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THEATER LAND ATTACK CRUISE MISSILE DEFENSE:

GUARDING THE BACK DOOR

BY

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About the Author

Lieutenant Colonel Igor J. P. Gardner graduated from the University of Northern Colorado in 1983. Following intelligence officer training, he was assigned to Headquarters, United States Air Forces in Europe, Ramstein Air Base, Germany, where he served as an air tactics analyst and current intelligence briefer. While there, he completed a master of science degree in international relations and Squadron Officer School. In 1988, he graduated from the USAF Fighter Weapons School at Nellis Air Force Base, Nevada, and was assigned to Kunsan Air Base, Korea, where he served as chief of operational intelligence for the 8th Tactical Fighter Wing. Reassigned to the Weapons School at Nellis, Lieutenant Colonel Gardner served in a variety of positions in the intelligence division. He was then assigned to the Pentagon, serving in a variety of positions including program element monitor, chief of the CSAF current intelligence briefing team, and executive officer to the Deputy Chief of Staff, Intelligence and Director Intelligence, Surveillance and Reconnaissance. Following graduation from Air Command and Staff College, Lieutenant Colonel Gardner attended the School of Advanced Airpower Studies. He is currently commander of the Intelligence Division, USAF Weapons School, Nellis Air Force Base, Nevada. He is married to the former Alice Marie Ferguson of Las Vegas, Nevada. They have one daughter, Allison.

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Abstract

This study examines the question: "Is the United States adequately preparing to counter the theater land attack cruise missile (LACM) threat?" The U.S.' overwhelming conventional warfighting capabilities, demonstrated during the Gulf War and more recent conflicts, have led potential adversaries to examine asymmetric means to defeat U.S. strategy. Of particular concern are weapons of mass destruction (WMD) and the means to deliver them. To date, Department of Defense agencies and the Services, under the collective rubric of theater missile defense, have spent billions of dollars developing systems and architectures to theater missile threats, focusing primarily on theater ballistic missiles. However, proliferation of advanced technology may cause land attack cruise missiles to become a larger part of the theater threat equation in the near future. Cruise missiles' typically low radar and infrared signatures, as well as low-altitude (in some cases terrain-following) flight profiles, make them difficult to detect and defeat.

Land attack cruise missiles are not a new threat; however, the last time they were used in combat by someone other than the U.S. was by Germany during World War II. This study examines the history of cruise missiles and theater missile defense. The treatment includes two case studies: *Operation Crossbow*, the Allied effort to counter German V-1 land attack cruise missiles and V-2 ballistic missiles, and the Desert Storm "*Scud* hunt." The study next examines joint and service doctrine to determine whether the lessons from past theater missile defense efforts were incorporated, and how joint and

service doctrine advocate countering the potential land attack cruise missile threat. Technological efforts to counter the threat are also examined, with the objective of determining to what extent the doctrine and technology mesh.

The thesis concludes by exploring implications of identified deficiencies and then recommending ways to alleviate them. While land attack cruise missiles are still considered an emerging threat, the uncertainty lies not in *if*, but *when*, the threat will appear. The land attack cruise missile threat could materialize very rapidly due to the proliferation of cruise missile enabling technology. Efforts to control the spread of this technology have been limited. Once deployed, the missiles' low pre- and post- launch signatures and unique flight characteristics could make them difficult to detect, track and kill. Effectively countering this potentially difficult threat at the theater level will require the integration and cooperation of all available capabilities and assets. Theater air and missile defense is inherently a joint mission. Defeating land attack cruise missiles will require complementary joint and service doctrine and concepts of operation, realistic testing and training, as well as advanced technology.

Chapter 1

Why Cruise Missile Defense?

The United States defense strategy for the 21st century seeks to shape the international security environment in ways favorable to United States interests, respond to the full spectrum of threats, and prepare now for an uncertain environment.[1] Overwhelming American conventional warfighting capabilities, demonstrated during the Gulf War, are leading potential adversaries to pursue other means to defeat U.S. strategy. To be a true full-spectrum force, the U.S. military must be able to defeat even the most innovative adversaries.[2]

For the last four decades U.S., forces have enjoyed almost complete freedom from enemy air attack. Iraqi *Scud* missile attacks on Israel and Saudi Arabia during the Gulf War, and their disproportionate political ramifications, served as a wake up call. Since 1991, there has been increased emphasis on "full-dimensional protection," a concept that calls for multi-layered defense of forces and facilities, across the spectrum of conflict, to enable U.S. forces to safely maintain freedom of action during deployment, maneuver and engagement. Of particular concern are weapons of mass destruction (WMD) and the means to deliver them.[3] Current efforts to develop and deploy a multi-tiered theater air and missile defense architecture are key components of achieving full-dimensional protection.

[1] A National Security Strategy for a New Century, (Washington, D.C.: Government Printing Office, October 1998), 6.

[2] William S. Cohen, Annual Report to the President and the Congress, (Washington D.C.: 1999), 6.

[3] *Joint Vision 2010* (Washington, D.C.: Government Printing Office), 22-24.

> We have robust missile defense development and deployment programs focused on systems to protect deployed U.S. forces and our friends and allies against theater *ballistic* missiles armed with conventional weapons or WMD. (Emphasis added)[4]

Protection against theater *ballistic* missiles has become a national priority.[5] Given the high degree of emphasis placed on ballistic missile defense, has the U.S. short-changed the other half of the theater threat missile equation: land attack cruise missiles? This thesis investigates the overall question: "Is the United States adequately preparing to counter the theater land attack cruise missile (LACM) threat?" It examines the history of cruise missiles, the current and projected LACM threat, the Joint and Service theater air and missile defense doctrines and employment concepts which provide guidance to commanders and strategists facing these potential threats, and current and near-term future technical capabilities to counter them.

Able to deliver the same payloads over similar distances with equal or greater accuracy, advanced LACMs have the potential to be even more deadly than ballistic missiles. LACMs typically have low radar and infrared signatures, and low-altitude (in some cases terrain-following) flight profiles, making them difficult to detect and defeat.[6] The proliferation of advanced weapons technology such as improved radar and infrared signature reduction, countermeasures, Global Positioning System (GPS) or Global Navigation Satellite System (Glonass) navigation, and terminal homing seekers will make efforts to counter these threats a greater challenge than ever before. Unlike theater ballistic missiles, efforts to prevent cruise missile proliferation have been largely

[4] A National Security Strategy for a New Century, 26.

[5] William S. Cohen, 119.

ineffective, and highly lethal systems may be in potential adversaries' arsenals within the next decade.[7]

DoD agencies and the armed services, under the rubric of Theater Missile Defense (TMD), have spent billions of dollars to date developing systems and architectures to defeat theater missile threats.[8] In the past this effort focused on theater ballistic missiles, not cruise missiles. Defeating TMD threats will require synchronization and integration of all the services' air and missile defense capabilities. These capabilities frequently overlap, fueling ongoing efforts by the Ballistic Missile Defense Organization (BMDO), the Joint Theater Air and Missile Defense Organization (JTAMDO), and the Armed services to seek incorporating them into a "Family of Systems" (FoS).[9]

While technology integration efforts hold promise, integration of TMD doctrine and employment concepts has not enjoyed the same degree of cooperation and success. Since the Goldwater/Nichols Act of 1986, the U.S. has placed increasing importance on joint doctrine. This emphasis now manifests itself in virtually every area of warfighting. The organization, command and control structure, deployment and employment of forces is laid out in detail in joint doctrine and, increasingly, in Service doctrine as well. The real TMD challenge may turn out to be developing congruent Joint and Service theater missile defense doctrine based on historical experience which, despite the various joint and Service doctrinal paradigms, employs the "Family of Systems" effectively.

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[6] Humphrey C. Ewing and Robin Ranger, *Cruise Missiles: Precision and Countermeasures* (Lancaster, U.K.: Center for Defence and International Studies, 1995), 20.

[7] See Dennis M. Gormley and K. Scott McMahon, "Proliferation of Land-attack Cruise Missiles: Prospects and Policy Implications," in *Fighting Proliferation: New Concerns for the Nineties,* ed. Henry Sokolski (Maxwell AFB, AL: Air University Press, 1996), 131-167.

[8] Lieutenant General Lester L. Lyles, USAF, Director, Ballistic Missile Defense Organization, Statement before the Subcommittee on Defense, Committee on Appropriations, United States Senate, 22 April, 1998. Available on-line at http: //www.acq.osd.mil/bmdo/bmdolink/htm/lyle22apr.html.

This study examines the question: "Is the U.S. adequately preparing to counter the theater land attack cruise missile (LACM) threat?" The study begins with an introductory chapter that places the question in context, and presents the methodology used. The second chapter selectively examines past and present cruise missile developments and operations, up to and including U.S. cruise missile attacks during Desert Storm.

The U.S.' overwhelming conventional warfighting capabilities, demonstrated during that conflict have led potential adversaries to pursue asymmetric means to defeat U.S. strategy. Of particular concern are weapons of mass destruction (WMD), and the means to deliver them. As discussed in the third chapter, proliferation of advanced technology may cause land attack cruise missiles to become a larger part of the theater threat equation in the near future. Cruise missiles typically have low radar and infrared signatures, and low-altitude (in some cases terrain-following) flight profiles, making them difficult to detect and defeat. Land attack cruise missiles are not a new threat; however, the last time they were used in combat by someone other than the U.S., was by Germany during World War II.

To determine similarities and differences in countering theater ballistic missiles and land attack cruise missiles, the fourth chapter examines two case studies: *Operation Crossbow*, the allied effort to counter German V-weapons; and the Desert Storm "*Scud* hunt." Joint and service visions and doctrine are examined to determine if, and how, they incorporate the lessons learned from the historic cases studies, and how they fit together to create the coordinated effort required to defeat the cruise missile threat. Ongoing efforts to incorporate individual service theater air and missile defense technology

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[9] Ibid.

capabilities into a “Family of Systems” are examined next to determine how they fit together with each other and current visions and doctrine. The treatment concludes with implications of identified deficiencies, and recommendations of possible solutions.

Chapter 2

Cruise Missiles: Past and Present

> *Could not explosives even of the existing type be guided automatically in flying machines by wireless or other rays, without human pilot, in ceaseless procession upon a hostile city, arsenal, camp, or dockyard?*
>
> Winston Churchill, 1925[10]

Cruise missiles are not new. The technology to develop and employ them has been available since before World War I. However, technological advances in the past two decades have made cruise missiles much more capable than was previously thought possible. This chapter provides a brief overview of cruise missile development since the early 1900s. It begins by providing some definitions to serve as a common starting point for discussion and then delves into cruise missile history up to the present.

Definitions

There is no single universally accepted definition of the term "*cruise missile*". Common definitions can become critical, however, particularly when viewed in the context of negotiating arms control and counter-proliferation agreements. The United States and Soviet Union agreed to the following definition in the Intermediate-Range Nuclear Forces (INF) treaty: "A cruise missile is an unmanned, self-propelled vehicle that sustains flight through the use of aerodynamic lift over most of its flight." Separately, it

[10] Joint Publication 3-01.5, *Doctrine for Joint Theater Missile Defense*, 1996, I-3. Hereafter this study will cite a Joint Publication as Joint Pub.

adds that a cruise missile is a "weapon delivery vehicle."[11] Another commonly accepted definition states "a cruise missile is a guided missile, the major portion of whose flight path to its target is conducted at approximately constant velocity; depends on the dynamic reaction of air for lift and upon propulsion forces to balance drag."[12] Interestingly this definition does not mention a weapons-carrying capability. Neither definition differentiates between rocket powered and air breathing weapons, or systems with either fully autonomous or man-in-the-loop guidance. Additionally, no effort is made to categorize the missiles by range. This study will use the INF definition because it addresses the unmanned flight and weaponization characteristics that make the cruise missile threat unique.

Unlike ballistic missiles, cruise missiles are usually categorized by intended mission and launch mode, rather than maximum range. The two broadest categories are anti-shipping cruise missiles and land-attack cruise missiles. Each type can be launched from an aircraft, ship, submarine, or ground-based launcher.

Anti-Ship Cruise Missiles (ASCM)

ASCM guidance systems are specifically designed for use against ships. The terminal guidance systems used on ASCMs are designed to home in on the target's signature using active and semi-active radar, radar homing, home-on-jam, infrared, or television seekers, or sometimes a combination of these. ASCMs can be powered either by air breathing engines, such as the turbojet used in the U.S. AGM-84 *Harpoon*, or rocket motors, as

[11] Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Elimination of their Intermediate-Range and Shorter-Range Missiles, (Washington, D.C.: 1988), Article II, paragraph 2.

[12] Joint Pub 1-02, *Department of Defense Dictionary of Military and Associated Terms 1998*, 118.

used in the French *Exocet*. They are typically armed with large, high explosive warheads designed to penetrate ships' hulls before exploding.

Even relatively small ships can carry a large number of the missiles, each capable of inflicting extensive damage to much larger naval combatants. The offensive power provided by ASCMs has made it possible for Third World countries to maintain relatively powerful naval forces that rely on comparatively inexpensive missile-armed patrol boats.

Land Attack Cruise Missiles (LACMs)

LACMs, such as the U.S. Navy's *Tomahawk* and the U.S. Air Force's Conventional Air Launched Cruise Missile (CALCM) are designed to fly a preprogrammed path to attack a fixed or mobile ground-based target, carrying various types of conventional or weapons of mass destruction (WMD) warheads. In the past LACMs required sophisticated guidance and complicated mission planning support infrastructure, and were largely confined to the arsenals of the major powers. Unlike ASCMs, only a few countries including the United States, Russia and France are known to have developed and fielded LACMs. However, several other countries are expected to field LACMs in the near future. The LACM threat has also been limited because unlike ASCMs, only a few LACM producers have exported such missiles. However, as cruise missile technology becomes more readily available in the future the LACM threat is expected to increase.[13]

In the past, the difficulties and expense involved in developing and fielding cruise missiles capable of flying at low altitude for long distances to precisely attack a target,

[13] National Air Intelligence Center (NAIC), *Ballistic and Cruise Missile Threat*, (Wright–Patterson Air Force Base, OH: 1998), 21.

were beyond the capabilities and resources of most nations. The proliferation of highly accurate space-based navigation systems, miniaturized avionics and propulsion systems, and warhead technology, may make the acquisition of a land attack cruise missile capability an achievable goal for many Third World countries.

Tactical Air-to-Surface Missiles (TASMs)

TASMs are similar to cruise missiles except that they are normally smaller and shorter ranged. TASMs can employ radio command, laser, anti-radiation homing, or electro-optical guidance systems. TASMs will benefit from the same technological developments as cruise missiles. As their capabilities increase, TASMs may become as stressing for short-range air defenses, as cruise missiles are for theater defenses. Due to their tactical focus, TASMs will not be discussed in further detail in this study.

Unmanned Aerial Vehicles (UAVs)

UAVs are powered vehicles that do not carry a human operator, use aerodynamic forces to produce vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or non-lethal payload.[14] This category includes drones, air vehicles (usually expendable) with preprogrammed flight paths, and remotely piloted vehicles (RPVs), which are usually controlled by a human operator and recoverable.

UAV are currently used for intelligence, surveillance and reconnaissance, but have also been used as targets and decoys. Like cruise missiles, they can be relatively easy to produce, and could also be used to deliver ordnance, including weapons of mass

[14] Joint Pub 1-02, 473.

destruction.[15] Many of the same factors which must be considered when facing the LACM threat will also need to be addressed should weaponized UAVs enter the threat picture in the future.

The History of Cruise Missiles

Cruise missiles, particularly the highly controversial U.S. Ground Launched Cruise Missile (GLCM), made headlines during the 1980s while their removal from Europe was discussed by the U.S. and the Soviet Union during the Intermediate Nuclear Forces weapons reduction talks. Following the removal of GLCMs from Europe, cruise missiles virtually disappeared from public view. It was not until the successful employment of U.S. conventional air- and sea-launched land-attack cruise missiles (*Tomahawk* and CALCM) during Desert Storm that public attention refocused on this potent weapon. However, Desert Storm was not the first successful employment of LACMs–their history is almost as long as that of the airplanes' on which they are based.

The Early Years

Even before World War I the idea of an unmanned, automatically controlled "flying bomb" or "aerial torpedo" circulated in the United States and a number of European countries. Such weapons were made possible by mounting an automatic control system based on gyroscopes in contemporary airframes. In 1916, Lieutenant T. W. Wilkinson, Jr. (USN) wrote a realistic appraisal of the potential benefits of the new technology, "The moral effect of such devices may be great. They are practically indestructible, unless a

[15] Jeffrey N. Renehan provides a detailed study of UAVs as potential WMD delivery vehicles in his SAAS thesis, *Unmanned Aerial Vehicles and Weapons of Mass Destruction* (Maxwell Air Force Base, AL: Air University Press, August 1997).

well-aimed shot disables [the] engine or control devices, and they cannot be driven off."[16] Unfortunately, the devices were expensive, required complicated launching facilities, and "use in long range attacks against forts and cities is of doubtful military value on account of [the] difficulty of striking at any desired point rather than at random within the limits of the city or fortress."[17]

During World War I and the years following it, the United States and Great Britain conducted several experimental programs to explore the operational capabilities and utility of the "flying bomb" concept, with little success.[18] However, the Germans, who first began pursuing "flying bombs" during the 1930s, enjoyed greater success.

World War II

The first effective LACM was Germany's V-1 (*Vergeltungwaffe Eins*, or Revenge Weapon One). The V-1, a simple pulse-jet powered weapon, carried a 1,870 lb. conventional high explosive warhead, had a range of about 200 miles and traveled at a speed of 350-400 mph at altitudes of 2,000-3,000 feet. The V-1s were cheap and did not use critical materials; therefore, they could be employed in great numbers. Their guidance systems were primitive, designed to guide the missile to hit large area targets, such as cities.[19]

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[16] Kenneth P. Warrell, *The Evolution of the Cruise Missile*. (Maxwell AFB, AL: Air University Press, September 1985), 8.

[17] Ibid.

[18] Ibid., 7-8, 12-16. Warrell provides a well-researched account of cruise missile development from the early 1900's to 1982. In 1917 the United States Navy pursued the "flying bomb" concept in earnest, awarding a contract for $200,000 to construct five experimental weapons. The resulting program met with mixed results before its final cancellation in 1922. The U.S. Army's "Liberty Eagle" program, popularly called the "Kettering Bug", was initiated in 1918 and also met with mixed results before its cancellation in 1920.

[19] Robin Ranger, et al., "Cruise Missiles: New Threats, New Thinking," *Comparative Strategy*, vol. 14, no. 3 (July 1995): 258. Werrell, 42-43.

V-1s were difficult to detect and attack because of their small size, relatively high speed and low-altitude flight profile. They were also durable, with few vulnerable parts and no aircrew to kill or injure. Because they could not be turned back they had to be destroyed, or allowed to crash on their own.[20]

However, V-1s also had limitations. The missiles' pulse-jet propulsion system could not operate at speeds of less than 150 miles per hour, requiring either an air launch, or catapult-assisted ground launch. On the other hand, they were not fast enough to outrun the Spitfires, Tempests, Mosquitoes and P-51 Mustangs sent up to intercept them. Fixed launch sites and predictable flight paths based on a constant course, altitude and speed meant that, once located, the missiles were relatively easy to engage. The poor accuracy of the missiles meant that they could only be used against large area targets such as cities. Finally, the V-1's small warhead limited the damage caused by those that managed to penetrate to their targets.[21] Even so, over 10,000 V-1s launched against targets in Great Britain caused more than 45,000 casualties, including 5,126 dead.[22] V-1 attacks on continental targets caused 14,758 additional casualties, including 4,683 dead.[23] While the V-1 was a notable technical achievement, fortunately for the Allies the Germans did not possess the technologies required to make the V-1 a more potent weapon.[24]

In 1944, the U.S. received enough recovered German V-1 parts to reverse engineer the weapons. The resulting JB-2 differed little from the German original, except for

[20] Werrell, 62.

[21] Werrell, 42, 62.

[22] Ranger, et al., 258. Werrell, 61.

[23] For additional background on the V-1 attacks during 1944-1945, see Robin Ranger, "Theater Missile Defenses: Lessons from British Experiences with Air and Missile Defenses," *Comparative Strategy*, vol. 12, no.4 (October –December 1993): 399-413.

[24] Werrell, 62. For a detailed account of the German V-1 and V-2 rocket programs prior to and during WWII see Michael J. Neufeld, *The Rocket and the Reich*, (New York: The Free Press, 1995).

launching and guidance. JB-2 testing by the AAF and the Navy continued until after the war. Accuracy continued to increase but remained below expectations; therefore, no operational JB-2 missiles were fielded.[25]

The Second Generation

Beginning in the late 1940s and throughout the 1950s, the United States attempted to develop a second generation of land attack cruise missiles that were to be nuclear armed, land and sea-based, and of medium and long range. However, this cruise missile generation could not yet compete with the proven technology of the manned bomber, or the new ballistic missiles. Reliability problems, and the inability to overcome technical barriers to developing effective guidance systems, continued to delay cruise missile development.[26] Nonetheless, missiles such as the *Snark*, the world's first land-based, intercontinental strategic cruise missile, with a range of 5,500 miles, provided an important indicator of the capabilities that similar cruise missiles could achieve today, given the reliable guidance systems now becoming more readily available.[27]

The United States was not the only country developing cruise missiles during the 1950s and 1960s. The Soviet Union also developed a wide range of air, surface and submarine-launched cruise missiles to counter U.S. aircraft carrier battle groups. The first of these anti-ship cruise missiles, the SS-N-2 *Styx*, entered the inventory in 1956.[28]

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[25] Werrell, 65-66, 67-68. The USAAF explored the use of radio-control guidance, replacing the preset engine cut-off controls used in the German originals. The U.S. Navy test-fired its "Loon" V-1 clones from ships, PB4Y-1 Privateer patrol bombers, shore launchers, and even from surfaced submarines.

[26] Werrell, 103.

[27] Ranger, et al., 259.

[28] Werrell, 150. Ranger, et al., 259. The Soviets compensated for their lack of carrier aviation by developing a large family of long-range cruise missiles.

During the following decades these and other Soviet anti-ship cruise missiles were widely exported to Soviet client states.

Third Generation Cruise Missiles

In the early 1970s, the United States began development of small, reliable, and accurate third generation cruise missiles, suitable for nuclear and conventional land-attack, and anti-ship missions. Advances in solid-state microelectronics made possible the development of on-board computer systems, solving previous guidance and accuracy problems. Accuracy began to approach that of ballistic missiles, and parallel advances in turbojet and turbofan engine technology, along with high-energy fuels, extended the ranges of the new cruise missiles to over 540 nm.[29] The U.S. Air Force's AGM-86B air launched cruise missile (ALCM) entered service in 1982. During the same time the U.S. Navy developed the BGM-109 *Tomahawk* sea-launched cruise missile (SLCM), for launch from surface ships or submarines.[30] The USAF's BGM-109 ground launched cruise missile (GLCM), another *Tomahawk* variant, was only briefly operationally deployed in Europe together with the *Pershing* II intermediate range ballistic missile (IRBM) before being removed in the late 1980s under the provisions of the Intermediate Range Nuclear Forces (INF) Treaty.[31] These early U.S. cruise missiles used the Terrain Contour Matching (TERCOM) navigation system, which provided accuracies within a few hundred feet over ranges of up to 1,200 nm. However, the TERCOM system

[29] Ranger, et al., 259.

