army had only three experimental PAC-2s available during this time frame.[37] In 1991, the PAC-2 was used in the Gulf War with mixed results. The PAC-2 was designed to detonate when it was close to a target. During the Gulf War the Scud missiles used by Iraq often broke up in terminal flight phase, which made it difficult for the PAC-2 to target the missile warhead.[38] After the war, Raytheon upgraded the missile guidance system with Guidance Enhancement Missile Plus (GEM+) that increases sensitivity to low radar cross-section targets. Initial missile upgrades were delivered to the U.S. Army in November 2002. The contract calls for 148 missiles to be upgraded to PAC-2 GEM+.[39]

The latest Patriot version is the PAC-3 hit-to-kill missile being developed by Lockheed Martin Missile with Raytheon as the system integrator. PAC-3 is the last Patriot missile version scheduled for production. The U.S. Army received its first production of PAC-3s in October 2001. Subsequent contracts for 88 missiles and another for 12 missiles were placed in December 2002 and March 2003 respectively. The Army expects to procure a total of 220 PAC-3 missiles by 2004.[40] PAC-3 was first deployed to OIF during March through April 2003. The Patriot variant is designed to collide with targets at speeds up to five times the speed of sound, which causes both to disintegrate.[41] The PAC-3's small design allows the launcher to hold 16 missiles compared to the larger PAC-2 configuration that holds only four missiles.[42] The Netherlands and South Korea have both requested procurement of the PAC-3.[43] While the Patriot system has played a focal role in the Army's air defenses over the last decade, and although significant improvements have been made, its effectiveness against the cruise missile is again limited by its inability to see over the horizon.

Another system, Medium Extended Air Defense Systems (MEADS), is scheduled to replace the Patriot in 2012 and is designed to provide lower-tier air defense, missile defense, and cruise missile defense for maneuver forces and other critical forward-deployed assets throughout all phases of tactical operations.[44] In 1999 the NATO Medium Extended Air Defense Management Organization selected MEADS International, Inc., to develop the new air and missile defense system. The international joint partnership includes the following companies: Marconi Systems in Italy, EADS/LFK in Germany, and Lockheed Martin in the United States, with MEADS fielding expected during 2012.[45] MEADS is mounted on a wheeled vehicle, which enables it to keep pace with fast-moving maneuver forces. Advanced radars provide 360 degrees coverage for surveillance and fire control. It has improvements over its predecessors, greater firepower and requires less manpower to operate. MEADS components are linked by a communications network architecture, which allows its units to be tasked for a predicted threat. Significantly, MEADS is interoperable, and therefore has access to sensors from other air defense systems. MEADS will give the ground forces a robust future air defense and will be a key element in providing the combatant commander joint interoperability required for an effective LACM defense.

Maritime Defense System

The U.S. Navy's strategy for defense against antiship missiles has always been based on arraying its most effective capability into a concept called "defense in depth." This defense in depth concept is a layered system composed of the following five rings:[46]

The first ring consists of airborne early warning and interception. The platforms used are the E-2C Hawkeye Airborne Early Warning and Control aircraft operating in tandem with the F-14 Tomcat armed with AIM-54C Phoenix air-to-air missile. The E-2C operating in a 100-mile range from the carrier battle group can detect aircraft and ships that are from 100 to 200 miles away. Currently, the Navy F/A-18 Hornet armed with the AIM-120 Advanced Medium Range Air-to-Air Missile (AMRAAM) has taken over the Fleet Air Defense role; however, it has a limited range and no long-range missile like the Phoenix. An additional limiting factor for this capability is that Phoenix missile production has been stopped and upgrades canceled.[47]

The second ring consists of the *Ticonderoga*-class cruisers and the *Arleigh Burke*-class destroyers, each with a very capable AEGIS missile defense system on board.[48] The AEGIS detection system consists of the SPY-1A radar, which automatically detects and tracks air platforms more than 200 miles away. The *Ticonderoga*-class cruisers use their Tomahawk cruise missile launch capability, AEGIS antiair missile systems, AN/SQQ-89 undersea warfare system, and C4ISR suite to form the most powerful surface combatants in Navy service.[49] Despite this formidable array, should an enemy submarine sink an AEGIS-armed escort, the task force group's defense would be significantly degraded.