[30] Ranger, et al., 260. The BGM-109 series was developed in three variants: the conventionally-armed tactical anti-ship cruise missile (TASM), the conventional land attack variant (TLAM-C), and the TLAM-N nuclear-armed land –attack missile. Also see Werrell, chapters V and VI for excellent background on development of all variants of U.S. third-generation cruise missiles.

[31] Rose E. Gottemoeller, *Land Attack Cruise Missiles*, (London: International Institute for Strategic Studies, 1987), 10-11.

required a large, expensive infrastructure to support its extensive imagery and mapping requirements.[32]

Like the U.S., the Soviets also developed, and in the 1980s deployed, long-range, land-attack cruise missiles on intercontinental bombers and submarines. These weapons, known in the West as AS-15 (air-launched) and SS-N-21 (sea-launched) were in many ways comparable to the U.S. cruise missiles.[33]

The Current Threat

This section examines the current status of the land attack cruise missile threat. This unclassified treatment of the current cruise missile threat is not intended to be all-inclusive, rather representative of the unique characteristics and capabilities LACMs incorporate, and what they may portend for the future.

Land-attack cruise missiles can accurately deliver conventional or WMD warheads over long distances against heavily defended targets, under environmental conditions that may preclude use of manned aircraft. Their construction can incorporate radar and infrared signature reduction techniques and technologies. These characteristics, coupled with their terrain-following flight profile and unpredictable ingress routes make them potentially very difficult to detect, much less defeat.

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[32] Ibid, 7. TERCOM uses an on-board computer, in which maps of the relevant terrain are stored, and a radar altimeter. The computer correlates radar altimeter data with the stored maps, calculates required corrections to put the missile back on course, and provides those corrections to the missile's autopilot.

[33] Ibid. 10-11.

Range

The real question to ask when considering this characteristic is “How much range does the enemy need to accomplish their objective? Just because a missile does not fly thousands of kilometers does not mean it is not worthy of consideration as a threat. In regional conflicts such as the Middle East, Korea, or the Indian Subcontinent, ranges of 50 miles may be more than sufficient to attack important targets of political or military significance. Due to advances in propulsion technology, avionics and warhead miniaturization, and other key enabling technology trends discussed in more detail in the next chapter, cruise missile ranges are increasing. Additionally, launching them off other airborne platforms, and adding larger wings or extra fuel tanks can extend cruise missile ranges. Substituting fuel for warhead payload may be another option that becomes more viable as accuracy increases, reducing the need for large warheads.

Accuracy

Modern guidance systems have made it possible to design highly accurate cruise missiles. Given developments in satellite navigation technology, discussed in the next chapter, it is likely that developing countries could develop navigation suites for cruise missiles capable achieving circular error probable (CEP) of less than 330 feet, possibly even less than 30 feet. [34] Such accuracies could make attacks on point targets with conventional munitions a viable option. With reliance on aerodynamic flight, the path of a cruise missile can be adjusted continuously. In contrast, if a ballistic missile’s guidance

[34] Joint Pub 1-02, 76. Circular error probable (CEP), is an indicator of delivery accuracy of a weapons system, used as a factor in determining probable damage to a target. It is the radius of a circle within which half of a missile’s projectiles are expected to fall. For more details on cruise missile navigation systems see Seth W. Carus, *Cruise Missile Proliferation in the 1990s*, (Washington, D.C.:

system permits even small deviations from the intended flight path, due to the ballistic flight profile and speeds involved, it might miss its target by a wide margin. Most tactical ballistic missiles currently deployed in third world arsenals can typically achieve CEPs of 3,000-6,500 feet.[35]

Lethality

The trajectory and speeds encountered by a cruise missile are roughly comparable to those of a manned aircraft, therefore, unlike ballistic missile warheads (which must withstand the stresses of launch and reentry, as well as velocities in some cases exceeding Mach 20), cruise missile payloads can be based on the wide variety of warheads bombs and sub-munitions developed for manned aircraft delivery. Of greatest concern is their ability to deliver weapons of mass destruction (WMD), including nuclear, biological or chemical (NBC) warheads.

Because of the factors discussed above, it may be easier to construct nuclear warheads for cruise missiles, than ballistic missiles. Although no developing country is confirmed to possess a cruise missile delivery capability for nuclear weapons, there is a disconcerting correlation between countries pursuing cruise missiles and those possessing weapons of mass destruction (WMD). In addition to the U.S., UK, France, China and Russia, there are at least eleven developing nations that have the capability to deploy land attack cruise

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Center for Strategic and International Studies, 1992), 18-19. This excellent work is the most comprehensive treatment of the land-attack cruise missile threat encountered during my research.

[35] During the Gulf War, Iraq achieved CEPs of roughly 2 kilometers (1 nm) with its Scud-derived 650-kilometer-range (350 nm) Al Hussein missiles. For details on Al Hussein accuracy see Gregory S. Jones, *The Iraqi Ballistic Missile Program: The Gulf War and the Future of the Missile Threat* (Marina Del Rey, CA: American Institute of Strategic Cooperation, Summer 1992), 31-32.

missiles and to produce WMD. Additionally, eight other countries with WMD have an ASCM capability.[36]

Cruise missiles are particularly well suited for the delivery of chemical and biological agents. These weapons are most effective when disseminated by releasing them into the air stream at lower altitudes and relatively slow speeds, making cruise missiles better delivery vehicles than ballistic missiles.[37] It is possible to equip cruise missiles with spray tanks, a relatively simple and readily available technology for releasing such agents, and the missiles could be programmed to maneuver around the target to distribute the chemical or biological agent in the most efficient manner.

Depending on the mission, LACMs could also carry conventional high-explosive unitary and cluster munitions or fuel air explosives. A considerable number of countries are capable of making conventional high-explosive warheads, cluster munitions, and fuel-air explosive (FAE) warheads designed for use in artillery shells, aircraft-delivered bombs, and rocket and missile warheads.[38] These warheads are effective against a variety of targets and their modification for use in cruise missile would not be difficult. Similarly, a country might be able to adapt existing aircraft-delivered munitions for use in cruise missiles.

[36] John T. Bowen, *The Poor Man's Air Force: Implications of the Evolving Cruise Missile Threat* (U.S. Army War College, PA: 1997), 11. Ranger, et al., 264-265. Carus, 80. See also Robert Shuey's CRS Report for Congress: *Ballistic and Cruise Missile Forces of Foreign Countries, ,* (Washington D.C.: Congressional Research Service, The Library of Congress, 1995), 3.

[37] Carus, 81. Supersonic missiles generally cannot dispense chemical and biological agents from sprayers since the high velocity airstream could destroy the agent by heating or shock.

[38] An FAE creates a cloud of explosive gas. When the cloud detonates, it produces powerful blast and overpressure. Cruise missiles are an excellent delivery system for FAEs; for maximum effectiveness, an FAE munition or dispenser needs to be moving relatively slowly to create the gas cloud. This is considerably easier to achieve with a subsonic cruise missile than with a supersonic ballistic missile reentry vehicle.

Survivability

To be effective, at least some cruise missiles must survive hostile air defenses. During World War II, the Allies were able to deploy highly effective defenses against German V-1 "buzz bombs." The V-1s typically flew at an altitude of between 2,100 and 2,500 feet, sufficiently high to be detected and engaged with considerable success.[39] The V-1 experience emphasized the need to develop cruise missile designs and employment methods that minimize the effectiveness of air defenses. To reduce cruise missile vulnerability, engineers concentrate primarily on two aspects of cruise missile design: flight profiles[40] and missile signature.

Most modern cruise missiles fly at extremely low altitudes, generally less than 150 feet, to complicate the detection and intercept problem of the opposing air defense network.[41] Many newer cruise missiles fly routes that optimize terrain features to mask the missile from hostile air defense sensors and air defense concentrations. Similarly, some cruise missiles can also be programmed to approach and attack a target in the most efficient manner; multiple missiles can attack the same target simultaneously from

[39] Werrell, 50.

[40] There are two generic flight profile categories, not associated with particular missile systems, which are typically used to model cruise missile threats. The first is a low altitude profile, with the target flying in the 100 to 2,000 foot altitude regime for up to 1500 nautical miles, at .5-.7 Mach. This profile usually assumes some type of flight route optimization for terrain masking. The second profile is a high altitude profile with the missile flying in the 50,000(+) foot altitude regime for the same distance, but at much higher speeds (1.5-3.2 Mach). *Air Combat Command Concept of Operations for Command and Control in Cruise Missile Defense*, Draft, August 1996, 7.

[41] Werrell, 162. During test in 1976, a Boeing AGM-86A flew terrain avoidance flight profiles with some portions as low as 30 feet above the ground. The ranges at which ground-based radars can detect cruise missiles are reduced significantly against low-altitude targets. Curvature of the earth automatically limits range, and missiles flying at low altitudes can be masked from radar detection by ground clutter (radar signals reflected from the ground itself). For excellent discussions of radar capabilities and limitations see, George W. Stimson, *Introduction to Airborne Radar*, Hughes Aircraft Company, El Secundo, CA: 1983.

different directions, overwhelming air defenses at their weakest points.[42] Other cruise missile designs take the opposite approach and fly high altitude, supersonic profiles, designed to defeat air defenses optimized against targets flying at subsonic or low supersonic speeds at low to medium altitudes.[43]

The latest generation of cruise missile designs also include greater efforts to employ low observable or "stealth" technologies that make it harder for air defenses to detect attacking missiles. These signature reduction efforts include minimizing radar cross section (RCS), and limiting the infrared and electronic emissions of the missiles. Although these technologies do not make the missiles invisible, they do reduce chances of detection and intercept.[44]

Flexibility

Cruise missiles can be armed with a wide variety of warheads, require less support infrastructure to deploy than manned aircraft and ballistic missiles, and can be launched from a wide variety of platforms, ranging from fixed land-based launchers to aircraft and naval vessels. The reduced signature of small cruise missiles may enable them to penetrate heavily defended targets, as well as complicating the task of air defenses by increasing the number of potential targets.

Given these capabilities, even countries that intend to rely mainly on manned aircraft may wish to obtain cruise missiles as a means of increasing the effectiveness of attacking

[42] NAIC, 19.

[43] Gottemoeller, 12.

[44] Rebecca Grant, *The Radar Game* (Arlington, VA: Iris Independent Research, 1998), 29. This work provides excellent background on stealth principles and technology, written in layman's terms.

aircraft. LACMs can support manned aircraft attacks by attacking enemy air defenses or instead of manned aircraft when such an attack would be impractical or too costly.[45]

Cruise missiles also have limitations. For some uses, cruise missiles may be less flexible than aircraft since they cannot be recalled once launched. Most current cruise missiles cannot engage targets of opportunity, nor can they evaluate a changed targeting situation.[46] However, the fact that cruise missiles and their technology continue to proliferate indicates that many developing nations have chosen to accept these limitations and focus on their capabilities instead.

[45] In Operation Desert Storm, coordinating aircraft and cruise missile attacks increased the effectiveness of both systems considerably. Cruise missiles freed allied aircraft to pursue other missions which could be better executed by manned aircraft, attacked several different objectives during weather conditions that precluded the use of other precision-guided munitions, and made possible daylight attacks on Baghdad without endangering pilots, or requiring large support efforts. Department of Defense, *Conduct of the Persian Gulf Conflict: Final Report to Congress*, (Washington, D.C.: Government Printing Office, 1991), 179.

[46] Richard Hallion holds the view that manned aircraft are a far superior weapon system: they are immensely flexible, can discriminate between targets up to the last moment because they have a “man in the loop”, are reusable, carry much greater payloads, and with modern precision-guided weapons can almost guarantee precision strikes. *Storm over Iraq* (Washington, D.C.: Smithsonian Press, 1992), 250-251.

Table 1. Selected World Cruise Missiles

Country	Missile Name	Range (nm)	Warhead Type(s)	Guidance Type(s)	Status (IOC)
China	Delilah 2	200+	Conv/WMD	I, GPS, IR	In Service
	C 802 LACM	160	*	GPS, TM	Development
France	Apache-A SCALP-EG	75-320	Conventional/ submunitions	I. GPS,TM,IIR	IOC 1999
Germany/ Sweden/Italy	KEPD-350	220+	Conv/unitary	*	2002
	KEPD-150	100+	Conv/unitary & submunitions	*	2002
India	Lakshya 2	320	Conv/WMD?	GPS	Development
Iran	*Silkworm* Upgrade	215	Conv/WMD?	GPS	Development
Iraq	*Ababil*	270	Conv/WMD?	TV	Development
Israel	*Popeye* 1	45	Conv/unitary	I, TV, or IIR	In service
	Popeye 3	190	Conv/unitary	I, TV or IIR	Development
Libya (ASCMs)	SSC-*Styx*	45	Conv/WMD?	I, AR or IR	In service
	Olomat Mk.2	45	*	I, AR or IR	In service
	AM-39 *Exocet*	30	*	I, AR	In service
North Korea (ASCMs)	HY-2 *Seersucker*	50	Conv/WMD?	I, AR or IR	In service
	C-801 *Sardine*	20	*	I, AR	In service
	AG-1	85	*	*	?
United Kingdom	*Storm Shadow*	300+	Conv/Penetrator	*	2002
Russia	Kh-55	1600	Nuclear	I, TM	In Service
	Kh-65SE	270-325	*	I, Glonass,TM	Proposal
	AFM-L *Alpha*	135	*	*	Development
South Africa	MUPSOW	125	Unitary & Submunition	GPS	Development
Syria (ASCMs)	SSC-1 *Sepal*	250	*	C, AR or IR	In Service
	SSC-3 *Styx*	45	*	I, AR or IR	In Service
Taiwan (ASCMs)	Hsiung Feng 2	45	*	I, AR, IR	In Service
	Hsiung Feng 3	105	*	*	Proposal

Notes:

AR	Active Radar	IR	Infrared
C	Command	IIR	Imaging Infrared
Glonass	Global Navigation Satellite System	IOC	Initial Operational Capability
GPS	Global Positioning System	TM	Terrain Matching
I	Inertial Navigation System	TV	Television

* Indicates information is not available.

Sources: NAIC, Ballistic and Cruise Missile Threat, (Wright-Patterson AFB, OH: 1999), 20; Robin Ranger, et al., Cruise Missiles: New Threats, New Thinking, Comparative Strategy, vol. 14, no. 3 (July 1995): 264-265; and David A. Fulghum, Cruise Missile Threat Spurs Pentagon Research, Aviation Week & Space Technology (14 July 1997), 44 85.

The Global Cruise Missile Arsenal

Over 70 countries currently have some type of cruise missile in their inventory, totaling over 20,000 missiles. [47] By far the vast majority of these are ASCMs. Since the early 1960's, when the former Soviet Union started exporting anti-ship cruise missiles (ASCMs), they have become an integral part of military forces worldwide.

Although this study focuses on the LACM threat, it may prove useful to examine the spread of ASCMs in more detail as it may provide some insight into current and future LACM proliferation. ASCMs have seen extensive use in combat since the 1967 Arab-Israeli War, when Egyptian *Styx* ASCMs sank the Israeli destroyer *Eliat*. ASCMs were later used during the 1971 Indo-Pakistani war, the Yom Kippur war in 1973, and the 1980-1988 Iran-Iraq war.[48]

The most notable ASCM employment, however, occurred during the 1982 Falklands conflict. Argentina launched five French-made AM-39 *Exocet*, her entire inventory, against British ships, scoring three hits. Air-launched *Exocets* sank the destroyer HMS *Sheffield* and the container ship *Atlantic Conveyor*; and ground-launched *Exocet* damaged the destroyer HMS *Glamorgan*.[49] With such records of accomplishment, it is not surprising that many nations have purchased large quantities of ASCMs from foreign suppliers, and several have developed an indigenous production capacity.

In contrast with ASCMs, their land-attack cousins were not employed in combat during the 46 years between the last use of German V-1s in 1945, and the 1991 Gulf War.

[47] Matt Ganz, “Cruise Missile Defense,” briefing slides and text, May 1996, n.p.; on-line, Internet, 14 December 1998, available from http://www.arpa.mil/APRATech-96/transcripts/ganz.html. Ranger, et al., 262.

[48] In 1988, an Iraqi Mirage fired two *Exocet* ASCMs at the frigate USS *Stark*, killing 37 sailors and heavily damaging the ship.

Surprisingly, despite the widespread acceptance of ASCMs, only a handful of countries have acquired, or attempted to develop LACMs. According to current assessments, only 16 countries, including the United States and Russia, currently have extensive LACM inventories.[50]

Cruise Missiles during the Gulf War

Sea-launched *Tomahawk* land-attack cruise missiles (TLAMs), and conventional air-launched cruise missiles (CALCMs) emerged as highly effective weapons during the 1991 Persian Gulf War. The U.S. cruise missiles demonstrated four advantages during the conflict. They had a low rate of launch failure, a high rate of hits on target, a low loss rate to enemy air defenses, and an ability to operate in adverse weather conditions, including those preventing use of manned aircraft.[51] The U.S. Department of Defense Final Report on the Persian Gulf War states that the cruise missile concept--incorporating an unmanned, low observable platform able to strike accurately at long distances--was validated as a significant new instrument for future conflicts.[52] Since the Gulf War, the United States has conducted several additional successful cruise missile attacks against targets in Iraq, Bosnia, Afghanistan, Sudan and Yugoslavia. U.S. cruise missile successes, and the advantages they have demonstrated, will undoubtedly enhance the attractiveness of LACMs.

Why have LACMs have not been developed and acquired as widely as tactical ballistic missiles and ASCMs? The technology required to develop and build such weapons was,

[49] Ranger, et al., 259.

[50] Ganz, "Cruise Missile Defense" briefing.

[51] Carus, 28. See also Department of Defense, *Conduct of the Persian Gulf Conflict: Final Report to Congress*, 773, 787.

until recently, not readily available to developing countries. In the past, only technologically advanced countries had the means and technology to develop and support such resource-intensive systems, and even they had to wait until the technology had reached a certain level. The United States waited to introduce LACMs into its inventory until a combination of technologies reached a critical point in their development. During the 1990s, these technologies, such as the highly accurate navigation systems necessary to attack land-based point targets, and the ability to produce them, have become widespread among industrialized and newly industrializing nations. Land attack cruise missile technology is no longer particularly unique.

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[52] Department of Defense, *Conduct of the Persian Gulf Conflict: Final Report to Congress*, 179.

Chapter 3

Cruise Missiles in the Future

As the 21st century approaches, the United States faces a dynamic and uncertain security environment.[53] Predicting the world beyond 2010 is probably no harder than predicting today's world was in 1989—difficult at best. However, policy makers require such predictions to facilitate planning, development and procurement of major weapons systems.

The proliferation of advanced weapons and technologies, particularly WMD and associated delivery capabilities, are of particular concern. The spread of these weapons and technologies could change the character of the military security challenges the U.S. will face in the future by increasing the number of serious potential threats the U.S. will face, and increasing the potential for regional destabilization in some parts of the world.[54]

Land attack cruise missiles pose a potentially serious threat to the interests of the United States. Hostile countries that acquire long range, highly accurate cruise missiles will have the capability to attack a wide range of targets that are important to the U.S. and its allies. LACMs armed with NBC weapons may be used to threaten or deter U.S. power projection capability, and to intimidate U.S. allies, friends and potential coalition partners.[55] This chapter examines cruise missile proliferation, what the U.S. and

[53] William S. Cohen, *Annual Report to the President and Congress*, (Washington, D.C.: 1999), 1.

[54] Ibid.

[55] *Report of the National Defense Panel*, (Washington, D.C.: Government Printing Office, 1997), 12-13.

international community are doing to counter it, and what may result if those efforts are unsuccessful.

Why LACM Proliferation?

Understanding what motivates developing countries to pursue missile proliferation as a whole is important to understanding the course of future LACM proliferation. In addition to the cruise missile capabilities discussed in the previous chapter, contributing factors can include: prestige, self-sufficiency, proliferation of anti-tactical ballistic missile (ATBM) systems, relative cost, and the availability of missiles and/or key enabling technologies.

Prestige

Prestige is frequently an important factor, sometimes more than operational considerations, in motivating a country to acquire a particular weapon system. This is especially true with respect to the way many countries view ballistic missiles. Development of ballistic missiles is an indicator of technological advancement for a nation's military industry. Acquisition of even a few missiles, especially by a WMD-capable state, commands immediate attention from the world community. However, U.S. cruise missile performance, during the Gulf War and since, has likely improved the prestige value of cruise missiles relative to ballistic missiles in the eyes of possible proliferants.[56]

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[56] Gormley and McMahon in *Fighting Proliferation*, 136.

Theater ballistic and cruise missiles provide many developing nations with air power projection capability not previously available within their resource constraints.[57] Depending on the missile system, the political intimidation potential may outweigh its military effectiveness. In the future, missile-equipped nations may not need to use large numbers of missiles to cause dramatic political change in a region; the mere threat or subsequent use of only a few weapons may be sufficient to achieve a national goal.[58]

Self-sufficiency

During the Cold War, the United States and the Soviet Union used arms and technology transfers as essential tools to further their influence in the developing world. Following the demise of the Soviet Union, many of its client states, who depended on their superpower patron for weapons and technology, lost their source of support and were left with aging weapons arsenals. Driven by necessity, and a desire to reduce future dependence on foreign sources, numerous countries created indigenous weapons development and production capabilities. The barriers that in the past made it difficult to develop advanced weapon systems are crumbling as more information and technology become readily accessible. Developing countries are taking advantage of today's "buyer's market" in aerospace to demand offsets with their purchases that will give them an indigenous maintenance and sometimes even production capability. Cruise missile development programs may follow the same pattern that has emerged with ballistic missile proliferation, where proliferants have turned to a mix of buying ready-made missiles and/or missile components from producers, as well as, pursuing an indigenous

[57] Bowen, 2.

[58] Joint Pub 3-01.5, 1-5, 1-6.

production capability. Although many countries rely on imported ballistic missiles (and parts), a significant number have established their own development programs.[59]

ATBM Proliferation

The relative attractiveness of cruise missiles may also increase with the growing availability of anti-tactical ballistic missile (ATBM) systems. Until the 1990s, ballistic missiles had an assured penetration capability, meaning that once a missile was launched, there was nothing a defender could do to stop the attack. Ballistic missiles travel at high velocities, and most surface-to-air missiles cannot intercept and destroy them. This is a major advantage of ballistic missiles over competing types of weapons. It is also a source of weakness. Because ballistic missiles fly at high altitudes, it is often possible detect and track them from long ranges. The proliferation and strategic importance of ballistic missiles has resulted in anti-tactical ballistic missile systems (ATBM) becoming standard component of sophisticated air defenses. Acquisition of ATBM systems by regional adversaries may make cruise missiles a more attractive option to developing countries.[60] Cruise missiles, with their relatively small size and ground-hugging flight profiles, are difficult to acquire, track and intercept with current defenses. The potential addition of signature reduction technologies and techniques will make the task of LACMD even more challenging.

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[59] NAIC, 4.

[60] Following the Gulf War, the U.S. initiated several programs to improve ATBM capabilities. The U.S. Army's Patriot PAC-3 and Theater High Altitude Area Defense (THAAD) programs, the U.S. Navy's Area Wide and Theater Area Wide initiatives and the Air Force's Airborne Laser (ABL) program are all the results of this effort. Other countries are also developing ATBM capabilities. The Israelis are developing their own *Arrow* ATBM, with U.S. assistance. Russia also claims several of its surface-to-air missile systems currently for sale have the ability to intercept ATBM's.

Cost

Cruise missiles are less expensive, and require less support infrastructure to field in significant numbers than manned aircraft or ballistic missiles. On the high end, a modern attack aircraft costs somewhere between $30 and 40 million.[61] A theater ballistic missile, such a the North Korean *Nodong*-1, costs approximately $1 million per missile,[62] while many land attack cruise missiles cost less than $750,000 apiece.[63] A cruise missile can deliver a similar sized warhead over a similar range more accurately and at a third to a tenth of the total cost of an equivalent ballistic missile.[64]

Simply acquiring the hardware is not enough. Many developing countries have spent significant portions of their defense budgets over the past several decades acquiring traditional airpower weapons and the infrastructure required to operate them. However, depending on the scale of the conflict, decision-makers may prefer to keep their manned aircraft in reserve as an "airforce in being," especially if their loss as a deterrent force could mean a significant shift in the long-term regional balance of power.[65] In such instances, cheaper and more numerous LACMs could become an attractive option.

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[61] Ted Nicholas and Rita Rossi, *U.S. Military Aircraft Data Book 1996*, 16th ed., (Fountain Valley, CA: Data Search Associates, 1996), 2-12, 2-13. Average unit cost of F-16 Falcon and F-A-18 were used as representative examples.

[62] *Assessing Ballistic Missile Proliferation and Its Control*, (Stanford, CA: Center for International Security and Arms Control, November 1991), 45. See also Reid Goldstein and Anthony Robinson, *Forecast International /DMS Market Intelligence Report: Missiles* (Alexandria, VA: Jane's Information Group, 1994) Tab D, "*Nodong*-1 (*Scud* –Mod Series), 1, the North Korean *Scud*-C costs $890,000 to produce and the Nodong-1 costs $1.4 million.

[63] Steve Fetter, "Ballistic Missiles and Weapons of Mass Destruction", *International Security*, Summer 1991, 11.

[64] Robin Ranger, "Cruise Missiles: New Threats, New Thinking," *Comparative Strategy*, 14, no. 3., July 1995, 256.

[65] Ronald E. Berquist, *The Role of Airpower in the Iran/Iraq War*, (Maxwell AFB, AL: Air University Press, 1988), 75. The author proposes a possible line of reasoning to explain the of lack of extensive offensive airpower use by both Iran and Iraq during their conflict; it may also explain Iraq's actions during the Gulf War. In attrition warfare, the need for deterrence in the future may mean that it is more important to keep an air force in existence for its deterrence value, than it is to use it in combat where

Availability

Today, largely due to the success of counter proliferation efforts such as the Missile Technology Control Regime (MTCR), discussed in more detail later in this chapter, ballistic missiles are becoming more difficult to acquire on the world arms market.[66] Cruise missile proliferation may be more difficult to prevent. International efforts to limit cruise missile proliferation have been less successful; countries seeking to acquire an LACM capability have a number of options to pursue.[67]

Direct purchase. Purchase of complete LACMs from current producers is the quickest option. A number of countries currently build cruise missiles, and are willing to export them. Between them, China, France, Italy, Great Britain, Russia, and the United States have exported anti-ship cruise missiles and UAVs to more than 40 developing nations.[68] However, none of the ASCM producers is known to have supplied land attack cruise missiles to developing countries. With the growing acceptance of the MTCR, and its restrictions on the export of long-range cruise missiles and cruise missile technology, developing nations may find it harder to acquire LACMs from the traditional suppliers of ASCMs. However, several countries producing ASCMs and ARMs are not party to, and therefore not regulated by the MTCR; therefore, they may be more willing to sell LACMs and related technology. The future cruise missile threat will be determined in large part by the willingness of producing nations to export their missiles. However, if

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losses are inevitable. It is more important to have an air force and not use it, than to use it and possibly lose it.

[66] Gormley and McMahon in *Fighting Proliferation*, 150-151.

[67] Ibid.

[68] Gormley, 98.

countries desiring an LACM capability find they cannot acquire them from existing producers, they will pursue other options.[69]

Converting ASCMs or UAVs. As noted above, there are approximately 75,000 ASCMs in existence today. Both ASCM and UAV technologies are potential building blocks that could essentially provide a "leg-up" to developing a land-attack cruise missile capability. However, only some of them are suitable for transformation into land-attack weapons. Many modern ASCM designs such as the French *Exocet* are densely packed with avionics, leaving little room for modification. Older missiles such as the Russian *Styx* and its Chinese derivative the *Silkworm*, are larger; replacing their older, bulkier avionics with more modern miniaturized equipment could provide room for additional capability in the form of additional avionics, seekers, warheads, and fuel.[70] UAVs provide similar opportunities to modify existing airframes. However, most current UAVs are designed for reconnaissance roles and would require substantial modifications to incorporate appropriate guidance packages and warheads. At least two land attack cruise missiles are based on Italian–built remotely piloted vehicles. Iraq's *Ababil* LACM is based on the *Mirach* 600 target drone, and Argentina's MQ-2 *Bigua* is based on the *Mirach* 100 RPV. [71]

Indigenous development. This is the longest route to achieving an LACM capability. Several options are available to a country with a desire to initiate indigenous production of LACMs. First, complete weapons can be built relying on components and production

[69] Gormley, 98-99. CARUS, 32.

[70] Another option is to increase missile range by trading off payload for fuel capacity. Matra, the French missile manufacturer, believes it can extend the range of its *Apache* air-launched cruise missile from 80 nm to 425 nm by reducing the warhead weight from 1,700 to 880 pounds, and increasing the amount of fuel carried. Reid Goldstein and Anthony Robinson, *Forecast International /DMS Market Intelligence Report: "Missiles,"* Tab B, 4-10.

expertise provided by a foreign supplier. Second, missiles can the built to foreign specifications, but using locally produced components. Finally, the country may be able to design its own weapons even if it relies heavily on foreign subcomponents.

Enabling Technologies

Cruise missiles differ from ballistic missiles as a proliferation threat because they share so many common technologies with other existing air vehicles. Of the four major cruise missile subsystems - airframe, propulsion, guidance, and warhead - none is prohibitively expensive, and a ready supply of materials and subcomponents is available on the international market.

Airframe

Aircraft airframe design can be directly applied to an unmanned vehicle. If a country can build a manned aircraft, it can probably produce a viable cruise missile airframe. Such airframes are relatively easy to build out of inexpensive, readily available aluminum. More sophisticated cruise missiles will likely incorporate composites and other advanced signature reduction materials and technologies into their airframes. Some of these materials are readily available. For example; high-strength composites useful for airframe construction, such as carbon fiber and other exotic materials, are now used in such diverse products as fishing rods and automobiles.[72]

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[71] Gormley, 97.

[72] If a country wants to increase the capability of its cruise missiles to penetrate enemy air defenses, it must identify technologies that aid signature reduction, signature masking, or other means to confuse detection systems. These include: paints and coatings that disguise the thermal signature of leading edges; radar jamming and spoofing technologies; suppression of engine exhaust signatures; and computer programs that predict radar cross section (RCS). Grant, *The Radar Game*, 22-43.

Propulsion

The advantage that cruise missile engine designers enjoy is that their engines only have to work once. Depending on the mission, designers can choose from a variety of engines. This number will likely increase in the future as engine production technology and knowledge continue to spread. Rocket motors are within the reach of many developing countries, but do not provide much flexibility, and because they must hold both fuel and the source of oxygen, are inherently shorter ranged.

Air breathing engines do not have to carry their own oxygen supply, permitting the production of missiles with longer endurance and longer ranges. Internal combustion engines with a propeller, such as those used on many reconnaissance UAVs, are easy to build, but due to their slow speeds and large radar signatures, have limited utility. The small turbine engines now obtainable on the international market are a more efficient and capable solution. Small turbo*jet* engines, such as those used in Harpoon missiles, are available from a variety of industrial and developing country manufacturers. Small turbo*fan* engines, like those in the U.S. Tomahawk and Russian AS-15, are for sale at air shows.[73]

Guidance

Cruise missile guidance technology can also benefit greatly from the commercial sector. As discussed in chapter 2, guidance technology was a significant barrier during the early history of cruise missile development. In the past, only the most advanced countries could master the complicated digital terrain and image-matching techniques required for accurate LACM guidance.[74] However, today's commercial airliners, and even private aircraft, are equipped with autopilots guided by state-of-the-art navigational technology, consisting of inertial and satellite navigation systems. If a country co-produces, assembles, or even maintains aircraft or their avionics, it is very likely to have both exposure to the technology and the expertise required to develop a cruise missile guidance system. Flight computers, inertial measurement units, altimeters, seekers and other components all benefit from advances in miniaturization of commercial technology. The availability of satellite navigation systems will now make it possible to produce highly accurate, relatively inexpensive cruise missile guidance systems.[75] Adoption of differential GPS (DGPS) could allow Third World countries to develop guidance systems with accuracy of 30 feet or less.[76] Due to selective availability, few countries will rely solely on GPS, because it would make them vulnerable to changes in U.S. policy.[77] In

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[73] According to Jane's *Unmanned Aerial Vehicles and Targets, 1996*, at least nine countries produce and sell compact turbojets/turbofans suitable for cruise missiles. See Carus, 76-79 for a detailed overview of available engine technologies.

[74] TERCOM technology has been overtaken by improved and miniaturized INS, GPS, Differential GPS, GLONASS, and other navigational satellite constellations, accessible to virtually any country. An off-the-shelf GPS is capable of obtaining 60 foot CEPs - better accuracy than early TERCOM systems in U.S. cruise missiles during the late 1970's. The U.S. is upgrading the Conventional Air Launched Cruise Missile (CALCM) and Tomahawk land-attack missile (TLAM), already very accurate systems, with a GPS. "USAF to Upgrade Cruise Missiles," *Jane's Defence Weekly*, 22 July 1998, 10.

[75] LACM guidance typically occurs in three phases: launch, midcourse, and terminal. During the launch phase, a missile typically uses only the inertial navigation system (INS). In the midcourse phase, a missile is guided by the INS with updates from one, or more, of the following systems: a radar-based terrain contour matching (TERCOM) system, a radar or optical scene matching system, and/or a satellite navigation system, such as the U.S.Global Positioning System (GPS) or the Russian Global Navigation Satellite System (Glonass). The terminal guidance phase begins when a missile enters the target area, and uses either more accurate terrain contour data or a terminal seeker - usually an optical or radar-based sensor.

[76] For an excellent review of GPS capabilities and limitations, and a discussion of DGPS see Raffir Gregorian, "Global Positioning Systems: A Military Revolution for the Third World?," *SAIS Review* 13, no.1 (Winter/Spring 1993).

[77] See Carus, 60-63, for discussion on GPS and Glonass signal degradation, including selective availability.

the absence of GPS or GLONASS, the reliability of cruise missile targeting would be more problematic.

If developing nations are able to build cruise missiles with satellite navigation systems that routinely provide uninterrupted accuracies of 10 feet, their terminal guidance problems could be solved. Such cruise missiles could deliver ordnance on target with accuracies comparable to that of many existing precision-guided munitions; a capability not currently available to many developing countries' air forces.

Warheads

Due to the slower speeds and less demanding flight regimes encountered by cruise missiles, and their similarity to manned aircraft, it should not be difficult for developing countries to design or modify existing warheads and munitions for cruise missile use. As noted above, cruise missiles are particularly well suited for the delivery of chemical and biological weapons through either submunitions or spraying.[78]

Technology Summary

Because a cruise missile is essentially nothing more than an unmanned aircraft, those countries interested in designing and building such a weapon benefit from the availability of aerospace technology and design in general. As the aircraft production, modification, and maintenance industry continues to expand, the technical and industrial infrastructure available for cruise missile design and manufacture will grow as well. Since airframe, propulsion, navigation, and warhead technologies contributing to cruise missile development are now available "off the shelf," little or no specialized infrastructure is

[78] NAIC.

required. Cruise missile development will require no specialized fuel, support, manufacturing techniques, materials or precision instruments. Not only will it become easier to acquire the technology; it will become extremely difficult to monitor and prevent proliferation of cruise missile technology, and to determine if a particular country has embarked on a cruise missile program.

Any country contemplating the acquisition or development of modern airpower weapon systems will likely put its resources into those systems which appear to hold the greatest potential for successful deterrence or coercion. At the same time countries will seek to increase their prestige in the international community. In the past, these airpower capabilities focused primarily on manned aircraft, ASCMs and more recently ballistic missiles. Development of WMD capabilities also played an important part in some of these countries' security policy equations. Still uncertain is just how aggressively developing nations will exploit the current revolution in guidance and navigation systems that now make the LACM appear so attractive as an alternative or complement to ballistic missiles and manned aircraft.[79] In a worst case scenario, with the advances and increased availability of key cruise missile technologies, U.S. forces will face a combination of threat systems including precision guided munitions, ballistic and land attack cruise missiles within the next decade[80]. While LACMs fielded by developing nations may not be as sophisticated as the Tomahawk (although they may be if systems such as Russia's AS-15 or the French *Apache* are exported to developing countries), they could nevertheless incorporate stealth technology and be armed with WMD warheads, a

[79] Gormley and McMahon, 146.

[80] David A. Fulghum, "Cheap Cruise Missiles a Potent New Threat," *Aviation Week & Space Technology* (6 September 1993), 54-55. See also David A. Fulghum, "Cruise Missile Threat Spurs Pentagon Research," *Aviation Week & Space Technology* (14 July 1997), 44-46.

formidable threat by any calculation. It seems clear that cruise missile proliferation should be of concern to the U.S., and efforts to constrain the spread of these weapons, and to cope with them once they have proliferated, should receive increasing attention.

Countering Proliferation

The remainder of this chapter will consider what policy options are available to counter cruise missile proliferation, and what should be done in case they fail. Although the focus is on U.S. responses to the problem, much of the discussion will necessarily have a broader focus, since many of the policy options available to the United States require the involvement of other countries.

According to the U.S. National Security Strategy, weapons of mass destruction pose the greatest single threat to global stability and security.[81] The proliferation of nuclear, biological, and chemical weapons and the means to deliver them pose a major threat to the security of the United States, its allies, and friendly nations. Nonproliferation initiatives are designed to enhance global security by preventing the spread of WMD, materials for producing them, and means of delivering them.

The United States is not alone in its concerns about the proliferation of WMD and delivery systems. Many members of the international community have joined the U.S. in seeking to prevent destabilizing buildups of conventional arms and limit access to sensitive technical information, equipment and technologies through multilateral treaties and regimes. The Missile Technology Control Regime (MTCR) is most pertinent in the context of this study.

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[81] *A National Security Strategy*, 1998, 6.

Missile Technology Control Regime (MTCR)

The MTCR is the principal international mechanism for attempting to control exports of missiles capable of delivering weapons of mass destruction.[82] This voluntary accord (not a legally binding international treaty) aimed at limiting "the risks of nuclear proliferation by controlling transfers that could contribute to the development of nuclear weapons delivery systems *other than manned aircraft*" (emphasis added) was signed by the United States, The United Kingdom, Canada, France, West Germany, Italy and Japan in 1987. By 1998, 29 countries had joined the MTCR as full partners. China has agreed to abide by the MTCR guidelines, but has not joined as a full partner. [83]

The MTCR is based on the premise that foreign acquisition and development of missiles can be delayed by making the acquisition of missile technology more difficult, expensive, and time consuming. Its voluntary guidelines concentrate on limiting the export of ballistic missiles and components, but also limit the export of some cruise missiles and associated subsystems. MTCR intentionally avoids placing restrictions on manned aircraft sales; because cruise missiles and manned aircraft share many technologies restrictions are less stringent for cruise missiles than ballistic missiles.

[82] In 1993 MTCR partners issued revised guidelines that were designed to limit the risks of proliferation of all weapons of mass destruction: chemical and biological as well as nuclear.

[83] As of the end of 1998, the MTCR Partners are: Argentina, Australia, Austria, Belgium, Brazil, Canada, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Russia, South Africa, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States. Rodney W. Jones and Mark G. McDonough, *Tracking Nuclear Proliferation*, (Washington D,.C.: The Brookings Institution Press, 1998), 311-314. See also "Commonly Asked Questions on the Missile Control Regime," n.p.; on-line, Internet, 3 March 1999, available from http://www.acda.gov/factsheet.

MTCR Categories

MTCR guidelines fall into two categories. Under Category I signatories agree to restrict the transfer of whole systems, components and manufacturing technology for missiles capable of delivering a 500 kilogram (1,100 lbs.) payload to a range of 300 kilometers (186 miles) or more. The Category I guidelines were supplemented in 1993 to direct MTCR members to assess whether recipient states could modify shorter range missiles or components via range-payload trade-offs to develop missiles meeting the 300-kilometer/500-kilogram threshold.[84]

Category II lists a variety of subsystems, components, machinery and technologies usable in the development of missiles and other military systems, as well as commercial systems. This category also includes complete rocket or UAV systems (defined under the regime to include cruise missiles, and target and reconnaissance drones) capable of "a maximum range equal or superior to 300 kilometers," regardless of payload. An MTCR member may export Category II items if it has determined that the items are not useable in a missile for NBC delivery or an item covered under the first category.[85]

The MTCR is not a treaty, nor does it have an associated enforcement agency. It is merely an agreement to abide unilaterally by the export restrictions. Therefore, the regime is vulnerable to conflicting national interpretations by each member nation. The accord makes no provision for penalizing countries that violate its guidelines, but individual members can—and have—imposed sanctions on violators unilaterally.[86]

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[84] Ibid.

[85] Ibid.

[86] *Nonproliferation Regimes; Policies to Control the Spread of Nuclear, Chemical, and Biological Weapons and Missiles*, (Washington D.C.: Government Printing Office, 1993), 46. The termination of the Argentine-Egyptian-Iraqi *Condor* II program, intended to produce a clone of the U.S. *Pershing* II ballistic

The dangers of ballistic missile proliferation have been analyzed extensively. It is now widely accepted that the spread of such weapons should be limited. Unfortunately, the potential dangers of cruise missile proliferation continue to receive less attention than the ballistic missile problem. The MTCR has been successful in constraining the spread of the most sophisticated ballistic missile related technology. The MTCR explicitly identifies cruise missiles and related technologies as a target of the regime. However, problems have arisen when dealing with “dual-use” technologies, especially those related to possible cruise missile use. The keys to the success of this regime are the members. With their active support, the MTCR will likely be able to curtail, but not stop, the proliferation of cruise missile technology. The dual use problem and the willingness of non-members (and in some cases members) to interpret the provisions of the agreement liberally will continue to result in at least limited proliferation of key LACM enabling technologies.[87]

The Future

Will Third World countries seek cruise missiles in the early part of the next century as they did ballistic missiles in the 1980's and 1990’s? It is difficult to tell what lessons developing countries drew from the Gulf War. The effectiveness of U.S. land-attack cruise missiles and the ineffectiveness of Iraqi ballistic missiles in Desert Shield/Desert

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missile; and the cancellation of South Africa’s ballistic missile /space launch program are two examples of the MTCR’s success. Other ballistic missile programs have suffered multi-year time slippages as a result of MTCR export controls. Jones and McDonough, 313

[87] Carus, 46. Carus states that cruise missile technology has received little attention, even when it poses a tangible threat. For example, United Nations Security Council Resolution 687, which requires Iraq to eliminate its unconventional weapons programs, contains provisions calling for the destruction of all Iraqi <u>ballistic</u> missiles with a range of 80 nm or more. Although UN investigators were until recently keeping a close watch on Iraq's ballistic missile programs, no one appears very knowledgeable about the status of Iraq's long-range cruise missile; the *Ababil*.

Storm may affect attitudes concerning the relative value of ballistic missiles and cruise missiles, and encourage countries to pursue LACM capabilities more actively. It is not yet clear whether this evaluation has caused developing countries to embark on LACM programs. Experience suggests, however, that if those countries decide LACMs contribute significantly to their security and prestige, they will likely make every effort to acquire them.[88]

The spread of ASCMs in the developing world during the 1970s and 1980s provides some important insights regarding the prospects for LACM proliferation. First, despite the high cost of ASCMs, many developing countries believed these weapons had great military utility. Despite the evident complexity of ASCMs, several developing countries have produced versions either developed indigenously or based on foreign designs. This suggests that it also may be possible for number of these countries to manufacture LACMs. Given their heavy investment in ballistic missiles, it is likely that the potential cost of acquiring LACMs will not prevent proliferation. Rather, the perceived utility of these weapons will be the critical factor in any acquisition decision.[89]

In the next decade, several countries will probably start production, and possibly export, of LACMs currently in development. The majority of these missiles will have the potential to perform precision-strike missions. Many will have similar features: a modular design allowing them to be manufactured with a choice of navigational suites and warhead options; the incorporation of stealth technology and self-protection systems; and the capability to fly high-subsonic, low-altitude, terrain following flight profiles. Even

[88] Carus, 31-32.

[89] Carus, 46.

more difficult to detect and intercept than current weapons, these LACMs may be fielded by potential enemies as early as 2005-2015.[90]

[90] "Army Air Defense Master Plan, The Threat: Evolution and Future Trends", *Air Defense Artillery Journal*, April-May 1997, 20-21. See also NAIC, 19.

Chapter 4

Countering the Threat - Two Case Studies

This chapter examines two historical examples of countering theater missile threats: Operation Crossbow, the Allied campaign against German V-weapons; and the Desert Storm operations against Iraqi *Scud*s. In both cases, the enemy missiles and their infrastructure were attacked, with varying degrees of success, before they were employed extensively. In the next conflict, theater missiles could attack first, with the objective of limiting U.S., allied, or coalition responses. These case studies underscore the inherent difficulty of countering theater missile threats, and highlight some of the doctrinal and technological aspects to consider when facing them.

World War II: Operation Crossbow

The Allied operation to defeat German V-weapons (V-1 land attack cruise missiles and V-2 ballistic missiles), Operation Crossbow, lasted from late 1943 through the summer of 1944. Militarily it was not clear exactly what objective the Germans hoped to achieve with the V-weapons. Hitler originally set the end of December 1943 as the target date for the start of the V-1 and V-2 terror campaign; however, technical problems delayed it until the Allied D-Day. In General Eisenhower's view had the attacks begun sooner and attacked different targets, they might have had a significant influence on Allied invasion plans and forces,

> It seemed likely that, if the German had succeeded in perfecting and using these new weapons six months earlier than he did, our invasion of Europe would have been exceedingly difficult, perhaps impossible ... if he had

> made the Portsmouth-Southampton area one of his principal targets, OVERLORD might have been written off. [91]

Though the Allies were aware of the V-weapon threat through a wide variety of intelligence sources, bureaucratic wrangling among the Allies hindered effective command and control of the operation well into 1944, when a joint Crossbow committee was established to resolve the contentious issues. These issues included "inadequate dissemination of intelligence, " "misapplication of forces," and "lag over damage assessment…[which] resulted in unnecessary duplication of attack and wasteful bombing effort."[92] Although the Allies targeted and destroyed many permanent launch, storage, support and production sites, the Germans were able to continue their operations. Newly constructed launch sites were protected by extensive camouflage, concealment, and deception techniques, allowing the Germans to launch approximately 15,500 V-1 and V-2 missiles between June 1944 and March 1945.[93]

These attacks caused domestic political concerns for British Prime Minister Winston Churchill. Initial intelligence reports that the Germans were working on missiles designed to deliver weapons of mass destruction against the U.K., triggered questions about the potential effects such terror weapons could have on national morale and the overall war effort.

The Allies increased their efforts to develop and implement both offensive and defensive countermeasures. These included strategic attacks on the V-weapon launch sites, storage, and production facilities; development of new fighter tactics to intercept and shoot down V-1s in flight; and deployment of barrage balloons and anti-aircraft artillery (AAA) along

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[91] Dwight D. Eisenhower, *Crusade in Europe* (New York: Doubleday, 1948), 260.