The Navy's third ring consists of the surface ship's own self-defense missiles, within NATO usually the Sea Sparrow, sometimes called the Improved Basic Point Defense Missile System (IBPDMS). The IBPDMS is old technology developed in the 1970s. It has a range of six miles, but its operational readiness is poor.[50] While this capability can be valuable for fleet defense, its limited range keeps it from being able to contribute to defending land-based forces.

The fourth ring uses different countermeasures, such as the SLQ-32 electronic warfare systems and the Super RBOC (Rapid Bloom Onboard Chaff) for defense against the cruise missile. SLQ-32 is 20-year-old technology that has low operational reliability. It has not received technology upgrades, and extended deployments have negatively affected maintenance schedules. Super RBOC shoots chaff (metal strips) into the atmosphere to distract missile radar.[51] Again, the effectiveness of the fourth ring depends on the technology installed on the respective ships and is focused on the fleet.

The fifth and final ring comprises the "last-ditch" weapons, because they involve very close interaction with the target. Two systems are the Vulcan/Phalanx Close In Weapons System (CIWS) and the Rolling Airframe Missile (RAM).[52] The CIWS is a radar-guided 20mm machine gun that fires 4,500 rounds per minute. CIWS's radar tracks the incoming target and the outgoing bullet stream to automatically make aim corrections to hit fast-moving and maneuvering targets. CIWS systems have been installed on more than 400 U.S. warships since its first testing in August 1973.[53] The Phalanx has received continual performance upgrades and remains a viable last-ditch weapon for missile defense. RAM was developed in cooperation with the West German Navy in the 1980s and subsequently entered service in 1993. RAM with its 21-tube launcher has performed very well in testing; however, it has been installed on only 27 U.S. Navy ships.[54] The erosion of "Defense in Depth" components has left the Navy primarily depending on the AEGIS for defense against the cruise missile. While the Navy AEGIS system provides significant fleet defense, its ability to support land forces can be severely constrained by the ship's ability to operate close to shore.

Airborne Defense Systems

The same limitations as those of the ground-based defense system apply to airborne assets. Airborne surveillance platforms are not currently operationally linked with surface-to-air missiles (SAMs), which puts the airborne-centered TLAM defense at a huge disadvantage. Lt Col Dave Peterson, a Seminar-B classmate and F-15 pilot, stated that a cruise missile could be shot down if it was detected soon enough.[55]

Understanding the need for improved air defense detection, in January 1996, the Department of Defense (DOD) and the Joint Chiefs of Staff directed the Army to take the lead in establishing an Aerostat Joint Project Office (Army, Navy, and Air Force).[56] A concept studies phase was completed in 1997, and a subsequent development contract was awarded to Raytheon Company in 1998. The Joint Land Attack Cruise Missile Defense Elevated Netted Sensor (JLENS) is believed to be a critical first step in developing a capability to provide over-the-horizon surveillance for defense against cruise missiles. JLENS's early detection capability gives current air defense weapons such as Patriot, Navy SM-2 missile, the AMRAAM, and SAMs the extra time required for effective defense against the cruise missile.[57]

JLENS is a large, unpowered, elevated sensor that resembles a balloon moored to the ground by a long cable. The sensor operates at altitudes between 10,000 and 15,000 feet. It is tactically relocatable and can operate from land or maritime sites. JLENS can remain on station for 30-day periods providing 24-hour-per-day coverage.[58]

In 1996 the U.S. Air Force in conjunction with the JLENS Project Office participated in the Roving Sands Aerostat Demonstration, where an over-the-horizon air picture was provided to the participants during the exercise.

> A connection to the Multi-Link Translator and Display System local area network allowed JLENS to inject tactical data information link-J messages into the Joint Tactical Information Distribution System, or JTIDS, network. JLENS transmitted the full air picture, including a number of targets that had not been reported before because the surface-based sensors did not have the capability to send track messages over the JTIDS network to Patriot, THAAD, AEGIS, and SHORAD. A German Patriot unit reported killing an unspecified cruise missile with JLENS' track number, demonstrating cueing by the JLENS.[59]

Subsequently in 1999 during the All Service Combat Identification and Evaluation Team, or ASCIET '99 exercise, JLENS displayed its utility in the joint arena. An aerostat measuring 15 meters long with the Cooperative Engagement Capability Relay installed allowed the Patriot air defense and Navy Aegis weapons systems to exchange radar data, share a Single Integrated Air Picture, and conduct simulated engagements for the first time in an operational environment. JLENS was designated an Acquisition Category II in March 1999. Acquisition plans call for 12 complete systems at an estimated value of $1.6 billion.[60]

The above finding indicated that JLENS furnishes the over-the-horizon radar acquisition capability required for the air defense system to be effective against cruise missile attack. JLENS's joint interoperability capability adds to its utility as a viable air defense tool. JLENS is a significant advancement in air defense, but additional work must continue to ensure its ability to deploy with the fielded forces as well as its ability to defend the full extent of CONUS borders.