[92] John F. Kreis, et al.,eds., *Piercing the Fog: Intelligence and Army Air Force Operations in World War II*, (Washington, D.C.: Air Force History and Museums Programs, 1996), 216-224.

known V-1 ingress corridors to shoot down any missiles that made it past the fighters. The political concerns became so great that Eisenhower directed that Crossbow take priority over all other Allied air operations, including those in support of the Normandy invasion and the Combined Bomber Offensive.[94]

At the height of the V-1 attacks, some 22 fighter squadrons including RAF Mustangs, Tempests, and Meteor jets, 2,000 barrage balloons, and 400 anti-aircraft artillery batteries (upgraded with new radars and proximity-fuzed shells), were tasked to defend against the V-1s.[95] When the Allied armies finally overran the launch sites in France, the Germans turned to air launching V-1s from bombers; later, newer long-range V-1s were launched from the Netherlands until those sites were also captured.[96]

Crossbow consumed 40 percent of all reconnaissance sorties after 1943.[97] In the course of the campaign British and American photoreconaissance completely blanketed a 7,500 square-mile portion of western France four times, photographed more than 100 selected locations weekly, overflew the German missile research and development facility at Peenemünde on the Baltic coast 50 times, and took over 1,250,000 photographs.[98]

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[93] Warrell, 60-61.

[94] In a top secret letter to his deputy Air Chief Marshal Sir Arthur Tedder on 18 June 1944, General Eisenhower repeated his order, issued verbally earlier in the day, to make *Crossbow* targets first priority. Alfred D. Chandler, Jr., ed., *The Papers of Dwight David Eisenhower, The War Years: III*, (Baltimore, MD: The Johns Hopkins Press 1970), 1933. James McGovern, *Crossbow and Overcast* (New York, NY; William Morrow & Co., Inc., 1964) 57.

[95] Jozef Garlinski, *Hitler's Last Weapons* (New York: Time Books, 1978), 162. Alan J. Levine, *The Strategic Bombing of Germany, 1940-1945,* (Westport, CT.: Praeger Publishers, 1992), 138.

[96] Levine, 138.

[97] *United States Strategic Bombing Survey (USSBS)*, vol. 60, "V-Weapon (Crossbow) Campaign," (Washington, D.C.: Military Analysis Division, 1945), 26-27.

[98] John F. Kreis, general editor, et al., *Piercing the Fog: Intelligence and Army Air Force Operations in World War II*, (Washington, D.C.: Air Force History and Museums Programs, 1996), 216.

Between August 1943 and April 1945, the U.S. Army Air Forces (AAF) and the Royal Air Force (RAF) together flew almost 69,000 sorties and dropped over 120,000 tons of ordnance in their efforts to destroy the German missile capability.[99] Crossbow consumed 14 percent of all allied strategic bombing sorties and 16 percent of the total tonnage. Tactical air assets devoted 17 percent of total sortie generation and 13 percent of total tonnage to Crossbow.[100]

The objectives of Crossbow were to delay the beginning of the German missile attacks, and to limit their intensity once they began. The British approach focused on missile launch sites, while the Americans targeted the supporting infrastructure, including support and production facilities, and the electric power grids that supported those facilities.[101]

The United States Strategic Bombing Survey concluded that while the air attacks against the V-1s imposed considerable costs on the Allies, they were effective in slowing down the German efforts. However, a British wartime study concluded that the cost ratio of Allied versus German expenses associated with the V-1 were around 3.8:1 in favor of the Germans.[102] Although it cost Germany less to produce and operate the V-weapons than it cost the Allies to counter them, the Allies could afford the cost, but Germany could not.

Overall, while the air attacks did delay the introduction of the V-weapons, they did not seriously hinder or halt launch operations once initiated.[103] Postwar analysis shows that the greatest influence on German efforts came from the indirect effects that bombing had

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[99] *USSBS*, vol. 60, 26-27.

[100] Ibid., 25-29.

[101] Kreis, et al., 221-223.

[102] USSBS, 23.

[103] Ibid., 22.

on disrupting V-weapon production and distribution.[104] Eliminating the threat required ground forces to seize the launch sites.

Scud Hunting - Operation Desert Storm, 1991

Almost 50 years after Operation Crossbow, U.S. forces were again tasked with the difficult mission of countering a theater missile threat. Although the missiles in this case were Iraqi theater *ballistic* missiles, operations to counter them are representative of the difficulties associated with finding, fixing, targeting, and destroying mobile missiles even with more modern sensor and weapons technology.

Within 24 hours after the beginning of Operation Desert Storm, Iraq launched the first of 88 *Scud* missiles against Saudi Arabia and Israel.[105] Just as in Operation Crossbow, political considerations drove the coalition to divert resources to counter the threat.

The technical aspects of the Iraqi missile threat were fairly well understood by the U.S. intelligence community before the war. Although some prewar technical estimates were not completely accurate, the general capabilities of the Iraqi missile program were documented. Iraqi missile employment during the Iran–Iraq war had been closely observed by the U.S. intelligence agencies and other outside observers. [106]

Before Desert Storm, Iraq had three variants of the mobile Scud missile in its inventory: the Soviet supplied SS-1 *Scud* (160 mile range), and two indigenously developed variants, the *Al-Husayn* (325 mile range) and *the Al-Hijarah* (400 mile range). All were

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[104] Ibid., 3.

[105] *Gulf War Airpower Survey (GWAPS) Report*: Summary Report (Washington, D.C.: Government Printing Office, 1993), 87.

[106] See Anthony Cordesman and Abraham Wagner's *The Lessons of Modern War, vol. 2, The Iran-Iraq War* (San Francisco: Westview Press, 1990) for a good discussion of Scud operations by both sides during that conflict.

relatively inaccurate weapons and could only be used to strike large area targets such as cities.[107]

The total number of missiles available to the Iraqis was unknown, however, the Defense Intelligence Agency estimated that the Soviet Union had delivered at least 600 missiles. Postwar information raised this number to 800, many of which were used to build the indigenous longer-range variants.[108]

To improve their capability to strike targets in Israel, Iraq built five fixed launch complexes, with 28 launch positions, in its western desert near the Jordanian border. These complexes put the 325-mile-range *Al-Husayn* missile within range of all major Israeli cities, and its nuclear facilities in the Negev desert. The existence of these sites led planners to believe that their elimination would reduce the threat. This view discounted the threat's mobility, which was demonstrated during Iraq's war with Iran.[109]

Based on Soviet and other Middle Eastern models, intelligence assessments stated that the Iraqis would (1) disperse their missile force from garrison, (2) minimize their exposure during movements, and (3) launch from concealed locations, using weather and darkness to reduce their vulnerability to detection and attack.[110]

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[107] *GWAPS*, vol. II, pt. 2, "Effects and Effectiveness", 317-319.

[108] According to the *Gulf War Airpower Survey* , Vol. II, pt. 2, "Effects and Effectiveness" (Washington, D.C., 1993) 321, roughly three Soviet Scud-B airframes were required to make Iraqi extended-range variants. After the war, the U.N. Special Commission (UNSCOM) team tasked to eliminate Iraqi WMD and ballistic missile programs verified the destruction of around 140 missiles. Together the missiles destroyed by UNSCOM, those shot during the Iran-Iraq war and Desert Storm, and those cannibalized to construct extended range variants, account for approximately 570-640 airframes. Due to the uncertainty of how many Iraq originally received, there is some speculation that Iraq may still possess some 100-200 Scud–B airframes.

[109] Michael Gordon and Bernard Trainor, *The General's War: The Inside Story of the Conflict in the Gulf* (New York: Little, Brown, and Company, 1995), 230.

[110] Air Force Historical Research Agency (AFHRA), Gulf War Collection, CIS-37-CIS-44.

The fixed sites may have been part of an elaborate deception plan. Although the fixed, pre-surveyed sites may have provided a margin of increased accuracy, the *Scud*s were an area weapon, and the additional accuracy margin may not have offered very much benefit, especially when considering the trade-offs of operating from known, easily identifiable locations. The Iraqis made use of other forms of deception as well, including using high-fidelity launcher mock-ups to deceive Coalition sensors (intelligence collection assets and analysts) and shooters, practicing radio silence and other emission control (EMCON) techniques, and employing shoot-and-scoot tactics.[111]

Coalition leaders were blindsided by the amount of political pressure the *Scud* attack caused. Many of them later admitted that they underestimated the *Scud'*s influence because of its inaccuracy and small warhead. General Schwarzkopf, Commander in Chief Central Command (CINCCENT) viewed the missiles as "militarily irrelevant," and his joint force air component commander, (JFACC) Lieutenant General Charles Horner, thought the missiles were "lousy weapons."[112] Washington thought otherwise.

In August 1990, President George Bush specified among the U.S. national objectives for the coming conflict "Security and safety of Saudi Arabia and the Persian Gulf." Implied was the destruction of Iraqi ballistic missiles and any program to mate them with weapons of mass destruction (WMD) warheads.[113] General Schwarzkopf in turn identified destruction of Iraqi ballistic missiles and nuclear, biological and chemical (NBC) capability as early as possible as an operational objective.[114] General

[111] Gordon and Trainor, 234.

[112] Ibid., 228-233.

[113] DoD, *Conduct of the Persian Gulf War: Final Report to Congress*, 73.

[114] DoD, *Conduct of the Persian Gulf War: Final Report to Congress, 73*.

Schwarzkopf relied on airpower, under the direction of General Horner, to achieve this objective.

General Horner envisioned three counter *Scud* objectives, which further refined CINCCENT's objectives to (1) keep Israel out of the war, (2) destroy Iraq's *Scud*-associated production facilities, and (3) find and destroy Iraqi *Scud* TELs that threatened the Arabian Peninsula. Destruction of the following target sets was intended to reduce the Iraqi threat to the region:

- Fixed *Scud* launchers.
- Ballistic missile support infrastructure.
- Known surveyed launch sites.
- Hardened aircraft shelters possibly hiding mobile launchers.
- Missile-associated research, development, and production facilities.[115]

Since they were "nuisance weapons," the list did not include mobile launchers.[116]. The theater commanders and their staffs recognized that targeting *Scuds* would be difficult, and that despite their best efforts some missiles would fly.[117] Reflecting the views of their leadership, planners believed the best strategy was for the coalition and Israel to absorb the attacks. In their view, to attempt to locate and destroy mobile TELs was sortie intensive and counterproductive.[118] Consequently, no strategies for finding and attacking mobile *Scud*s were developed or exercised before the war began.[119]

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[115] *GWAPS*, vol. 1, part.1, "Planning," 165-66.

[116] *GWAPS* "Summary Report," 43.

[117] *GWAPS*, "Planning," 166.

[118] AFHRA, Gulf War Collection, CENTCOM/CENTAF briefing to CJCS, 17 August 1990.

[119] *GWAPS*, "Summary Report," 43.

However, following the first *Scud* launches against Israel, Washington grew concerned about the implications of Israel entering the war, and increased pressure on General Schwarzkopf to redirect forces to stop, or at least suppress, the missile launches.[120] The counter-*Scud* effort rapidly expanded. The diversion of attack assets and C^4I bandwidth was greater than expected, eventually involving the daily sortie-generation equivalent of an entire fighter wing.[121]

> The *Scud* hunt included continuous airborne surveillance of western and southern regions of Iraq, positioning strike aircraft within *Scud* launch areas for more immediate targeting, attacks on communications links thought to be transmitting *Scud* launch authorization, attacks on suspected sites, and strikes against *Scud* production and storage facilities. By war's end nearly every type of strike and reconnaissance aircraft employed in the war participated in the attempt to bring this threat under control, but with scant evidence of success.[122]

Scud-related targets used up at least 1,460 sorties. Half were directed against fixed launch sites and other locations, such as aircraft shelters and highway overpasses, suspected of hiding *Scud* TELs. Of the remaining sorties, 30 percent attacked infrastructure or production facilities, with only 15 percent conducted against suspected TELs.[123] U.S. and British special operations forces played an important role in the latter effort, by providing vital targeting information on suspected *Scud* activity. However, despite some 80 post-mission debriefs claiming *Scud* "kills", review of all available

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[120] Gordon and Trainor, 230.

[121] James Coyne, *Air Power in the Gulf* (Arlington, VA: Air Force Association, 1992), 55.

[122] Eliot A. Cohen and Thomas A. Keaney, *Revolution in Warfare? Airpower in the Persian Gulf War* (Annapolis, MD: Naval Institute Press, 1995), 14-15.

[123] *GWAPS*, vol. II, part. 2, "Effects and Effectiveness," 331-332.

information indicates not a single *Scud* was confirmed destroyed from the air before launch.[124]

This should not have come as a surprise. In late 1990, an exploitation effort named "Project Touted Gleem" was conducted using an actual *Scud*-B TEL. During the exploitation, various strike aircraft flew missions against the TEL to determine their abilities to find and attack it. The results were not encouraging, suggesting that the TEL would be difficult for aircrews to find during the day, and even harder to find at night with forward-looking infrared (FLIR) sensors.[125]

However, air operations were not the only means used to counter the Iraqi missile threat. The difficulties in hunting *Scud*s from the air were only part of the problem. Ground-based air defenses, in the form of Patriot surface-to-air missiles, were an integral part of the overlapping air and missile defense capability deployed in the theater during Desert Shield. The Patriots were designed to defend point targets such as airfields and ports, not entire cities. They suffered mixed results in fending off the *Scud* attacks; in many cases intercepting Patriots deflected the incoming *Scud*s, leaving the warheads and debris to rain down on Israeli and Saudi cities.[126]

The *Scud*s were not only a political threat to the coalition; they also posed a danger to coalition forces. On 16 February 1991, a *Scud* impacted within yards of an ammunition pier berthing seven ships, including the USS *Tarawa* unloading its AV-8B *Harriers*, at

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[124] David Eshel, "Ballisitic Missile Defense: In Search of an Effective Defense." *Jane's Defence Weekly*, Vol. 31, , Issue no. 10 (10 March 1999): 71. *GWAPS*, "Effects and Effectiveness," 340. *GWAPS*, "Summary Report", 65, 83. Gordon and Trainor, 227.

[125] GWAPS, Effects and Effectiveness, 335.

[126] Gordon and Trainor, 239.

Al Jubayl, Saudi Arabia.[127] On 25 February, a *Scud* hit an U.S. barracks in Al Khobar, a Dhahran suburb, killing 28 troops and wounding 98 others -- the largest single American casualty toll in the war.[128] According to an internal Army report the risk of even more substantial casualties was greater than generally realized. The similarities between the crowded ports and staging facilities in the U.K. before D-Day, and the crowded camps near Ad Damman and Al Jubail, Saudi Arabia during Desert Storm were striking.

> On the day the war started there were roughly 35,000 soldiers in camp…had the enemy possessed the capabilities or the will to attack the camps with intensity, the very nature of the deployment could have changed to that of a national disaster.[129]

The effectiveness of Coalition counter-*Scud* efforts remains debatable; however, one of the outgrowths of Desert Storm was an increased worldwide focus on improving capabilities to counter mobile missile threats.

Conclusions

The two case studies discussed above highlight the difficulties of effectively countering different aspects of a mobile theater missile threat. *Crossbow* operations against the V-1s were designed to counter relatively primitive cruise missiles, launched mostly from fixed (although well-camouflaged) launch sites, flying predictable flight profiles to known target areas against overlapping defense assets arrayed in depth. Even with the bombing efforts directed against the launch, support and production facilities on the continent, and the U.K.'s overlapping defenses, some missiles managed to penetrate to their target.

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[127] Commander Charles C. Swicker, *Theater Ballistic Missile Defense from the Sea: Issues for the Maritime Component Commander*, Newport Paper Number Fourteen, August 1998, on-line, Internet, 10 May 1999, available from http://www.nwc.navy.mil/press/npapers/np14/np14toc.htm.

[128] Gordon and Trainor, 239.

[129] "VII Corps Debarkation and Onward Movement," *1st Infantry Division (Forward) Desert Shield/Storm After Action Report*, 30 May 1991, in Gordon and Trainor, 240.

During Desert Storm, coalition forces again faced a mobile (in this case only ballistic) missile threat, however; in that case, it was a multi-axis threat against widely separated geographic areas.

The objectives in both cases were to find and attack concealed or mobile missile launch capabilities before the enemy could launch the weapons, and if the weapons were launched, to intercept them prior to them reaching their targets.

Some general conclusions drawn from these case studies are: (1) Planning requires comprehensive intelligence on the entire enemy missile system; (2) Effective attacks against small, mobile targets require real-time reconnaissance support; (3) Attacking an enemy's missile infrastructure can be effective as a long-term strategy, but will likely not have an immediate impact; and (4) Political pressure can (and will) directly determine resource allocation.[130]

Countering mobile missile threats is not a new challenge. As these two case studies show, many of the aspects of countering such threats today are not new. To prevent having to relearn them, lessons from previous experiences should be codified in doctrine and passed on. The next chapter provides an overview of U.S. Joint and service doctrine for countering theater air and missile threats (since cruise missiles incorporate characteristics of both) to determine if the lessons have been passed on.

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[130] Lieutenant Colonel Mark Kipphut, "Theater Missile Defense Reflections for the Future," *Airpower Journal*, vol. X (Winter 1996): 40. See also Robin Ranger, "Theater Missile Defenses: Lessons Learned from British Experiences with Air and Missile Defenses," 407-409.

Chapter 5

Visions and Doctrine

Too often vision has outrun reality and resulted in disappointment and reaction.

Robin Higham[131]

This chapter begins with a general discussion of the role joint and service visions and doctrine play in theater air and missile defense. Next, because of their importance in describing what the services think and do, several key terms and concepts are defined. Then service JTAMD-related doctrine is examined to determine if and how the services plan to counter the LACM threat, and why they want to do it their way. Finally, a look at joint doctrine will determine whether the combination of joint and service doctrine presents adequate answers to the Joint Force Commander faced with countering a land attack cruise missile threat.

Full-dimensional protection

Joint Vision 2010 states that protection of U.S. forces and facilities must be provided across the spectrum, from peacetime to crisis and at all levels of conflict. Development and deployment of a multi-tiered theater missile defense architecture, combined with offensive capabilities to neutralize any systems before and immediately after launch, will

[131] Air Vice Marshal Tony Mason, *Air Power: A Centennial Appraisal* (London, U.K.: Brassey's Inc., 1994), xv.

be critical to maintaining freedom of action -- freedom from attack and freedom to attack.[132]

The U.S. military services pursue competing visions of war. Each vision is advocated by a service, and emphasizes the importance of its primary medium (air, land, or sea) or mission. The services then develop the doctrine and forces required to execute these visions. For example, the Air Force believes the control and exploitation of air and space provide the key to success. Its doctrine and acquisition priorities stress air forces capable of achieving this control and exploitation through independent actions. The Army focuses on the successful execution of a decisive land campaign. The Navy and Marine Corps stress maneuver from the sea, and their new doctrine emphasizes littoral warfare and power projection. These visions can have a profound effect on the way the military carries out national security policy. To reconcile the services' sometimes clashing views, joint doctrine attempts to integrate them into a unified vision of joint warfare.

Service visions, and their approach to joint operations, affect joint warfare by influencing the service doctrine and forces that provide the building blocks for joint operations. Doctrine is intended to provide records of what organizations believe are the best ways to accomplish their missions and objectives.

> Military doctrine presents fundamental principles that guide the employment of forces. *Doctrine is authoritative and provides the distilled insights and wisdom gained from our collective experience with warfare…*Though neither policy nor strategy, joint doctrine deals with the fundamental issue of *how best to employ the national military power to achieve strategic ends***.**[133] [Emphasis added]

[132] *Joint Vision 2010*, 22-23. See also Cohen, *Annual Report to the President and the Congress, 1999*. 124.

[133] Joint Pub 1, vi.

Definitions and Terminology

Definitions play an important part in joint and service doctrine. They provide a common language, not only for debate and discussion, but also for military action. Rapid communication is essential to countering an air or missile threat. Without joint terminology and the common reference it provides, it would be extremely difficult to bridge the gaps between service and joint theater air and missile defense doctrine, tactics, training, and procedures.

Air Superiority or Air Supremacy. The JCS definition of *air superiority* is: "that degree of dominance in the air battle of one force over another which permits the conduct of operations by the former and its related land, sea, and air forces at any given time and place without prohibitive interference by the opposing force."[134] Although the enemy can still resist, air superiority provides the freedom of action that allows the JFC to operate air, land, and sea forces when and where he chooses. *Air supremacy* is defined as: "that degree of air superiority wherein the opposing airforce is incapable of effective interference." With air supremacy, friendly forces are free to operate without fear of air attack.[135]

Both definitions relate air effectiveness to the friendly forces' ability to operate, and only discuss opposing air operations in terms of the enemy forces ability, or inability to interfere with friendly operations. With air superiority, the enemy may still be able to oppose friendly air operations in limited areas, at limited times, or in limited quantities. With air supremacy, enemy air operations are not a factor in friendly operations. While air supremacy is obviously the more desirable condition, in the context of LACMs, with

[134] Joint Pub 1-02, 23.

large numbers of low RCS cruise missiles ingressing from multiple attack axes, achieving air supremacy may not be a realistic expectation.

Counter Air is an U.S. Air Force term for air operations conducted to attain and maintain a desired degree of air superiority by the destruction or neutralization of enemy forces. *Both offensive counterair (OCA) and defensive counterair (DCA) actions are involved.* The former range throughout enemy territory - generally at the initiative of the friendly forces. The latter are conducted near or over friendly territory, and generally react to the actions of enemy air forces.[136]

Antiair and Strike Warfare. Naval counterair doctrine, based on the Composite Warfare Commander (CWC) concept, has its own unique lexicon and service-specific procedures. The U.S. Navy and Marine Corps use the a*ntiair* and s*trike warfare* terms for defensive and offensive counterair, respectively. *Antiair* warfare is "those actions required to destroy or reduce to an acceptable level the enemy air and missile threat."[137] It includes such measures as the use of interceptors, bombers, antiaircraft guns, surface-to-air and air-to-air missiles, electronic attack, and destruction of the air or missile threat both before and after it launches. The Naval Services' s*trike warfare* is not defined in joint terminology, but includes operations conducted against enemy air assets and air defense systems before they launch or attack. Strike operations include TMD attack operations.[138]

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[135] Ibid.

[136] Ibid., 110.

[137] Ibid., 49.

[138] See *Naval Warfare Publication (NWP) 10-1, Composite Warfare*, and *Fleet Marine Force Manual (FMFM) 5-50, Antiair Warfare* for further details.

Theater Missiles and Theater Missile Defense (TMD). The Joint Chiefs of Staff (JCS) define theater missiles (TMs) as: "ballistic missiles, cruise missiles and air-to-surface missiles whose targets are within a given theater of operations…Of primary concern are the increasingly accurate ballistic and cruise missiles armed with conventional and WMD warheads"[139] Theater missile defense (TMD) is defined as:

> The identification, integration, and employment of forces supported by other theater and national capabilities to detect, identify, locate, track, minimize the effects of, and/or destroy enemy TMs. This includes the destruction of TMs *on the ground and in flight*, their ground-based launchers and supporting infrastructure; TM-capable ships and vessels in port or at sea; and enemy aircraft armed with the air-to-surface missiles. TMD operations are accomplished by integrating a mix of mutually supportive passive defense, active defense, attack operations and C4I measures." (Emphasis added)[140]

The definition of "*Joint TMD*" adds the concept of integrating joint force capabilities through a mix of mutually supportive means. For the purposes of this study, *cruise missile defense (CMD)* is a subset of TMD.

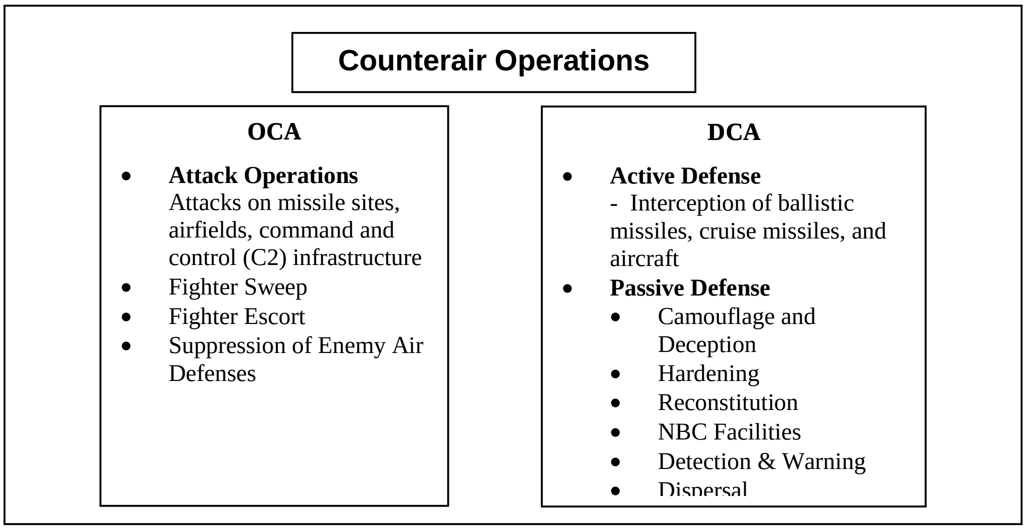
Overview of Counterair operations

The objectives of counter air operations are to facilitate friendly operations against the enemy, and protect friendly forces and vital assets by obtaining air superiority. Air superiority prevents adversaries from interfering with friendly air, space, or surface force operations, and helps assure their freedom of action and movement. Successfully

[139] *Joint Pub 3-01.5,* I-2. Short range, non-nuclear, direct fire missiles, bombs, and rockets such as Maverick or wire-guided missiles are not considered "theater missiles" for the purposes of this Joint Pub.

[140] Ibid. This joint definition is one example of the root causes of service debates about who should be in charge of TMD. Since all the services have a capability to conduct offensive and defensive operations against some aspect of the TMD threat, particularly cruise missiles, how does the Joint Force commander determine who should be the supported component for TMD? The controversy surrounding

countering air and missile threats is an inherent part of achieving air superiority. Counterair can be viewed in two broad categories: O*ffensive Counterair (OCA), attack operations* intended to destroy enemy weapons prior to launch; and D*efensive Counterair (DCA),* which includes *active defense* to intercept threats once airborne; and *passive defense,* designed to reduce the effectiveness of enemy attacks (fig. 1).[141]



Source: Joint Pub 3-01,Joint Doctrine for Countering Air and Missile Threats, Final Coordination Draft, 3 June 1997, vi.

Figure 1. The Counterair Framework

Offensive Counterair (OCA). OCA operations seek to dominate the enemy's airspace. OCA consists of offensive measures to destroy, disrupt, or neutralize enemy aircraft, missiles, launchers, and their supporting infrastructures and systems, preferably before launch.[142]

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the Joint Forces Air Component Commander and Area Air Defense Commander are just two of the ongoing debates.

[141] Joint Pub 3-01, v-vi.

[142] Joint Pub 3-01, vi.

Defensive Counterair (DCA). DCA operations protect friendly forces and ensure freedom of action by intercepting enemy aircraft (manned or unmanned), ballistic missiles, and cruise missiles. DCA includes all measures designed to detect, identify, intercept, and destroy or negate any threats attempting to attack or penetrate the friendly air environment. DCA uses both active and passive methods to protect forces and vital interests.[143] DCA operations normally revolve around the concept of defense-in-depth, with multiple systems employed in sequence to thin the threats out progressively.

Doctrine for Joint Theater Air and Missile Defense (JTAMD)

The keystone publication of the joint doctrine series, Joint Pub 1: *Joint Warfighting*, can be best summarized as "joint warfare is team warfare." It emphasizes the benefits of teamwork between the services and provides examples of the contributions of each service component to the joint team. There are two general views of how best to accomplish this teamwork.

In the first view, each service provides unique capabilities aligned with its service vision, but the capabilities may overlap between forces. In this case, joint commanders choose what specific capability they need to meet their objectives, and designate a single service component to lead in the execution of that mission. The other services provide support as required. This approach requires minimum joint coordination or training. However, it may encourage the services to pursue independent operations for independent objectives, forfeiting the potential cost and effectiveness benefits of synergistic operations.

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[143] Ibid. vi.

The second view stresses the synergy of integrated operations. Joint commanders identify required capabilities, and each service provides the appropriate elements from its forces. These service forces are then combined to produce the desired effects. This joint approach's intent is to ensure unity of effort and the coordination of forces toward common goals. However, problems may arise when this approach goes too far, that is, when the desire to include each service in the "team" becomes more important than choosing the best solution. In such cases, combat effectiveness may decrease.

Ideally, joint doctrine should describe how the services work together by providing general guidance for joint military operations. However, it often falls short of this ideal, the result of service-unique views and concepts being brought together and consolidated (or watered down) before being packaged in compromise solutions. These compromises are driven by the fact that joint doctrine guidance is considered authoritative, and to be followed "except when, in the judgement of the commander, exceptional circumstances dictate otherwise."[144] If conflicts arise between joint and service doctrine, joint doctrine has precedence.

Joint Pub 3-0, *Doctrine for Joint Operations*, is the keystone document of the joint operations series, and "offers a common perspective from which to plan and operate… It provides the bases that guide the employment of the joint air, land, sea, and space team. "[145] It provides a broad description of counter air missions. Subordinate publications provide guidance for specific mission areas. Joint Pub 3-01, *Joint Doctrine for Countering Air and Missile Threats* is the primary document outlining joint strategy for counter air operations. Joint Pub 3-01.5 addresses joint theater missile defense doctrine,

[144] Joint Pub 3-0, *Doctrine for Joint Operations*, 1993, i.

[145] Ibid., v, and cover letter from CJCS.

and Joint Pub 3-01.6, not yet published, will discuss doctrine for joint air defense operations. These subordinate publications provide an organizational model for theater forces, and general guidelines, but little specific guidance.

Joint Pub 3-01.5 acknowledges that proliferation of and advances in missile and associated technologies, coupled with the pursuit of weapons of mass destruction (WMD) capabilities, are expected to increase and can provide adversaries with potentially decisive attack capability. It highlights the notion that theater missiles may be political weapons as much as military weapons.[146] Joint Pub 3-01.5 also emphasizes that land-attack cruise missiles present a different challenge from ballistic missiles.[147]

The purpose of joint theater missile defense (JTMD) is to counter the missile threat by coordinating and integrating the same four operational elements associated with theater counterair operations: *passive defense*, *active defense*, *attack operations*, and *command control communications computers and intelligence* (C^4I) into cohesive and coherent TMD operations. JP 3-01.5 which, judging by its title, should describe theater missile *defense* operations, not only includes a*ttack operations* as one of its four operational elements, but also states "the preferred method of countering enemy TM operations is to attack and destroy or disrupt TMs prior to their launch."[148]

The TM threat may appear across the range of military operations, so a robust combination of friendly active defense and attack operations is required to defeat it; TMD is inherently a joint mission. The nature and extent of U.S. global interests require that theater missile defense (TMD) forces be rapidly deployable or employable from the

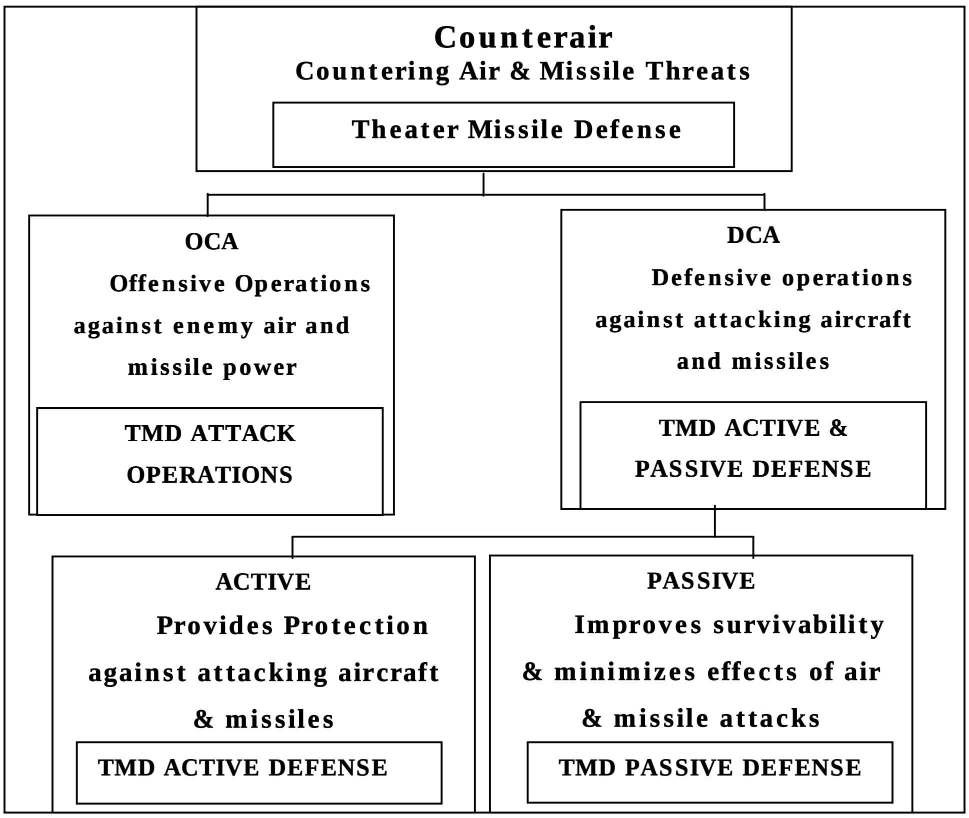
[146] Joint Pub 3-01.5, vii.

[147] Ibid., III-8.

[148] Joint Pub 3-01.5, xi.

United States, forward bases, and/or ships, and must be integrated into all phases of the operation and mission areas from the beginning.[149]

TMD systems, therefore, should build on existing systems and doctrine and, when appropriate, incorporate the newest technologies and concepts. All TMD systems must be able to integrate with the existing command and control (C^2) architecture.[150]



Sources: Joint Pub 3-01,vi. and Joint Pub 3-01.5, I-4.

Figure 2. How Counterair and TMD fit together

The Joint Force Commander (JFC) must define and implement a methodology and establish guidance and objectives for JTMD. Examples of what the guidance should include are shown in table 2.

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[149] Ibid., vii.

Table 2. JFC Joint Theater Missile Defense Guidance

Joint Force Commander - Joint Theater Missile Defense Guidance	
Methodology for JTMD planning	Definition of the areas of operations of components
Priority of the JTMD effort. What targets are most important for attack operations. What friendly assets must be protected by active defense	Apportionment and capabilities/forces made available to functional components
Guidance on component-to-component coordination to facilitate deconfliction and timely TMD operations	The role of the joint force commander's staff in coordinating JTMD activities

Source: Joint Pub 3-01, II-1.

The JFC's concept of operations specifies the desired objectives and provides guidance for the employment of C^4I, attack operations, and active and passive defense.[151] To facilitate the integrated operation of all components' TAMD weapon systems, the JFC will normally assign overall air defense responsibility to an Area Air Defense Commander (AADC). According to joint doctrine, authority to integrate air defense forces and operations in overseas land areas will be delegated to the AADC. Ideally, the AADC will also be the Airspace Control Authority (ACA). If the JFC establishes a joint force air component commander (JFACC), he may also assign AADC responsibilities (see table 3) to the JFACC.[152]

[150] Ibid., vii.

[151] Joint Pub 3-01.5, II-1.

[152] Ibid., II-5. Also see Joint Pub 3-52, *Doctrine for Joint Airspace Control in the Combat Zone,* and the Joint Pub 3-01 series for more guidance on the AADC.

Table 3. Area Air Defense Commander Responsibilities

AADC responsibilities	
Develop friendly active defense capability database.	Develop and execute plans for launch warning information dissemination to all components, allies, and host nation civil authorities.
Develop and execute detailed plans, including weapon control procedures and measures, to disseminate launch warning and cue information to components and active defense forces for engaging incoming TMs.	Ensure, through organization and application of appropriate procedures, that the optimum effectiveness is realized from each of the various active defense weapon systems and that no unnecessary restrictions are placed on their employment.
Develop and execute plans for JTMD active defense operations.	

Source: Joint Pub 3-01, II-5, II-6.

The JFC will normally assign responsibility for the planning and execution of JTMD attack operations outside the other component commanders' areas of operation (AOs) to the Joint Force Air Component Commander (JFACC). Since the location of these AOs may change with the movement of forces or with changes in JFC guidance, joint doctrine states that the JFACC should also plan for and maintain cognizance of the theater-wide attack operations effort. This will ensure that the JFACC is prepared to support the other component commanders, for example, when they request JFACC support in conducting JTMD attack operations within their AOs.[153]

The JFACC plans and executes attack operations in the theater based on JFC guidance. Because the JFACC maintains theater-wide awareness of JTMD attack operations, and the integral relationship between these operations and the other operational elements of JTMD, the JFC *may* assign the responsibilities of the AADC to the JFACC. According to JP 3-01.5, if conducted by separate individuals, detailed procedures should be established to integrate JFACC and AADC activities.[154]

Component Commanders plan and execute JTMD operations as directed by the JFC, and active defense in accordance with weapon control procedures and measures established by the AADC (if designated). Inside their AOs, component commanders are normally designated supported commanders for attack operations. Beyond surface AOs, the JFACC is normally designated supported commander for attack operations. Close coordination among the various commanders involved is critical.[155]

As discussed earlier, joint doctrine is intended to be authoritative, and if conflicts arise between it and service doctrines, joint doctrine will take precedence for the activities of joint forces. The remainder of this chapter examines Service doctrine to determine if there are any such conflicts, and whether and how they are being resolved.

Service Doctrine

Service doctrines describe war as each service sees it, describing the best way for that service's forces to operate in a war, and how the individual service's forces should be integrated into the joint world. Although the meaning and use of doctrine varies among the services, their doctrine provides a way to examine and compare their views. In doing so, it becomes apparent that the services' approaches to TMD (and therefore CMD) vary. The following sections will examine their doctrines to determine how each handles the theater cruise missile defense question. Much of the theater air and missile defense and

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[153] Ibid., II-5, II-6, II-7.

[154] Ibid.

[155] Ibid., II-7.

related doctrine is being rewritten, or revised. The following analysis uses the latest available versions.

The Air Force View

Air Force doctrine is based on control and exploitation of air and space to achieve both independent air and integrated service objectives. Its counterair doctrine stresses the goal of complete air supremacy and emphasizes an offensive, theater-wide solution to counterair challenges. To assure that concentration of effort and economy of force requirements are met, *"the entire offensive and defensive counterair effort should be controlled by one air officer under the centralized control, decentralized execution concept."* (Emphasis in original)[156]

Counterair consists of operations to attain and maintain a desired degree of air superiority by the destruction or neutralization of enemy forces. Counterair's two elements (OCA and DCA) enable friendly use of otherwise congested airspace and disable the enemy's offensive air and missile capabilities to reduce the threat posed against friendly forces.

The Air Force believes that because air and space forces are inherently offensive and yield the best effect when so employed, OCA is often the most effective and efficient method for achieving the desired degree of air superiority. This function consists of operations to destroy, neutralize, disrupt, or limit enemy air and missile power as close to its source as possible. The aircraft and missile threat may include fixed and rotary-wing

[156] AFDD-1, *Air Force Basic Doctrine*, 1997, 46-47.

attack aircraft, reconnaissance aircraft, unmanned aerial vehicles, air-, land-, and sea-launched cruise missiles, ballistic missiles, and air-to-surface missiles.[157]

DCA concentrates on defeating the enemy's offensive plan and on inflicting unacceptable losses on attacking enemy forces. DCA is synonymous with air defense, and consists of active and passive operations to defend friendly airspace and protect friendly forces, materiel, and infrastructure from enemy air and missile attack. It includes detection, identification, interception, destruction of attacking enemy air and missiles, and normally takes place over or close to friendly territory.[158]

The Air Force believes that cruise and ballistic missiles are an extension of the air threat and, as air threats, should properly fall under the responsibility of the theater air defense commander. The Air Force advocates that the primary method of preventing theater missile employment is aggressive attack operations as a component of the overall air campaign strategy. However, the Air Force also believes that enemy air and ballistic missile systems should be attacked throughout their life cycle--production, preparation, launch, and enroute to their target. [159]

To facilitate seamless control, the Air Force wants to take the lead in developing and fielding a theater command, control, communications, and intelligence system capable of integrating all future air and missile defense systems.[160] The Air Force supports the

[157] Ibid.

[158] Ibid., 47.

[159] Air Force XORT, "Air Force Theater Air and Missile Defense Requirements," briefing slides, n.p.; on-line, Internet, 11 March 1999, available from http://www.c2tic.hurlburt.mil.

[160] Maj James M. Holmes, *The Counterair Companion: A Short Guide to Air Superiority for Joint Force Commanders,* (Maxwell AFB, AL: Air University Press, 1995), 52.

position that the responsibilities of the JFACC, AADC, and airspace control authority (ACA) are interrelated and should *normally* be assigned to one individual.[161]

The Army View

Army doctrine links the air superiority battle directly to the ground battle, and states that, history notwithstanding, U.S. forces cannot always count on having air supremacy.[162] It states that counterair operations are inherently joint, and all members of the combined arms team perform air defense operations.[163]

Army counter-air doctrine provides expanded counter-air guidance, focus, and objectives for all levels of Army counter air forces from the theater down to the division. It emphasizes the synchronization of joint offensive and defensive counter-air resources to deliver operational and tactical flexibility to ground commanders. Army doctrine separates theater missile defense and theater counterair (theater air defense) operations into two different but closely related mission areas. "Counterair targets are manned aircraft and UAVs, while TMD targets are comprised of ballistic, cruise, and air-to-surface missiles. *Operations to protect the force from theater missiles differ fundamentally from those actions taken to defend against the counterair threat*." (Emphasis added)[164]

To counter the spectrum of aerial threats, current Army doctrinal initiatives are built on the premise that a seamless defense must be the overall goal of the air and missile defense

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161 Air Force Doctrine Center Issue Forum: *Use of Area Air Defense Commander (AADC) Capability & Command and Control of Aerospace Power*, n.p.; on-line, Internet, 21 Sep 98, available from http://www.hqafdc.maxwell.af.mil.

162 Field Manual (FM) 100-5, *Operations, June 1993,* 2-18.

163 Ibid., 2-13. For additional details on combined arms air defense operations see FM 44-8, *Combined Arms for Air Defense*.

efforts. To seek efficiency by avoiding duplication, it divides threats into those best countered by manned aircraft, and those best countered by surface-based systems.[165] According to Army doctrine, the unique challenges posed by theater missiles require a highly responsive C2 structure that decentralizes engagement operations to the lowest level. By comparison, the requirement to avoid fratricide of friendly aircraft mandates strict and highly centralized control of counterair engagement operations.[166] While acknowledging that there are some areas where counterair and TMD operations overlap, further analysis of the doctrine suggests that the term TMD as used in Army doctrine would be accurately defined as TBMD, as most of the differences deal primarily with the unique characteristics of theater and short-range ballistic missiles, not cruise missiles.

Army doctrine states that the Joint Force Commander (JFC) usually assigns the Joint Force Air Component Commander responsibilities as both airspace control authority and the area air defense commander (AADC); it also states that depending on force composition and threat, these responsibilities may be assigned to the Joint Land or Maritime Component Commanders (JFLCC or JFMCC).[167]

The Naval View

Naval doctrine represents the fusion of Navy and Marine doctrine. Navy doctrine emphasizes employment of ships, aircraft and other Navy assets specifically in maritime

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[164] FM 44-100, 1-4.

[165] Ibid., 4-1.

[166] Ibid., 1-5.

[167] FM 44-100, 6-5.

environments, while Marine doctrine focuses on support and employment of air/ground task forces in maritime and land areas.[168]

In the Navy's new keystone doctrinal document "*Forward...From the Sea,*" the Navy's focus shifts from an open ocean threat to near land (littoral) operations against increasingly capable regional powers. The Cold War global maritime threat has been replaced by regional challenges that are equally demanding. This change in focus alters the primary naval air defense mission from blue water, open-ocean defense, to a more offensive extension of naval air defenses over land.[169]

The Navy bases its fundamental approach to warfare on a very specific form of the idea of centralized control and decentralized execution. Navy doctrine emphasizes the composite, integrated relationship between air, surface and subsurface warfare areas. In the Navy's Composite Warfare Commander (CWC) concept, forces are assigned to a specific warfare area commander.[170] The Antiair Warfare Commander (AAWC) is responsible for all Navy antiair warfare operations, including TAMD active defense.[171] Under the CWC concept, the strike warfare commander (STWC) is responsible for strike operations, including TMD attack operations.

Naval theater air defense objectives include: initiating and maintaining control of airspace early in a crisis or conflict; permitting safe entry of follow-on U.S. and allied forces into a theater of operations; and protecting and supporting forces and facilities ashore. When viewed through the perspective of operating a warship in restricted littoral

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[168] Naval Warfare Doctrine Center, "Doctrine Perspective," briefing slides, n.p.; on-line, Internet, 9 May 1999, available from http://www.nwdc.navy.mil/Doctrine/web98/tsld039.htm.

[169] *Forward...From the Sea*, Department of the Navy, Washington, D.C.: 1994.

[170] Naval Warfare Publication (NWP) 10-1, *Composite Warfare*.

[171] NWP 10-1.21, *Antiair Warfare Comander's Manual*, and NWP 32, *Antiair Warfare*, detail the Navy's implementation of AAW.

environments, the reduced reaction times and voluminous, overlapping threat missile and aircraft coverage present new challenges to naval TAMD.[172]

Cruise missile defense is not new to the Navy - anti-ship cruise missiles (ASCMs) have been a potential threat to U.S. naval operations for several decades. Unlike ASCMs, against which the Navy has fielded defensive weapons and doctrine, theater defense against LACMs is a more recent concern. The Navy, in concert with BMDO, JTAMDO, DARPA and the Army, is developing "upper-tier" and "lower-tier" systems to counter theater ballistic missiles ("upper tier"), and aircraft and cruise missiles ("lower tier"). However, the Navy's capabilities to defend against LACMs over land are currently limited because of sensor elevation and range constraints inherent in ship-based littoral operations. While the emphasis appears to remain on TBMD, the Navy has experimented with operational concepts designed to improve its theater LACM defense capabilities.[173]

Marine Corps doctrine closely resembles the doctrine of its sister naval service, but emphasizes amphibious operations. USMC doctrine emphasizes defense in depth against aircraft and missile threats to gain and maintain the degree of air superiority required for the Marine air-ground task force (MAGTF) to conduct operations. The MAGTF uses offensive antiair warfare (OAAW) or air defense to reduce or eliminate the enemy's air and missile threat and to participate in theater missile defense. Within the MAGTF, AAW includes the aircraft, surface-to-air missiles and electronic warfare assets required to destroy or reduce the enemy's air and missile threat (both before and after it launches)

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[172] Captain Garry Holmstrom, "Joint Theater Air and Missile Defense : A Primer for the Surface Warrior," *Surface Warfare*, vol.23, no.2 (March-April 1998): 29.