Despite these promising initiatives current land, maritime, and air defense systems continue to be limited in their abilities to perform cruise missile defense for combatant commanders.

Moving Forward on LACM Defense

DOD has acknowledged its lack of sufficient defense against cruise missile attacks, and is taking steps to correct the deficiency. Concurrently, enemies of the United States are also aware of this weakness, and can be expected to exploit it.

The U.S. family of legacy systems to counter the LACM threat is not only incapable of handling the threat projected by 2010, it is also completely inadequate to work effectively against even the limited current threat. Even with enhancements to current systems, U.S. forces will not be able to provide a defense sufficient to protect key power projection access facilities such as ports and bases, and vital areas such as forward-based command and control centers.

A planned, synchronized attack against land forces by an enemy employing both numerous ballistic missiles and cruise missiles using GPS/GLONASS (GLONASS is the Russian version of GPS) for precise guidance and targeting would simply overwhelm current U.S. legacy capabilities. Adding simple countermeasures to hostile LACMs such as stealth and towed decoys only compounds an already challenging problem. Stealth reduces the radar cross-section of an already low-signature cruise missile, increasing the difficulty of detection and tracking. Use of towed decoys can create such a sufficient kill vehicle miss distance that the cruise missile can survive. The LACM threat today is similar to the submarine threat of World War II, a situation where a small number of relatively inexpensive German submarines were initially able to asymmetrically counter seemingly overwhelming allied sea power. The United States has maintained air superiority or even supremacy in all conflicts over the past half century, but that paradigm is not necessarily destined to remain a given assumption.

A senior planner for Operation DESERT STORM recently stated in *Aviation Week and Space Technology*:

> The U.S. is not going to get the luxury of one cruise missile arriving every five minutes. If I were the enemy, I'd fire them in barrages. And I'd put dummies up front and at a little higher altitude to attract the defenses. I'll bet eighty percent would get through. The Navy is the only service with a viable close-in defense system (the Phalanx 20mm gatling gun).[61]

The kill chain to attack an LACM consists of detecting, identifying, tracking, and finally targeting the cruise missile. Each of these four phases is critical to success. For instance, if the cruise missile can be detected, tracked, and targeted with a weapon, it still has to be identified in order to prevent fratricide of friendly air assets. Consider the complexity of an air picture in which the blue force has several hundred manned and umanned aircraft airborne (both coalition and joint), has its own cruise missiles and ballistic missiles in flight, and is simultaneously trying to cope with dozens or even hundreds of threat cruise and ballistic missiles.

The key factor to successfully provide for cruise missile defense is the development of a robust and joint single integrated air picture (SIAP). Unfortunately, each of the Services continues to approach the LACM threat with a "stovepipe" mentality. Each Service has its own vision for air defense, and an inherent and historical tendency to remain platform oriented. A Pentagon agency called the Joint Theater and Air Missile Defense Office (JTAMDO) has been given the mission of setting joint missile defense requirements, but has been relatively ineffective because detailed requirements from the Services have not been adequately forthcoming.[62]

Recognizing that the Services were pursuing independent cruise missile defense initiatives, the Office of the Secretary of Defense chartered the Joint Cruise Missile Defense (JCMD) Joint Task Force (JTF) to conduct a joint test and evaluation (JT&E). Unfortunately, the JCMD JT&E is simply chartered to evaluate the current and near-term effectiveness of a typical Joint Integrated Air Defense System (JIADS), and its final report is not due until 2005.[63] Interestingly, the methodology for LACM defense can be surveyed from a top-down approach (U.S. Navy), or a bottom-up approach (U.S. Air Force). The question is, should one develop a system starting with the detection phase of the kill chain, or starting from the final kill phase of the chain? What should be developed first, the detection sensor, or the kill vehicle?