[173] See chapter 7 for additional details on these experiments.

to an acceptable level (not further defined).[174] Much of USMC aviation-related doctrine is currently undergoing revision.

Doctrinal Areas of Concern

Controlling joint theater air and missile defense forces is one of the largest doctrinal areas of contention between the services. Arguments about control of theater missile defenses parallel the arguments over control of theater air forces. All the services recognize the need for offensive and defensive actions, and the role the commander in selecting the proper bounds to fit specific conditions. However, as discussed above, the services take different approaches to achieving this balance. The Air Force and Army group offensive and defensive air actions together under theater counterair operations. The Navy and Marine Corps separate offensive and defensive counterair efforts.

Much of the dispute has coalesced around two command positions described earlier; the JFACC and AADC. Although joint and service doctrine recognize the need for a structure to coordinate the JTAMD efforts of all the components, divergent service positions about the exactly what role these two commanders should play remain unresolved.

The doctrinal dispute over the JFACC centers on the interpretation of his authority. The Air Force's theater view of airpower generates its desire for centralized control of all theater air power in pursuit of theater objectives. According to the Air Force, "The essence of the JFACC concept is not simply the best designation of the single commander for air. Its broader focus is the development of a concept of air operations to meet the

[174] FMFM 5-50, 1-1.

objectives set by the JFC,"[175] including theater air and missile defense. To the Air Force, the JFACC is (or should be) a functional component commander. As such, the JFACC should centralize the planning and control the execution of all the air operations of the joint force (with guidance from the Joint Force Commander). The other services, however, view their air elements as extensions of their service that should be integrated with their surface forces.[176] They advocate limiting the JFACC's role to deconfliction of the various components' air efforts, and directing only those air assets declared excess to their requirements. The Air Force is concerned that unity of effort of effort will suffer if the JFACC's ability to integrate air assets to accomplish theater objectives is limited by the other component's direct air support requirements.[177] Not surprisingly, current doctrine is a compromise. Services retain operational control of their direct support sorties, but must make excess sorties available to the JFACC to execute the JFC's theater-wide plan.

The Area Air Defense Commander Controversy centers on the command relationship between the JFC, the JFACC and the AADC. Joint doctrine states the JFC will *normally* assign overall responsibility for air defense to an AADC and *preferably*, the AADC will also be the airspace control authority. If the JFC establishes a joint force air component

[175] Deputy Chief of Staff, Plans and Operations, Headquarters, United States Air Force, *JFACC Primer*, 2nd Edition (February 1994), 20.

[176] For the Navy and Marine Corps, the JFACC is analogous to the CWC's air resources element coordinator (AREC) who manages the air assets excess to the antiair, antisurface, and antisubmarine commanders in the Navy's composite warfare system. Current joint doctrine is a compromise between Air Force total theater airpower desires and the Naval services' concept of the JFACC as a coordinator. The surface component commanders retain control of direct support sorties, with the excess air assets provided to the JFACC to execute theater-wide JFC objectives.

[177] Peter P. Perla, et al., *The Navy and the JFACC: Making Them Work Together*, report no. CNR 202, (Alexandria, VA.: Center for Naval Analysis, April 1993), 15.

commander (JFACC), then the JFC *may* also assign the responsibilities of the AADC to the JFACC."(emphasis added)[178]

The Air Force position is that all three positions are interrelated and should normally be assigned to one individual. It advocates an integrated air defense system that combines the control of all counterair and missile defense systems under the control of the theater air defense commander (under Air Force interpretation of joint doctrine that would normally be the JFACC/AADC/ACA). Designating one commander as the JFACC, AADC and ACA ensures unity of effort in planning and executing fully integrated JTAMD operations.

The other services believe, to varying degrees, that the joint doctrine should provide the JFC with three options for defining this relationship: (1) the JFACC and ADC as two separate and co-equal individuals, both responsible directly to the JFC, (2) the JFACC and AADC responsibilities assigned to the same individual, or (3) the AADC subordinate to the JFACC.[179]

The Army position is that regardless of which option is chosen, when a significant portion of the JFC's air defense capability is contributed by a component other than the AADC's, a senior officer from that component may be assigned as deputy AADC.[180]

The naval service' positions reflect their different view of counterair operations under the CWC concept. They support the option of designating the JFACC as the supported

[178] Joint Pub 3-01.5, II-5.

[179] Richard Lardner, "Joint Staff Gets Closer to Settling Air, Missile Defense Doctrine Debate," *Inside the Pentagon,* February 4, 1999, on-line, Internet, 4 February 1999, available from http:ebird.dtic.mil/feb 1999.

[180] Author personal interview with Lieutenant Colonel Brian McClean, Air Force Doctrine Center, Maxwell AFB, 8 March 1999.

commander for offensive (attack) operations and the AADC the supported commander for defensive (air defense) operations, with both individuals responsible to the JFC.[181]

[181] For details on naval AADC approach see http://ndcweb.navy.mil/concepts/airdef.

The disputes over JFACC control could have a direct influence on Chapter 6

Cruise Missile Defense Technology

> *The key to the future probably lies in the "intellectual task" of getting a better "fit" between advanced hardware, concepts and doctrine, and organizations than the opponent.*
>
> —Barry D. Watts[182]

With the potentially growing threat of LACMs looming in the future, the U.S. military is developing defenses against cruise missiles. Since existing air defense systems have never been tested in battle against modern cruise missiles, their effectiveness remains uncertain.[183] This chapter examines efforts to improve JTAMD since the Gulf War, focusing specifically on capabilities to counter theater land-attack cruise missile threats.

TMD and Anti-Cruise Missile Efforts since Desert Storm

The questionable results of efforts to counter mobile missile threats during the Gulf War caused increased high-level interest in improving those capabilities rapidly. Immediately following the war, numerous diverse efforts were launched to improve existing TAMD capabilities, and to develop new ones. While the initial focus of those efforts was understandably on theater *ballistic* missiles, theater land attack cruise missiles are also becoming important in the overall threat calculus. This section examines organizational, technological, and operational responses since Desert Storm to improve U.S. JTAMD capabilities, and how they apply to countering current and future LACM threats.

[182] Barry D. Watts, "*Doctrine*, *Technology and War*," address to Air & Space Doctrinal Symposium, Maxwell AFB, AL, 30 April-1 May 1996, draft, 27.

Requirements

In 1991, the Joint Requirements Oversight Council (JROC) determined that the theater missile defense mission cannot be accomplished with just one or two systems, it requires multiple systems designed to counter an ever-growing and diverse missile threat during all phases of flight.[184] Eight years later, the latest Mission Need Statement (MNS) for Joint Theater Air and Missile Defense, which recently entered the Joint Requirements Oversight Council (JROC) approval process, still documents the same requirements.[185] It states,

> Current air and missile defense capabilities may not fully protect US, allied, and coalition forces, and other defended assets within assigned theaters of operations from air and missile attack to a level of protection required by a joint force commander. Protection is also required during initial crisis and contingency responses, and forcible entry scenarios, in which U.S. forces have a limited ability to protect U.S. interests ashore from attack. With the exception of most recent active defense system developments, U.S. systems have been predominantly developed to counter the manned aircraft threat. *Current air and missile defense capabilities are insufficient to counter the full spectrum of anticipated threats.* [Emphasis added.][186]

It goes on to state that U.S. joint doctrine requires air and missile defense mission objectives which are both offensive and defensive in nature. These objectives include:

- Threat launch prevention accomplished by attacking not only airfields and launch platforms, but supporting command and control, and infrastructure as well; and other offensive actions.
- Protection accomplished through both active and passive defensive measures, of friendly forces and other military, civilian and designated geopolitical assets.

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[183] Carus, 85.

[184] Joint Requirements Oversight Council Memorandum (JROCM)-064-91, *Theater Missile Defense Mission Need Statement*, approved on 18 November 1991.

[185] *Mission Need Statement for Joint Theater Air and Missile Defense,* final draft, April 1999. When approved this Mission Need Statement will supersede JROCM-064-91.

[186] *Mission Need Statement for Joint Theater Air and Missile Defense,* final draft, April 1999, 3. This document will hereafter be cited as *JTAMD MNS*.

- A robust battle management command, control, communications, computers and intelligence (BMC4I) FoS architecture—characterized by information sharing, integration and synchronization—which acts as a force multiplier for seamless offensive and defensive operations.[187]

Fulfillment of the objectives of an integrated air and missile defense system is characterized by interoperability (of both planning and execution capabilities) which affords defense-in-depth. Defense-in-depth against land-attack cruise missiles requires intelligence preparation of the battlespace (IPB), and 360-degree multi-dimensional coverage to detect, track, engage and kill attacking missiles. Engaging the threat requires a consistent view of the battlespace to coordinate defenses within the theater of operations/joint operations area. Combat identification of enemy, friendly and neutral assets within the battlespace will be critical to allow maximum range engagement of the threat while minimizing or eliminating the risk of fratricide. Finally, an effective combat assessment process is required to determine if desired objectives are being accomplished.[188]

Shortfalls

Current capabilities available to the JFC to counter the cruise missile threat are primarily upgrades to existing systems, many of which were designed to counter the "Cold War" manned aircraft threat. While classification restrictions prevent an in-depth analysis of these systems capabilities against modern LACMs, based on the mission needs discussed above there are still some significant capability shortfalls. As discussed in the previous chapter, the JTAMD concept includes four "pillars" (Attack Operations, Active defense,

[187] JTAMD MNS, 1.

[188] JTAMD MNS, 2.

Passive Defense, and BMC4I). The following sections examine current and planned JTAMD technological capability options that are (or will be), available to the JFC within the next decade. They are discussed in the context of the appropriate doctrinal "pillar" they support.

Attack operations

Attack operations are characterized by offensive actions intended to destroy and disrupt enemy missile capabilities before, during, and after launch. The primary objective of attack operations is to destroy the enemy's missile capability before it is used. The capability to counter a theater missile (ballistic and cruise) threat requires destruction of the missiles, launchers, and the supporting infrastructure.[189]

In the past, emphasis centered on improving individual system capabilities to conduct attack operations against theater missiles. Due to their unique nature, conducting attack operations against LACMs may require a combination of rotary-and fixed-wing aircraft, land or naval surface-to-surface weapons, special operations forces, electronic warfare assets, and maneuver forces.[190] In the interest of space, this discussion will not discuss individual systems, but will instead concentrate on overall capabilities.

Joint tests, exercises, and analyses have identified attack operations as the most challenging pillar of TAMD.[191] The key to successful attack operations against LACMs is locating, identifying, tracking, and attacking these time-critical targets rapidly. Attack operations against an LACM threat are challenging because they are relatively small

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[189] Joint Pub 3-01.5, III-10.

[190] Ibid., III-11.

[191] Ballistic Missile Defense Organization, *Theater Air and Missile Defense (TAMD) Master Plan, 1998-B,* draft, 9-4.

targets, and will normally be dispersed, mobile, electronically quiet (with few emissions to intercept and track), and numerous.[192] Joint surveillance and reconnaissance sensor management, intelligence collection, processing, and dissemination, $C^{2,}$ and weapons pairing are essential for effective AO. Despite extensive efforts to develop appropriate materiel and non-materiel solutions, current capabilities are fragmented, stovepiped, and largely ineffective.[193]

Attack operations depend on integration and synchronization of procedures among the attack operations-capable forces in a theater. Many initiatives are under way to streamline AO doctrine, strategy, operational concepts, tactics, techniques and procedures (TTP), testing, and training. The Joint Attack Operations Working Group (JAOWG) was established in 1997 to serve as a focal point for coordinating these efforts, and to develop an integrated investment strategy.[194]

While significant progress has been made in sensor and weapon accuracy, U.S. TAMD forces employed in attack operations still have only limited capabilities to locate, suppress, disrupt, or destroy time-critical targets on the ground within the short timelines expected with the LACM target set.[195] There is a continued reliance on reactive, post-launch attacks, rather than the pro-active, pre-launch attack operations that are required.[196] While current attack operations capabilities could make it more difficult for an enemy to launch LACMs, there is certainly room for improvement.[197]

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[192] Joint Pub 3-01.5, III-11.

[193] *TAMD Master Plan*, 9-4.

[194] Ibid.

[195] Ibid.

[196] JTAMD MNS.

[197] Results of recent exercises indicate that U.S. forces have made progress in AO since Desert Storm. According to General Ronald Fogleman, during Roving Sands 1995, roughly 17 percent of the

Passive Defense

Passive defense provides essential individual and collective protection for friendly forces, population centers, and critical assets through tactical warning, reducing targeting effectiveness, reducing vulnerability, and providing for recovery and reconstitution following an attack.[198] Assessments of current passive defense measures indicates they do not adequately protect friendly forces and assets against enemy air and missile attacks, nor do they provide sufficient warning to friendly forces and civilian populations. [199] Although the shortfalls are well documented, this area (with the exception of warning) appears to be the one least emphasized in current technology programs. The inherent difficulties of providing adequate warning against multi-axis attacks by low altitude, low observable threats are daunting. Because of the potential requirement for continuous 360-degree, large-area coverage, most of the theater missile warning effort since Desert Storm has revolved around space-based assets; however, even those have focused primarily on detecting theater ballistic missiles.

Surveillance

The lack of an air- or surface-based, continuous, theater-wide, 360-degree, multi-dimensional surveillance capability, and the limited detection and engagement ranges of some current weapons systems, severely limit the ability to defend U.S. joint forces

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entire air effort went into TBM attack operations over five days. Joint air forces were able to degrade enemy TBM infrastructure (TELs, cranes, and support equipment) by 40 percent. Although conducted against a larger size (Scud TELs) and less numerous target set than expected with a LACM threat, the results are encouraging. General Fogleman's remarks were delivered to the American Defense Preparedness Association/National Defense University Foundation breakfast Seminar Series on Missile Defense, Counter-Proliferation, and Arms Control, Washington, D.C., June 16, 1995.

[198] Joint Pub 3-01.5, III-5.

[199] JTAMD MNS, 4.

against LACM attacks.[200] Although modifications to the E-3 Airborne Warning and Control System (AWACS) have improved its abilities to detect low radar cross section (RCS) cruise missile-type targets flying at low altitude, none of the currently fielded air and missile defense surveillance systems can effectively detect, classify, and identify most advanced threats postulated for the 2010 time frame.[201]

Active Defense

Active defense is a critical element of JTAMD. Even with highly successful attack operations, some LACMs will probably be launched. Active defense measures are intended to intercept and destroy attacking cruise missiles in flight, before they threaten friendly operations. An active defense is especially important for force projection, because units are most vulnerable while entering the theater of operations, when the organization and forces for passive JTAMD and attack operations may not yet be fully in place. Current JTAMD concepts of operations (CONOPS) use fighter combat air patrols (CAPs) and surface-to-air missiles (SAMs) to provide overlapping defense-in-depth against manned and unmanned aircraft, and missile threats. However, the effectiveness of their efforts are limited by the individual systems' capabilities. It is likely that current air-to-air and surface-to-air weapons will not be able to negate the most advanced threats postulated for the 2010 timeframe with a sufficiently high degree of confidence to protect defended assets from direct and collateral damage.[202]

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[200] Ibid., 3.

[201] Ibid.

[202] Ibid.

Fighters

Fighter active defense operations against LACMs may involve area or point defense CAPs, with the objective of intercepting the missiles early in their flight, before they become a factor to friendly operations or interests. While specific capabilities of the fighters currently in the U.S. inventory are classified, USAF F-15C *Eagles*, armed with AIM-120 *AMRAAM* and AIM-7M "H build" missiles, have the most capability against low radar cross section targets. The capabilities of the remaining fighters, including the F-14 *Tomcat*, F-16 *Fighting Falcon*, and F/A-18 *Hornet*, against low-RCS cruise missiles are somewhat more limited. [203]

Surface-based Defenses

Patriot. The Patriot surface-to-air missile system is currently operational with the U.S. Army and several allied nations. The Patriot program was initiated in 1965, but not fielded until the early 1980s. Designed to replace the HAWK and *Nike* systems, Patriot was initially intended to intercept only air-breathing threats. Each Patriot battery consists of one radar, eight launchers, 32 missiles and an environmental control station (Patriot's central nervous system). It is important to note that Patriot's phased-array radar does not provide 360-degree coverage. Patriot units try to compensate for this limitation by overlapping radar coverage with other units, and predicting likely avenues of attack when positioning their radars.[204]

[203] Author's interview with Major Thomas Bergeson, F-15 pilot, weapons officer, and former AIM-7 instructor at the USAF Weapons School, Maxwell AFB, AL, 16 March 1999.

[204] Author's interview with Patriot battery commander at Tabuk Royal Saudi Air Force Base, Saudi Arabia, 1991.

The Patriot system has undergone a series of upgrades called Patriot Advanced Capabilities (PAC). Shortly before *Desert Shield* a modernization program was initiated to improve the system's capabilities to intercept theater ballistic missiles. Patriot upgrades have continued since the Gulf War, and will be discussed in further detail later in this chapter.[205]

Short-range Air Defense (SHORAD). While not a theater-wide capability, the army has also upgraded its SHORAD units' capabilities to provide maneuver units point defense against LACMs. The addition of improved forward area air defense command, control, communications and intelligence (FAADC3I) systems with their associated Sentinel radars, and Avenger and Bradley Linebacker systems armed with Stinger infrared-guided SAMs, provide ADA units a demonstrated capability to effectively intercept attacking LACMs.[206]

Naval SAMs. The Navy's Aegis cruisers (*Ticonderoga* class) and destroyers (*Arleigh Burke* class), form the backbone of the Navy's capabilities to counter theater LACM threats. Upgrades to the ships' AN/SPY-1 radar, Aegis computers and software, and vertically-launched Standard Missile are designed to optimize their performance against both ballistic and cruise missiles.

Sea-based JATMD offers a unique capability, not always available to the other Services' JTAMD assets. Since the ships can be stationed offshore in international waters near

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[205] The PAC-2 *Guidance Enhanced Missile (GEM)*, incorporates an improved fragmentation warhead, and a quicker-reaction dual-beam fuze, giving it increased capabilities against ballistic missiles or low-flying, low-radar-cross-section cruise missiles. The PAC –3 is an entirely new missile. See BMDO Fact Sheet AQ-99-04, *Patriot Advanced Capability –3*, February 1999, available on-line at http://www.acq.osd.htm/bmdo/bmdolink.

[206] These systems' combined capabilities were demonstrated for the first time during Exercise Roving Sands '96 when as part of a Theater Missile Defense Advanced Warfighting Exercise, Avenger, Bradley Linebacker and Stinger teams successfully intercepted MQM-107D cruise missile surrogates. For

potential "hot spots", there is no requirement to secure foreign approval for their deployment. As long as they can deploy within range of their weapon systems, they could protect critical seaports, airbases, and other critical assets.[207] However, at longer stand-off ranges their abilities to detect, track, and engage low-flying, low-RCS cruise missiles over land are limited.

BMC4I

Joint interoperability is the single most significant deficiency in JTAMD operations today.[208] Specifically, the BMC4I structure remains divided across organizational and functional lines, as well as alliance and coalition lines. Current BMC4I systems do not support a timely flow of accurate information to meet current and anticipated threat projections. This precludes rapid fusing of critical information and hampers rapid operational and tactical exploitation of data.[209]

Additionally, current air and missile defense systems cannot effectively detect, classify, discriminate and identify most postulated advanced threats. The battlespace over future joint operating areas will likely contain friendly assets similar to hostile aircraft and missile systems, increasing the combat identification (Combat ID) challenge. The situation will be further complicated by the unpredictable nature of the LACM threat and

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additional details see Capt Kathleen Gainey, "Cruise Missile Shoot," *Air Defense Artillery Journal*, January –March 1997, 20-21.

[207] BMDO Fact Sheet AQ-99-02, *Navy Area Ballistic Missile Defense Program*, February 1999, available on-line at http://www.acq.osd.htm/bmdo/bmdolink.

[208] JTAMD MNS, 3

[209] Ibid.

LACM's ability to attack from multiple directions from air, land, or sea-based launch platforms.[210]

Organizational Responses

In an effort to coordinate the numerous disparate efforts initiated by the services and DoD organizations to improve TAMD capabilities following the Gulf War, and to ensure a proper "fit" in the area of theater missile defense, DoD created a multi-agency process to help ensure that all the pieces of the puzzle (research and development, requirements, acquisition, operational architectures and doctrine, to name just a few) were addressed. This Joint Theater Missile Defense (JTAMD) Process allows requirements definition, development of operational concepts and architectures, and development of a master plan that, for a given threat, can show what technological capability, cost and operational concept hurdles must be overcome.[211]

The Ballistic Missile Defense Organization (BMDO)

In March 1991, a separate department was created within the Strategic Defense Initiative Organization (SDIO) to deal with theater missile defense requirements. In 1993, in response to SDIO's reorientation to protecting the U.S. homeland against limited missile attacks and defending theaters against shorter range ballistic missiles it was renamed the Ballistic Missile Defense Organization (BMDO). SDIO's missile defense technology base became the foundation for a new missile defense program that emerged from the

[210] Ibid. 3-4.

[211] Brigadier General Richard Davis, Deputy Director, Ballistic Missile Defense Organization, DoD News Media Briefing, March 10, 1998, n.p.: on-line, Internet, 24 March 1998, available from http://www.acq.osd.mil/bmdo/bmdolink.

1993 Bottom-Up Review (BUR). Under its new charter BMDO was responsible for Ballistic Missile Defense (BMD) which included Theater Missile Defense (TMD), National Missile Defense (NMD), and advanced ballistic missile defense technologies.[212] While those priorities remain, they have been modified slightly. In 1997 BMDO assumed the additional responsibility of developing and integrating a joint architecture for theater air and missile defense (TAMD) to defeat both ballistic and cruise missiles. It shares those responsibilities with another organization – the Joint Theater Air Missile Defense Organization (JTAMDO). [213]

Joint Theater Air Missile Defense Organization (JTAMDO).

In January 1997, the Secretary of Defense and the Chairman of the Joint Chiefs of Staff announced the implementation of a new management structure to be used by the Department of Defense in providing the joint force commanders an improved capability to defend against air and missile threats. A primary objective of that new structure was to effectively and efficiently integrate DoD's requirements and acquisition activities for Theater Air and Missile Defense (TAMD). JTAMDO is a CJCS control activity, and reports to the Joint Staff's Director for Force Structure, Resources, and Assessment (J-8). Its primary responsibilities are to define the joint requirements and operational concepts

[212] BMDO Fact Sheet SR-98-01, *History of the Ballistic Missile Defense Organization*, March 1998, available online at http://www.acq.osd.htm/bmdo/bmdolink.

[213] Lieutenant General Lester L. Lyles, Director Ballistic Missile Defense Organization (BMDO), Statement before the Subcommittee on Defense, Committee on Appropriations, United States Senate, April 22, 1998, online, Internet, 7 December 1998, available from http://www.acq.osd.htm/bmdo/bmdolink. Briefing to Airpower Symposium and author's personal interview with Lt Gen Lester L. Lyles, Boston, MA, 19 November 1998.

to ensure the joint development and fielding of an integrated theater air and missile defense system.[214]

Under the new management structure, BMDO leads acquisition activities, including planning and ensuring the testing of theater air and missile defense architectures. BMDO works with JTAMDO and the services to translate operational requirements into systems architecture, and carries out systems engineering, integrated testing, and program acquisition functions.[215] BMDO and JTAMDO, working with the CINCs and services, have developed a "2010 JTAMD Vision" to enable joint employment concepts and improve joint and allied TAMD operations. The goal of this vision is to build a theater-wide, integrated joint force capable of achieving the requirements discussed above. The next section addresses the current and planned JTAMD operational concepts and systems that are the foundation of this JTAMD effort.[216]

2010 JTAMD Vision and Operational Employment Concepts

From an enemy's perspective, combining manned aircraft, cruise missiles and ballistic missiles in simultaneous multi-axis attacks could saturate U.S., allied, or coalition air and missile defenses, increasing the chances that some portion of the attacking force, possibly armed with WMD, will reach their targets. JTAMD planning must account for such worst-case scenarios. To counter such threats effectively, all TAMD capabilities available to the JFC must be considered and managed as an overall JTAMD system. The *2010 JTAMD Vision* is intended to guide the development of operational concepts and

[214] DOD News release No. 021-97, 16 January 1997, "Joint Theater Air Missile Defense Organization Established." TAMD Master Plan, 1-3.

[215] Lt Gen Lester L. Lyles, Statement of before the Subcommittee on Defense.

[216] *TAMD Master Plan*, 2-1.

integrated architectures, as well as help structure an assessment process to increase the efficiency and effectiveness of defenses, and extend the battlespace to create defense-in-depth. To achieve these goals, employment concepts must be integrated and collaborative so as to take advantage of each service's capabilities.[217]

Taking the approach that one must walk before running, the JTAMD vision establishes two employment concept depictions, based on time. The first includes current capabilities and those expected through the year 2003. Current and 2003 employment concepts incorporate separate fighter engagement zones (FEZs) and missile engagement zones (MEZs). These zones are necessary because confidence in combat ID, interoperability, and the air picture is insufficient to allow simultaneous employment of fighters and SAMs within the same airspace. By 2003, these capabilities may improve enough to allow limited opportunities for employing Joint Engagement Zones (JEZs) with fighters and SAMs employed simultaneously.[218]

By 2010, current and 2003 employment concepts will hopefully have given way to integrated employment concepts that achieve 360-degree coverage, and allow cooperative and efficient engagements based on a fully integrated BMC4I structure and TAMD systems.[219] To enable such joint engagement, the JTAMD Vision focuses on six integral concepts: Joint Collaborative Planning and Engagement; a Single Integrated Air Picture (SIAP); Combat Identification; Automated Decision Aids; Integrated Fire Control; and Attack Operations.

[217] Ibid.

[218] *TAMD Master Plan*, figure 2-1, 2-2.

[219] Ibid., figure 2-3.

Joint Collaborative Planning and Engagement

Future employment concepts will view individual weapon systems as contributing elements to the overall JTAMD architecture. The planning process will be a collaborative effort to determine the best fit and optimum joint laydown for the collective TAMD capabilities. The goal is to have air, land, and sea forces positioned and prepared to support each other as a joint force that operates as a single defensive unit.[220]

Single Integrated Air Picture (SIAP) Concept

Real-time execution of an integrated JTAMD plan requires a level of coordination and communication far beyond current standards. By providing the ability to display a fused air picture of common, continuous, and unambiguous tracks of all airborne objects within a specified surveillance area, the SIAP concept will allow each part of the TAMD force to make decisions based on an equivalent level and quality of information. More than a mere situational awareness tool, the SIAP networking concept will provide fire-control-quality data to shooters to enable target engagements regardless of data source.[221]

Combat Identification

Improvements to the air picture have the potential to dramatically change the way a JTF commander conducts air and missile defense. However, without accurate target classification and identification information, friendly forces will not be able to exploit the SIAP or other improvements fully. Long-range, wide-area combat identification is necessary to employ weapons to their maximum potential, before threat LACMs become

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[220] Ibid., 2-3.

[221] *TAMD Master Plan*, 2-3, 2-4.

a factor to friendly forces. The 2010 vision relies on each system contributing identification information so that multiple inputs can be fused accurately at the earliest opportunity. This is intended to provide ID information to forces at all levels, allowing fully decentralized engagements with minimal fear of fratricide.[222]

Automated Decision Aids

Automated engagement decision aids will be required for efficient management of weapons and engagements. These aids will use common algorithms and the SIAP to produce identical and simultaneous engagement recommendations at each participating TAMD node, in accordance with the rules of engagement (ROE).[223]

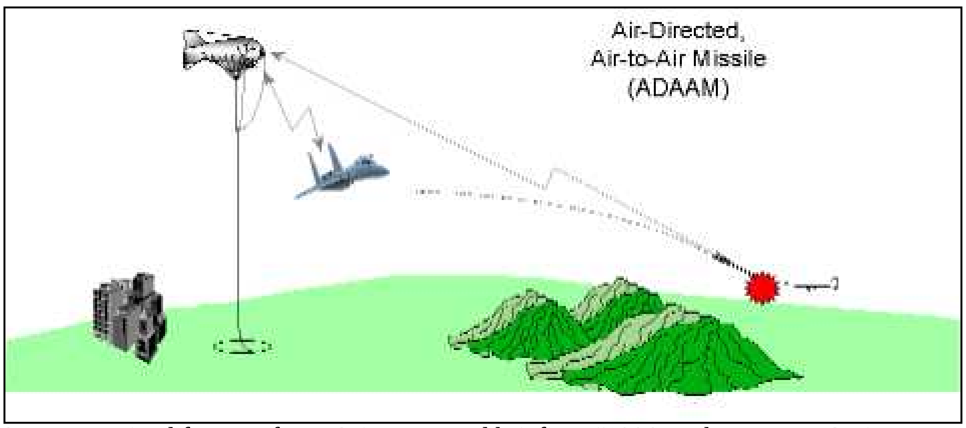
[222] Ibid., 2-4.

[223] Joint Theater Air and Missile Defense Organization brochure, and author's personal interview with Colonel Frank Bjoring, Director, TAMD Operations & Architecture, JTAMDO, 22 February, 1999.

Integrated Fire Control

In the future, individual weapons systems' sensors will be augmented by non-organic fire-control sensors and integrated data networks, allowing TAMD forces to overcome current single-sensor limitation such as line-of-sight and jamming. By 2010, elevated precision sensors and airborne (and possibly spaceborne) fire control radars (AFCRs) on other than "shooter" platforms will augment the shooters' target tracking and identification capabilities.[224]

Figure 3. ADAAM



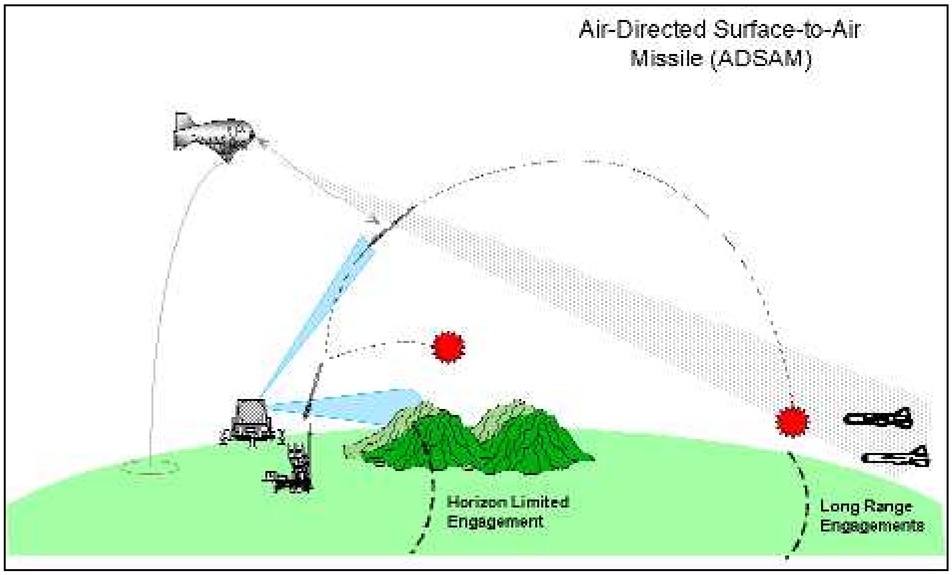
Source: Derived from Defense Science Board briefing, "1996 Task Force on Cruise Missile Defense," 11/27/97-A171-DSB-1.

These capabilities will enable advanced engagement concepts such as air-directed air-to-air missiles (ADAAM) and air-directed surface-to-air missile (ADSAM) (see figures 3 and 4.) In these concepts the AFCRs (instead of the fighters or SAMs) conduct the target tracking and provide the track data to the shooters. Fighters and SAMs will use these off-board data as inputs for their firing solutions ("engage on remote"), or simply launch missiles without radiating, and allow the AFCR to guide the missiles to the target

[224] TAMD Master Plan, 2-5.

("forward pass"). ADAAM allows fighters to conduct "launch and leave" tactics (fighters can turn away from their target after missile launch) that increase survivability and engagement opportunities, while also maximizing the kinematic range of their missiles.

Figure 4. ADSAM



Source: Derived from Defense Science Board briefing, "1996 Task Force on Cruise Missile Defense," 11/27/97-A171-DSB-1.

ADSAM overcomes the fundamental horizon line-of-sight limitations of surface-based fire units against low-altitude targets. It also maximizes the reach of SAMs, potentially allowing earlier and longer-range engagements of low altitude LACMs while still over enemy territory, as well as opportunities for multiple engagements.[225]

Attack Operations

Attack Operations in 2010 JTAMD are intended to eliminate the enemy's ability to present a coordinated air and missile threat, and reduce the total number of threat missiles

[225] Ibid.

and aircraft entering the commander's battlespace to levels that can be effectively accommodated by "catcher's mitt" active defense capabilities. To achieve this vision, the JTF commander must be able to locate, identify, and attack time-critical targets and their supporting infrastructure as early as possible. However, as discussed earlier, because of their smaller size and lower signatures, attack operations against LACMs could be more difficult than against TBMs. Similar to the advanced concepts that will provide integrated fire control for active defense systems, attack operations in 2010 will capitalize on cooperative management and integration of surveillance and attack assets to allow collaborative target engagement.

Family of Systems (FoS)

BMDO and JTAMDO are the primary agencies responsible for the development and integration of current and future JTAMD systems, C2 systems, and sensor capabilities. Given the complexity and diversity of current and expected missile and aircraft threats, current technology is not capable of providing a single system capable of performing TAMD; multiple systems working in unison as an integrated Family of Systems (FoS) are required.[226]

The FoS concept is intended to provide a cohesive, coherent, and effective method of supporting Attack Operations, Active Defense, Passive Defense, and Integrated BMC4I concepts. The FoS concept is an evolving, flexible configuration of interoperable weapon systems, C2 centers, and sensor capabilities. While development of these systems is dispersed throughout the services and DoD, the goal is to treat the JTAMD

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[226] BMDO Fact Sheet AQ-99-16, *The Family of Systems Concept*, March 1999. Available from http://www.acq.osd.htm/bmdo/bmdolink.

FoS as a normal acquisition program. When fielded, the FoS will allow joint force commanders to tailor the available mix of systems and capabilities according to situation and threat.[227] The FoS program strategy includes incorporating existing service programs, and developing new advanced systems and capabilities for the future.

FoS systems are typically divided into two categories: upper and lower tier (or terminal phase). Upper tier systems are intended primarily for use against theater ballistic missiles, while lower tier systems can engage TBMs as well as cruise missiles and manned aircraft. While the FoS will eventually counter the entire JTAMD threat spectrum, the remainder of this discussion focuses on those components of potential benefit in countering LACM threats.

Existing Programs

Cooperative Engagement Capability (CEC).

This U.S. Navy cooperative engagement concept provides new air defense capabilities to TAMD, not by adding new radars or weapon systems, but by distributing sensor and weapons data from existing systems in a new way.[228] Similar to what the JTAMD SIAP concept is intended to provide in the future, CEC's real-time sensor netting integrates radar and other sensors to provide an identical, fire control quality picture of the battle space as though it were viewed through the collective eyes of all participants in the CEC network. The resulting common picture provides improvements in track accuracy, continuity, and ID consistency, allowing reduced reaction times and extended

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[227] Ibid.

[228] Raytheon E-Systems, *Cooperative Engagement Capability*, available from Raytheon E-Systems Business Development at jiao@eci-esysts.com.

engagement ranges. The system entered service with the Navy in 1996 and has been used in a variety of LACMD tests and experiments since then.[229]

Patriot Advanced Capabilities 3 (PAC-3)

PAC-3 is the most recent upgrade to the Patriot system and includes three increasingly sophisticated configurations. During 1995 and 1996, the two initial configurations were deployed. The final PAC-3 configuration is expected to reach the field in 2001. These modifications improve most of the Patriot's system components. Upgrades to the radar will improve its multifunction, and low-altitude threat detection and threat discrimination capabilities. Other improvements include new hit-to-kill missiles with lethality enhancements, better C^3, and greater interoperability with other services' JTAMD systems.

Improved interoperability will be critical in countering LACMs flying at low altitude and using terrain to mask themselves from surface-based sensors. In such cases, Patriot will require data from elevated sensors to provide tracking and intercept data.

Navy Area TBMD

The Navy Area TBMD enhancements to the Aegis/Standard Missile air defense system are intended to provide a tactical missile defense capability comparable to that of the Army's PAC-3. The SM-2 Block IV missiles deployed on Aegis *Ticonderoga*-class cruisers and *Arleigh Burke*-class destroyers will be modified to optimize performance against both cruise and ballistic missiles, including the addition of an infrared seeker to

[229] Office of Naval Research, "Summary of the Cruise Missile Defense ACTD Mountain Top Demonstration," n.p.; on-line, Internet, 7 April 1999, available from http://www.onr.navy.mil.

improve intercept accuracy. Navy Area is scheduled for First Unit Equipped (FUE) in 2003.

Suffering from the same line-of-sight limitations as Patriot, to intercept LACMs flying terrain-following profiles over land, the Aegis cruisers and destroyers will also require tracking and firing data from some form of elevated sensor.

Airborne Laser (ABL)

The Air Force's YAL-1 *Airborne Laser* (ABL) is part of BMDO's "FoS" but the Air Force manages and budgets for the program.[230] Although ABL has been advertised primarily as a "boost phase" intercept capability against theater ballistic missiles, recent press reporting indicates that the Air Force may also explore its capabilities to defend against cruise missiles.[231]

Based on the Boeing 747 airframe, ABL uses an onboard, passive infrared sensor operating in a 360-degree sweep and is capable of autonomous detection, acquisition, and tracking of theater missiles with no external cueing required for TBMs[232]. To intercept the missiles, ABL uses a high energy, chemical oxygen iodine laser (COIL) in the multi-hundred kilowatt class. Able to engage at least three targets nearly simultaneously, ABL

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[230] Lt Gen Lester L. Lyles, Statement, April 22, 1998.

[231] David A. Fulghum, "Airborne Laser Aimed at New Defense Roles," *Aviation Week & Space Technology*, October 5, 1998, 111-112. Greg Seigle, "Tactical Laser Tested By Boeing," *Jane's Defence Weekly*, vol. 31, issue no. 10 (10 March 1999): 17. According to *Jane's*, Boeing Rocketdyne is working on a scaled down derivative of the ABL, called airborne tactical laser (ATL). This smaller laser could be carried on a wide range of aircraft including the V-22 Osprey, the U.S.Navy P-3 Orion maritime patrol aircraft, and C-130s. The ATL is designed to fire up to 100 shots without reloading. According to Boeing Rocketdyne, so far the U.S.Navy has expressed the most interest in the system.

[232] David A. Fulghum, "Airborne Laser Aimed at New Defense Roles," *Aviation Week & Space Technology*, October 5, 1998, 111-112. According to the author, ABL program officials have refused comment on whether the ABL's sensors would be sensitive enough to detect cruise missiles' reduced signatures.

will carry sufficient laser fuel to engage 30 to 40 targets per 12- to 18-hour (air refueled) mission.[233]

Two limitations currently associated with ABL, particularly in the CMD role, are detection and intercept ranges and weather requirements. ABL's detection and intercept capabilities against cruise missiles are classified; however, the current laser range estimate is 135 nm. Depending on the scenario, this could mean ABL would need to fly close to, or even over, enemy territory to counter LACMs.[234] Orbiting at 40,000 feet it would be an inviting target for enemy air defenses, requiring at least some measure of air superiority in its area of operations. Weather would play an important role in ABL's ability to engage low-flying LACMs. Weather can adversely affect the electronic sensors and laser energy, particularly when penetrating clouds, to the point that their effectiveness against LACMs flying below a cloud deck may suffer significantly. The ABL is to begin a test program in 2001, with its first test "shot" against a TBM surrogate planned for 2002. The first of seven ABLs could be operational as early as 2008[235]

Medium Extended Air Defense System (MEADS)

Formerly known as Corps SAM, MEADS is an international effort to develop a replacement for the widely deployed HAWK SAM system. This highly mobile system, designed specifically for limited area defense and protection of maneuver forces, is intended to provide 360-degree coverage against short-range ballistic missiles, cruise

[233] Ibid.

[234] John Donnelly, "Airborne Laser Found Unlikely to Meet Range Requirements," *Defense Week*, March 8, 1999, 1.

[235] David A. Fulghum, "Airborne Laser Aimed at New Defense Roles," *Aviation Week & Space Technology*, 5 October 1998, 111-112 and John Donnelly, "Airborne Laser Found Unlikely to Meet Range Requirements," *Defense Week*, 8 March 1999, 1.

missiles, and other air-breathing threats.[236] MEADS' defining characteristic will be tactical and strategic mobility. It will be easily deployable to a theater, and once there will be able to keep pace with rapidly moving maneuver forces. MEADS will feature a wheeled vehicle, and will use a multi-canister vertical launcher to protect and launch its interceptors. Its missiles will use hit-to-kill attacks to destroy TBMs, and will have enhanced-lethality, high-explosive warheads for use against cruise missiles and other air-breathing threats. Like the Patriot and Navy SAMs, MEADS will require off-board sensor data to attack terrain masked targets.[237]

The United States, Germany, and Italy are partners in MEADS; however, recent U.S. funding prioritization decisions have made its future status uncertain.[238]

Advanced Technology Programs

Among the objectives of JTAMD advanced technology programs are improved performance or reduced costs for acquisition programs, and technical solution options to mitigate advanced and unpredicted threats.[239] Both BMDO and DARPA have crucial roles in creating an effective but affordable JTAMD system. Many DARPA and service cruise missile defense advanced technology projects are "black" and beyond the purview of this study. However, senior officials have stated that at least $100 million in advanced

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[236] Paul G. Kaminski, Undersecretary of Defense for Acquisition and Technology. "DoD's Ballistic Missile Defense Programs." Prepared remarks to the Military Research and Development Subcommittee, House National Security Committee, 6 March, 1997, n.p.; on-line, Internet, 7 December 1998, available from http://www.defenselink.mil/speeches/1997.html.

[237] BMDO Fact Sheet AQ-99-11, *Medium Extended Air Defense System*, February 1999.

[238] Greg Seigle, "USA Seeks New MEAD Funding From Partners," *Jane's Defense Weekly*, vol. 31, issue no. 12 (24 March 1999): 3.

[239] RDT&E Budget Item Justification Sheet (R-2 Exhibit) March 1996, RDT&E, Defense wide /BA 02/03 (Applied Research/Advanced Technology Development) PE: 0602173C/0603173C (Proj: 1660) PE Title: Support Tech (U).

research funding is being applied to the problem. The projects include research in the areas of long-range, low frequency radars, use of aerostats (tethered balloons) to carry acquisition and fire control radars, and a variety of platform (air-and ground-based) and missile sensor upgrades.[240]

Joint Land-Attack Cruise Missile Defense Elevated Netted Sensor System (JLENS)

The purpose of elevated sensors is to overcome the horizon limit of surface-based systems discussed above.[241] JLENS is a follow-on to the U.S. Army's Aerostat concept. JLENS will use a radar mounted on a tethered aerostat to detect attacking cruise missiles amid ground clutter, and pass targeting information to surface or air-launched missiles via datalink. The Aerostat's radar system, located under the belly of the balloon, is able to track aircraft and cruise missiles at a range of up to 150 nautical miles.[242]

JLENS is intended to complement ground-based and fixed-wing airborne sensors. The JLENS program has participated in several exercises. Current schedules envision the initial JLENS prototype beginning development and testing in the year 2000, with an initial "ready to go to war" capability by 2002. The current schedule calls for 12 complete systems deployed by 2005.[243]

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[240] David A. Fulghum, "Classified Projects Drive Defense Schemes," *Aviation Week & Space Technology*, 14 July 1997, 51-52.

[241] The JTAMD operational vision for 2010 prescribes the use of elevated surveillance and precision tracking sensors. Sensor elevation affords the ability to look down at the battlefield at extended ranges unhampered by terrain masking or earth curvature. This would allow over-the-horizon (OTH) detection, classification, identification, tracking and engagement of threat land attack cruise missiles, and affords each weapon system in the joint family of theater air and missile defense systems the opportunity to achieve intercepts at the maximum effective kinematic range of its interceptors.

[242] *JLENS Fact Sheet*, n.p.; on-line, Internet, 5 May 1999, available from http://www.smdc.army.mil/FactSheets/JLENS.html.

[243] U.S.Army Space and Missile Command, JLENS Pamphlet, n.p; on-line, Internet, 5 May 1999, available from http://www.smdc.army.mil/JLENS/JLENS.htm and JLENS Fact Sheet.

Cruise Missile Defense Advanced Concept Technology Demonstration (ACTD)

ACTDs provide a framework for seeking emerging technologies to respond to critical military requirements and to incorporate those technologies into fieldable prototypes. These prototypes are then placed in the warfighters' hands for evaluation. The fundamental question posed during that process is, "Does this capability respond adequately to the need?" If so, that capability can be fielded years earlier than would otherwise be possible.[244] The ACTD discussed below was intended to explore and alleviate the ground-based horizon line-of-sight problems encountered by surface-based SAMs.

Cruise Missile Defense ACTD. The focus of this ACTD, also called "Mountain Top," was the detection and engagement of beyond-radar-horizon cruise missile targets. The goal was to detect, track, and successfully engage cruise missiles at ranges beyond the radar line-of-sight of surface-based air defense units, and to assess joint air defense operation doctrine and concepts.[245]

As depicted in Figure 5, elevated sensors located on a Hawaiian mountain ridge operated in concert with a U.S. Navy Aegis cruiser and U.S. Army Patriot battery to detect, track, and engage target drones at ranges beyond the radar lines of sight of the surface-based air defense units.

The objectives during Phase I of the CMD ACTD were to demonstrate air-directed surface-to-air missile (ADSAM) over-the- horizon engagement by using "Mountain Top"

[244] Paul G. Kaminski, remarks to the Acquisition and Technology Subcommittee, Senate Armed Services Committee, 19 March 1997.