The U.S. Navy uses a top-down approach with Network Centric Warfare. Known as cooperative engagement, Network Centric Warfare uses joint sensor netting to build a "single air picture for a joint force which would enable units to engage a target with their own weapons, even if the target's track did not come from their organic sensors."[64] This approach broadens the battlespace for LACM defense and provides for the necessary layered defense in depth.

The U.S. Air Force is not necessarily on board with Network Centric Warfare. General Jumper, Commander of Air Combat Command, is a critic contending that:

> I'm not welcoming people with briefcases strapped to their arms that have a network solution. I'm looking for the killing solution.… What kills me about plans for network-centric programs is that they are a solution looking for a problem. I'm out there saying we're going to do Ground Moving Target Indicator with the integration of manned, unmanned and space platforms. I know what I'm doing, and that's finding targets to kill. And it's

> going to be networked with command and control [elements in] the air operations center on the ground, and it's going to have hooks to people afloat and on the ground…. But I'm not going to undertake this amorphous network-centric thing without a verb in it. I'm going to start with the thing that kills the target and invent the network that locates it, identifies it and instantly get the information to the person or the warhead that is going to blow it up.[65]

In effect, the current U.S. Air Force approach to LACM defense is to start with the shooter and work backward to the sensor that provided detection. This methodology may create problems in the area of battle-management command, control and communications (BMC^3) as evidenced in the problems and inabilities Link 16 has in communicating with fielded systems in the Army, Marine Corps, and Navy. The key problem area to focus on is joint BMC^3—not the kill vehicle itself. Each Service could have its own kill vehicle, but that vehicle better be able to communicate and incorporate data from a joint system of BMC^3.

To get on the right track, OSD should aggressively direct the military Services through guidance from the Chairman of the Joint Chiefs of Staff (*Defense Planning Guidance* or *Quarterly Defense Review*) to develop the capability to provide a joint single integrated air picture that would be used to both detect and identify an LACM and then target it with the appropriate kill device. Such a system would provide the capability to fuse multiple sensors from air, ground, and naval assets into a single picture, identify the target as hostile, track it, and allow for cooperative engagement from a host of joint kill vehicles. Getting all the Services to jointly develop common BMC^3 is the key.

Several technologies are available that can furnish the sensors needed to populate a JIADS capable of LACM defense. The inherent challenges associated with detecting and tracking low radar cross-section cruise missiles operating close to ground clutter require “very low-frequency, long-range, phased array radars with advanced clutter rejection and as rapid a sweep time as possible.”[66] Detection ranges on the order of 200 nautical miles are necessary to give adequate time to position the kill vehicle to destroy the LACM. In addition, 360-degree coverage not currently available with such systems as the Patriot must be inherent to prevent the threat from flying its LACM around friendly defenses, and hitting protected areas from the rear.[67] The large size of such radars has generated renewed interest in the use of lighter-than-air vehicles. One concept on the drawing boards is a tethered blimp stationed at 70,000 feet capable of remaining on station for a month and carrying a 4,000-pound payload.[68] The main problem with blimps is the difficulty in deploying them into theater due to their limited speeds. This has generated interest in alternate methods of deploying radars, such as using large-bodied aircraft or satellites.

Several concepts exist in the employment of radars aboard wide-bodied aircraft to perform LACM detection and identification. One method would be to upgrade current E-3 AWACs and E-8 JSTARs aircraft with advanced radar systems capable of tracking LACMs. Another is to use a palletized roll-on, roll-off radar system that could be placed aboard a multitude of aircraft found in the battle area. In the prosecution of air warfare, numerous large-bodied tanker aircraft are used for air refueling operations. Currently these aircraft spend numerous hours flying in assigned orbit patterns so as to refuel attack aircraft, but accomplish relatively little else. Placing radar sensors aboard tanker aircraft, and netting them into the BMC^3 system would add necessary robustness and depth to an LACM defense.

A robust joint single integrated air picture employing the concepts of network centric warfare and cooperative engagement can provide the necessary means to detect, track, and identify LACMs as well as a host of other aerospace threats such as helicopters, fixed-wing aircraft, unmanned aerial vehicles, and ballistic missiles.

The final step in the process to defeat the LACM threat is the development of the kill vehicle or "interceptor." Of prime importance here is the necessity to develop kill vehicles that remain cost effective.