[245] This ACTD was approved by the DUSD(AT) in May 1994 as a joint U.S. Army and U.S. Navy demonstration under U.S. Navy lead. ACTD tests and associated activities were conducted at the Pacific Missile Range Facility, Kauai, HI, and were completed in early February 1996. For additional program details see http://www.acq.osd.mil/at/cmd.htm (Accessed 14 December 1998).

sensors and radars (simulating an airborne platform) to detect, track, engage, and kill over-the-horizon cruise missile targets; and to provide insights into new air defense concepts of operations.[246]

The Phase I CMD demonstration was completed in January 1996. Four successful intercepts of simulated LACMs (flying over water) by ship-launched SM-2 missiles directed by the "Mountain-top" radar established proof of the ADSAM concept. Emerging U.S. Navy technologies used included advanced radars, the Cooperative Engagement Capability (CEC), which linked the Mountain Top sensor suite and the surface-based air defense unit sensors; and SM-2 missile seeker modifications that enhanced performance in high clutter environments.[247] The U.S. Army also tested its PAC-3 active radar missile seeker technology.[248] It achieved a 98% success rate in over 100 engagement tests.[249]

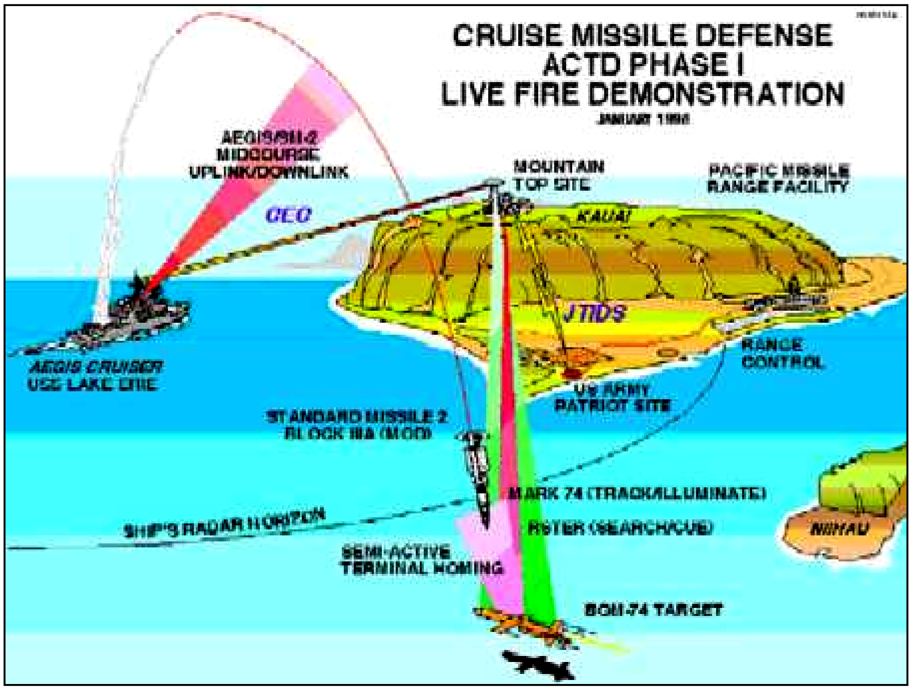
[246] Office of the Undersecretary of Defense for Acquisition and Technology, "Cruise Missile Defense Phase I," n.p.; on-line, Internet, 7 April 1999, available from http://www.acq.osd.mil/at/cmd.htm.

[247] Ibid.

[248] Ibid.

[249] Ibid.

Figure 5. CMD ACTD Phase1 1.1Imonstration CMD



Source: Office of the Undersecretary of Defense for Acquisition and Technology. "Cruise Missile Defense Phase I." Online. Internet, 7 April 1999. Available from http://www.acq.osd.mil/at/cmd.htm.

In less than two years, this ACTD validated the concept of an airborne sensor linked to a surface ship or air defense unit via Cooperative Engagement Capability to enable low flying cruise missiles to be engaged at greatly extended over–the–horizon ranges.[250] A follow-on phase involving fixed wing and aerostat sensors was proposed, but has never been approved.

Other Technology Efforts

Many different organizations are currently exploring technologies and concepts to counter the LACM threat. Some of these include ground-based lasers, such as the Theater High-Energy Laser (THEL) ACTD, a joint U.S./Israeli effort, and the Defense

[250] Jacques S. Gansler, Under Secretary of Defense for Acquisition and Technology, Statement Before the Subcommittees on Procurement and Research and Development, House Committee on National Security, A&T Overview, February 26, 1998, n.p.; on-line, Internet, 7 December 1998, available from http://www.fas.org/man/congress/1998/hnsc_redraft.html.

Advanced Research Agency's (DARPA) Low Cost Cruise Missile Defense Program, which is pursuing weapon seeker and guidance technologies to improve current weapons' intercept and kill capabilities.[251]

Exercises and Demonstrations

To ensure that they meet the user's requirements, new CMD technologies and operational concepts must be tested and evaluated. JTAMDO, in cooperation with BMDO, the services, and DoD, will validate emerging joint TAMD capabilities through a series of integrated analyses, simulations and demonstrations. Additionally, TAMD-related objectives will be integrated into a variety of exercises. The JTAMD process includes a Joint Capabilities Demonstration Program (JDCP). The overall focus of this program is to validate JTAMD operational concepts, interoperability for the 2003 and 2010 time frames, and to address improvements to the JTAMD FoS.[252]

JTAMD program officials acknowledge concerns over attaining the proper mix of modeling and simulation, hardware in the loop, and actual flight test within projected budgets and demanding program schedules.[253] Obviously, the preferred approach would be to conduct full-up flight tests against realistic threat emulators as frequently as possible. However, the high costs of testing the myriad of systems that will ultimately

[251] This ACTD was initiated by a memorandum of agreement between the United States and Israel in 1996 to develop a ground-based high- energy laser weapon system that uses proven technologies to provide a new JTAMD active defense capability. The THEL could significantly enhancing coverage of combat forces and theater-level assets against short- to medium-range threats, including LACMs. Deployment is planned for late FY 1999. David C. Isby, "Missile Defense, U.S.Army Considers THEL II As a Mobile Anti-Missile Weapon," *Jane's Defence Weekly*, vol.3, issue 2, (12 February 1999), n.p.; on-line, Internet, available from http://janes.ismc.sgov.gov.

[252] TAMD Master Plan, 7-1.

[253] William B. Scott, "Mix of Simulation, Flight testing Troubles BMDO Leaders," *Aviation Week & Space Technology*, 24 February 1997, 64-67.

make up the JTAMD architecture will likely make this option fiscally untenable. As a result, about two thirds of the testing of advanced systems will be conducted through simulations.[254]

The JTAMD Demonstration Plan presents a series of validation steps from characterizing current capabilities through demonstrating incremental improvements to advanced technologies and concepts. The steps lead to a wrap-up event, projected for fiscal year 2003, focusing on the SIAP, combat ID, integrated fire control, and the supporting BMC4I. The current approach for satisfying the requirements to demonstrate and validate advanced concepts or technologies is to use planned service and joint demonstrations, tests, simulations and exercises (hereafter referred to as venues). These venues provide both opportunities and constraints for executing JTAMD events.[255]

Venues

This section highlights some of the recent venues used to facilitate JTAMD cruise missile defense demonstration programs. The list is not all-inclusive, but it should provide some idea of the current efforts to bring the JTAMD Vision to fruition. Past efforts to use existing venues to demonstrate or validate new technologies and concepts have met with some difficulties.

The major focus of CINC and service exercises is training with their "go to war" equipment and systems. Large annual joint exercises, such as the "Roving Sands," and "Ocean Venture" series, contain scenarios, Blue Force lay-downs, and threat parameters designed to achieve specific exercise objectives. These objectives may conflict with

[254] Michael A . Dornheim, "Missile Defense Soon, But Will It Work?", Aviation Week & Space Technology, 24 February 1997, 38-39, 41.

JTAMD program objectives; thus inserting new technology and prototype systems may interfere with achieving CINC or Service training objectives.[256] However, despite these potential problems some CMD vignettes and scenarios have been incorporated into some of the large service and joint exercises.

For example, during Roving Sands ’96 U.S. Army SHORAD assets (Sentinel, Linebacker, Avenger and Stinger) conducted successful intercepts against MQM-107D cruise missile surrogates.[257] During Roving Sands ’98, the capability to forward off-board target cueing data to Patriot was tested. Track data on LACM surrogates (T-38s) was successfully passed from the Sentinel radar to Patriot via the Joint Tactical Information Distribution System (JTIDS).[258] Future Roving Sands exercises will examine cruise missile defense-in-depth, attack operations, and coalition C^4I interoperability issues.[259]

Other exercises and demonstrations such as the All Service Combat Identification Evaluation Team (ASCIET) and the Theater Missile Defense Initiative (TMDI) have focused on joint interoperability and TAMD C4I interface. Some of the doctrinal issues explored during these exercises include integration of component capabilities, synchronization and execution of fires, and the separation of JFACC and Area Air Defense Commander responsibilities.[260]

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[255] TAMD Master Plan, 7-4-7-5

[256] TAMD Master Plan, 7-17

[257] Roving Sands, held annually at White Sands Missile Range, NM, is billed as the world’s largest Joint Tactical Air Operations exercise. Its purpose is to plan, establish and exercise a Joint and Combined Integrated Air Defense System. Gainey, 20-21.

[258] TAMD Master Plan, 7-8

[259] Ibid., 7-11, 7-14.

[260] ASCIET conducts annual evaluations to investigate and assess various combat ID and SIAP concepts on the battlefield and in the battlespace. These evaluations highlight command and control issues

Although not an optimum solution, using existing venues to test and experiment with future capabilities will likely remain the most workable solution in a resource-constrained environment. The challenge will continue to be to incorporate a larger percentage of overall FoS capabilities into these exercises to achieve a more realistic appraisal of real-world CMD capability short-falls.

Joint Cruise Missile Defense Feasibility Study

The U.S. Air Force Air Combat Command has initiated a formal feasibility study to address joint CMD. This study is the first step in getting approval to conduct a joint test and evaluation (JT&E) program to capture a baseline of current JTAMD system capabilities and to evaluate and quantify the effects of C2, sensor, and shooter system near-term improvements in the CMD mission area. A nonmaterial objective is to provide an assessment of current CMD procedures. The JT&E will produce a set of deficiencies and limitations of existing and near-term JTAMD systems capabilities and employment concepts. It will also produce a set of recommended improvements and revisions to joint CMD tactics, techniques and procedures (TTPs).[261] Not surprisingly, according to the study group director, the single biggest limiting factor in properly evaluating current and near-future CMD capabilities and employment concepts is an appropriate venue to allow evaluation of the entire CMD architecture (sensors, weapons systems and C^4ISR) against realistic threat emulators.[262] Consequently, the JTAMD land attack cruise missile

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associated with detecting, identifying, tracking and intercepting theater air and missile threats (including LACMs) using the FoS. TMDI is a CINC USACOM initiative, directed by the Chairman of the Joint Chiefs of Staff, addressing the joint TAMD C^4I architecture, processes, and procedures at the operational level of war. Ibid. 7-11.

[261] Ibid. 7-19.

[262] Author's personal interview with Col Frank Strasburger, JCMD Feasibility Director, Eglin Air Force Base, 26 March 1999.

concepts have been tested in pieces, but the capabilities of all the pieces working together however, an examination of all capabilities working together remains an elusive goal.

Conclusions

If the key to the future really does lie in the intellectual task of getting a better fit between advanced hardware, concepts and doctrine, and organizations than the opponent, then the U.S. appears to be adopting a piecemeal approach to the challenge. As described in this chapter, large amounts of funding, brainpower and time have been thrown at the problem. Many organizations have their fingers in the CMD pie, and yet the overall picture remains one of a large number of diverse efforts, without an overall umbrella to guide them. The clearest indication of this lack of unity of effort is that joint CMD capabilities have never been tested all at the same time, against a realistic threat. While there are likely a variety of interservice and interorganizational factors involved, the end result is that with the potentially growing threat of LACMs looming in the future, the effectiveness of U.S. military defenses against cruise missiles remains uncertain. Thus, we do not yet know whether the country's current systems, which have the assessed technical capabilities to defeat LACMs, will be able to do so.

Chapter 7

Conclusions and Recommendations

> *Victory smiles upon those who anticipate the changes in the character of war, not on those who wait to adapt themselves after the changes occur.*
>
> Guilio Douhet[263]

In the preceding chapters, I have discussed what I perceive to be the neglected side of theater missile defense: the potential threat posed by theater land attack cruise missiles. Air superiority provides strategic flexibility and freedom of action to joint force commanders. Joint force commanders need a balanced strategy and balanced forces to guarantee that air superiority. Theater missile defense, against both ballistic and cruise missiles is a vital part of that strategy. The U.S. military understands the importance of TMD as part of the overall air superiority equation, but current doctrine, interservice issues, and acquisition programs are hampering the process. In this final chapter, I will provide a summary and some recommendations for the future.

Summary

While few likely regional adversaries currently possess an LACM capability, a serious threat could materialize in a relatively short period of time. LACMs provide an adversary with several important advantages over alternative delivery means. Their small size could provide a greater survivability, both before and after launch, than either theater ballistic missiles or manned aircraft. LACM flight characteristics make them well suited

[263] Guilio Douhet, Command of the Air, trans. Dino Ferrari (1942; new imprint, Washington, D.C.: Office of Air Force History, 1983) 30.

for WMD delivery, particularly for chemical and biological agents. The means to achieve a highly accurate LACM capability are rapidly becoming widely available, through the purchase or transfer of existing off-the-shelf technology and conversion of widely proliferated ASCMs and UAVs. While some uncertainties exist about how future LACM threats will evolve (quantities, ranges, types of payloads, degrees of low observable technology incorporated), even relatively "low tech" LACMs could present serious challenges to today's defenses. WMD warheads, the 360-degree threat, combat identification and fratricide avoidance are major challenges that must be solved to effectively counter LACM threats.

Theater missile defense (against both ballistic and cruise missiles) is a key aspect of counter air strategy, and the ability to effectively counter LACMs will be essential to achieving air superiority, much less air supremacy. As defense budgets continue to decline in search of the elusive peace dividend, the U.S. military will continue to face the problem of doing more with less. These resource reductions, combined with the likelihood that future adversaries will learn form their predecessors and attempt to counter U.S. strategy asymmetrically, make it all the more important that the services fight as an integrated and effective joint team. Currently, no single service has the resources required to defend a theater against a serious LACM threat. This will require a balanced, joint force trained to operate under common doctrine, with fully integrated command and control, and overlapping sensor and shooter system coverage.

Defense against LACMs will require a mix of attack operations, active and passive defense, and C^4I optimized for the particular theater. It will require a mix of surface, air and space systems to gain command of the air rapidly by destroying enemy cruise missiles and their support systems on the ground and in the air. Only through such concerted efforts will the joint force commander achieve freedom from attack in order to gain freedom to attack.

To assure integration, cruise missile defense doctrine and capabilities require the same level of effort currently focused on theater ballistic missile defense in the areas of common doctrine, system modernization and integration, and joint training.

Recommendations

TMD should be incorporated into joint counterair doctrine, and should address the LACM threat specifically, highlighting the differences and similarities between countering LACMs and other theater air and missile threats. It should describe how joint counter cruise missile assets will be integrated under a joint commander, and it should define procedures and systems to guarantee timely communications among all components of the counterair system to ensure that all available assets' capabilities are optimized.

To counter the theater-wide threat LACM threat, it will be vital to ensure the joint force commander assigns the task to a subordinate commander with a theater-wide perspective. In my opinion, this responsibility should rest with the JFACC, wearing the additional hat of AADC. While the command relationships will need to be tailored to the specific theater situation, I believe the JFACC will have the best capabilities to control both the offensive and defensive aspects of the theater-wide counterair effort. Defeating the LACM threat will require unity of effort, a balanced mix of service core capabilities and forces to avoid duplication; centralized control to avoid fratricide and "leakers," and, at the same time, flexibility to adapt to changing threat situations.

Countering cruise missiles will require additional focus on maintaining and modernizing service capabilities against the evolving threat, and making those capabilities interoperable. Conducting offensive and defensive operations against enemy cruise missile capabilities will require a mix of systems; budget limitations will continue to drive the U.S. to developing and fielding multi-role systems. However, all the services' counterair systems, while not specifically designed to counter LACMs, should incorporate the capabilities to attack and/or defend against this threat.

C^4I is a vital part of successfully countering LACM threats. Many of the currently fielded systems are "stovepipe systems" optimized for the needs of one service, and in many cases they have limited capabilities to communicate with one another. Information delays and errors caused by such incompatibility may prove costly when trying to deal with a large number of time-sensitive inbound threats, potentially armed with WMD warheads. Focus on system interoperability has increased significantly. BMDO and JTAMDO are expending a sizeable portion of their budgets and efforts to ensure that future counterair systems, regardless of which service is acquiring them, will be fully interoperable arrows in the JFC's quiver. Joint system compatibility must remain a priority, and additional effort and resources should concentrate on making currently fielded systems more interoperable.

Finally, joint counterair operations require constant training across service and system boundaries. Realistic joint training to identify and iron out doctrinal and equipment deficiencies before they cost lives and resources is a vital requirement. Such training will allow participants in the process to understand how they fit into the big picture, as well as identifying the strengths and weaknesses of the processes and systems involved. Realistic threat depiction is a key factor in learning the right lessons from exercises, and it is especially important when dealing with a multi-axis, theater-wide threat that challenges the entire counterair system. Past joint exercises have not played the entire joint counterair system against realistic threat emulators. This must change if an objective evaluation of current counterair (and TMD) doctrine and system capabilities against today's LACM threat, much less future threats, is desired.

Conclusion

Full dimensional protection is more than just a vision. The control of the battlespace to ensure that friendly forces can maintain freedom of action is a fundamental prerequisite for dominating an opponent across the full range of military operations.[264] U.S., allied, and coalition forces have come to expect air superiority (if not air supremacy), and depend on it. The nature of modern warfare demands that the services fight as a team to achieve it.

Although our ability to predict the future is limited, as the U.S. continues to demonstrate its dominance on the conventional battlefield, we should assume that future adversaries will learn and adapt their strengths to attack our perceived weaknesses. They will look for new ways to attack our interests, our forces, and our friends and allies. Asymmetric methods to counter U.S. superiority, including WMD and the means to deliver them, may be perceived as viable means to affect U.S. power projection and coalition-building capabilities. Adaptive enemies, emerging technologies, and weapons proliferation including land attack cruise missiles will characterize the U.S. national security environment. We "must prepare *now* for an uncertain future."[265]

[264] JV 2010, 2.

[265] A National Security Strategy for a New Century, 23, [Emphasis added].

Abbreviations and Acronyms

AADC	Area air defense commander
AAWC	Antiair Warfare Commander
ABL	Airborne laser
ABM	Anti-ballistic missile
ACA	Airspace Control Authority
ASCIET	All Service Combat Identification Evaluation Team
ACTD	Advanced concept technology demonstration
ADAAM	Air directed air-to-air missile
ADSAM	Air directed surface-to-air missile
ALCM	Air launched cruise missile
AOR	Area of responsibility
ASCM	Anti-ship cruise missiles
AW	Air Warfare
AWACS	Airborne warning and control system
BDA	Battle damage assessment
BMC4I	Battle management command, control, communications, computers, and intelligence
BMDO	Ballistic Missile Defense Organization
BPI	Boost-phase intercept

C^2	Command and control
CALCM	Conventional air launched cruise missile
C^4ISR	Command, control, communications, computers, intelligence, surveillance and reconnaissance
CAP	Combat air patrol
CEC	Cooperative engagement capability
CENTCOM	United States Central Command
CEP	Circular error probable
CG	Guided-missile cruiser
CINC	Commander in chief
CMD	Cruise missile defense
CONOPS	Concept of operations
CW	Chemical warfare
CWC	Composite warfare commander
DARPA	Defense advanced research projects agency
DCA	Defensive counterair
DoD	Department of Defense
EMCON	Emissions control
EW	Early warning
FAE	Fuel-air explosive
FoS	Family of systems
GEM	Patriot Guidance enhanced missile
GLCM	Ground launched cruise missile

Glonass	Global navigation system
GPS	Global Positioning System
INF	Intermediate range nuclear forces
IOC	Initial operational capability
IPB	Intelligence preparation of the battle space
IR	Infrared
IRBM	Intermediate range ballistic missile
IRST	Infrared search and track
JCS	Joint Chiefs of Staff
JFACC	Joint force air component commander
JFC	Joint force commander
JFMCC	Joint force maritime component commander
JLENS	Joint Land-Attack Cruise Missile Defense Elevated Netted Sensor System
JROC	Joint requirements oversight council
JSTARS	Joint surveillance and target attack radar system
JTIDS	Joint tactical information distribution system
JTMD	Joint theater missile defense
JTAMD	Joint theater air and missile defense
JTAMDO	Joint theater air and missile defense organization
LACM	Land attack cruise missile
MAGTF	Marine air-ground task force
MEADS	Medium extended air defense system

	(formerly CORPS SAM)
MEZ	Missile engagement zone
MTCR	Missile Technology Control Regime
NATO	North Atlantic Treaty Organization
NBC	Nuclear, biological, chemical
NCA	National Command Authority
NMD	National missile defense
OAAW	Offensive antiair warfare
OCA	Offensive counterair
PAC	Patriot advanced capability
Pk	Probability of kill
R&D	Research and development
RCS	Radar cross-section
ROE	Rules of engagement
RPV	Remotely piloted vehicle
RV	Reentry vehicle
SAM	Surface-to-air missile
SIAP	Single integrated air picture
SDIO	Strategic Defense Initiative Office
SOF	Special operations forces
SUW	Surface Warfare
TACAIR	Tactical aircraft
TBM	Theater ballistic missile

TBMD	Theater ballistic missile defense
TEL	Transporter-erector-launcher (for TBM)
TERCOM	Terrain Contour Matching
THAAD	Theater high-altitude area defense
TLAM	Tomahawk land attack missile
TM	Theater missile
TMD	Theater missile defense
TTP	Tactic, training and procedure
UAV	Unmanned aerial vehicle
WMD	Weapons of mass destruction

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theater missile defense.

The JFACC must balance theater-wide air objectives (offensive and defensive) with surface component AO priorities, but he is unable to do so if he does not control the forces. If the JFACC is not able to direct theater air forces in pursuit of the JFC's counterair objectives, the resulting lack of unity of effort could lead to piecemeal, uncoordinated operations. Modern JTAMD systems include air-to-air, surface-to-air, and surface-to-surface weapons, whose employment must be coordinated - not only maximize their effectiveness against the threat, but also to minimize the danger to friendly forces. Who will command and control these assets is still being hotly debated inside the Beltway.

Conclusions

While all of the services recognize that control of the air environment is important to achieving theater objectives, their divergent visions of warfare stress the importance of the mediums and missions for which they are responsible. Each of the services, with the possible exception of the Air Force, takes a "stovepipe" view of the JTAMD problem, focusing on its own area of operations and capabilities. Countering air and missile threats is a theater problem that will likely cross the boundaries of all the components.

As was learned during Operation Crossbow in World War II and the *Scud* hunt during Desert Storm, detecting and targeting mobile theater missile systems can be very difficult. Successful JTAMD operations will depend on the effective integration of all the components' TAMD assets (including attack capabilities).

Current JTAMD doctrine provides definitions and basic ideas, but not the specific guidance required for the mission. Protecting friendly forces and interests from air and missile attack will require that barriers forged by traditional views and current Service doctrine be overcome. Joint and service doctrine should help, not hinder, the Joint Force Commander's efforts to counter theater air and missile threats. Joint and service doctrine for defeating theater air and missile threats must provide for defensive and offensive operations to defeat the threat, through coordinated operations involving all components' capabilities. Until the doctrinal disputes hampering such synergistic operations are resolved, the JFCs will be forced to figure it out for themselves.