Currently the Patriot Advanced Capability-3 (PAC-3) missile used by the U.S. Army has a unit-production cost of two million dollars. The U.S Navy's prototype follow-on land attack cruise missile to replace the Tactical Tomahawk is estimated to have a unit production cost of only $40,000.[69] Although the Patriot is capable of killing cruise missiles its poor cost-per-kill against low-cost threats such as crude cruise missiles and unmanned aerial vehicles makes it prohibitively expensive in the current cruise missile defense regime. "Adversaries could use cruise missiles to overwhelm U.S. defenses and deplete limited Patriot inventories," according to *Defense Week*.[70]

Currently, the U.S. Army is developing a low-cost cruise missile interceptor that relies on commercially available technology and off the shelf components. The Army estimates the cost of that interceptor to be in the $100,000 range. Flight tests are expected to begin in Fiscal Year 2005 (FY05), and low-rate initial production could occur as early as FY07-08. This interceptor, with a length of 14 feet and weight of 700 pounds, is expected to have a range of approximately 50 miles. It will use an active sensor and be netted to overhead sensors as it flies to target. It will climb to 70,000-80,000 feet before descending in its terminal kill phase. The Army's concept is that this low-cost interceptor will be used against unsophisticated cruise missiles (those lacking stealth and defensive countermeasures), while Patriot systems will be used to attack sophisticated LACMs.[71]

The Defense Advanced Research Projects Agency (DARPA) hosts a low-cost cruise missile program in its special projects office responsible for developing an affordable missile seeker "for use in an interceptor system to defeat raids of unsophisticated air vehicles."[72] DARPA researched six low-cost seeker types: (1) a noise radar seeker, (2) a micro-electromechanical machine system (MEMS) electronically steerable array antenna (ESA) seeker, (3) a laser seeker, (4) an infrared seeker, (5) an optical ESA, and (6) an ultra-high-frequency seeker. The MEMS ESA seeker held the most promise, and DARPA awarded a contract in 2001 for a MEMS ESA seeker.[73]

DARPA's MEMS ESA seeker has been incorporated with a derivative of the U.S. Air Force ADM-160A miniature air-launched decoy (MALD) to form the miniature air-launched interceptor (MALI), a very low-cost supersonic cruise missile interceptor. MALI uses low-cost commercial off-the-shelf hardware found in MALD, and was successfully flight tested in December 2001.[74]

To move forward with a viable LACM defense, the U.S. military must immediately set itself on a path to accomplish the following by 2010:

1. Under <u>direct leadership from the Office of the Secretary of Defense</u>, DOD should develop a <u>joint</u> single integrated air picture (SIAP) based on network centric warfare and cooperative engagement.

2. DOD should aggressively employ technology to develop and deploy a robust <u>360-degree</u> layered Joint Integrated Air Defense System (JIADS) capable of detecting, identifying, tracking, and killing LACMs, including LACMs equipped with stealth and countermeasure technologies.

3. DOD must ensure that the cost of the kill vehicles used is commensurate with the costs associated with threat LACMs. DOD can't go broke in the process and the fielded interceptors must be numerous enough to counter a robust threat.

Conclusion

> Future adversaries could have the means to render ineffective much of our current ability to project military power overseas. Saturation attacks with ballistic and cruise missiles could deny or delay U.S. military access to overseas bases, airfields, and ports…. New approaches for projecting power must be developed to meet these threats.
>
> *Quadrennial Defense Review Report*, 30 Sept. 2001[75]

As the rest of the world struggles to find ways to counter the overwhelming military might of the United States, the allure of weapons such as the cruise missile will increase. The threat has been proven to be real even though it has not been effectively used against U.S. forces in major combat. In addition to the nation-states that pursue this capability to further their regional objectives, the United States must also be aware of the nonnation-state actors such as terrorists and criminals probing for soft, high-visibility targets.

The limitations of current U.S. legacy systems, whether employed from the air, land, or sea, create vulnerability for the combatant commander that must be aggressively addressed. Effectively, the technology and means exist to reliably counter the LACM threat, but the threat must be officially recognized and serious steps must be taken to deploy a functioning system by 2010. OSD must ensure that the Services work together to develop a JIADS capable of providing a single integrated air picture. Network Centric Warfare and cooperative engagement lead the way.

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