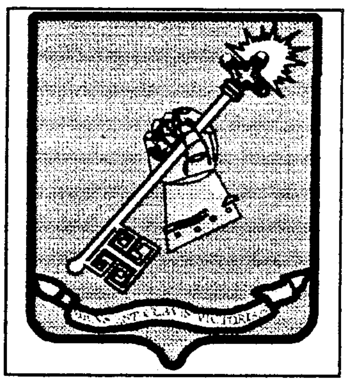
SCUD ALERT!:

The History, Development, and Military Significance of Ballistic Missiles on Tactical Operations

A Monograph
by

Major Bryon E. Greenwald
Air Defense Artillery



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ABSTRACT

SCUD ALERT!: THE HISTORY, DEVELOPMENT, AND MILITARY SIGNIFICANCE OF BALLISTIC MISSILES ON TACTICAL OPERATIONS by Major Bryon E. Greenwald, USA, 69 pages.

While the Persian Gulf War confirmed the political and strategic utility of using ballistic missiles as a terror weapon, the effect of ballistic missiles on tactical operations has received much less attention. Despite growing evidence of technological advances in guidance and warhead systems that warrant concern, much of the current literature ignores the operational and tactical impact of ballistic missiles on the battlefield. Even the US Army's most forward looking document, US Army Training and Doctrine Command (TRADOC) Pamphlet 525-5, *Force XXI Operations* (1 August 1994), disregards the impact of these weapons on tactical operations. Thus, this monograph breaks new ground and demonstrates why military leaders and planners should pay more attention to the emerging tactical threat from ballistic missiles, unconventional warheads, and weapons of mass destruction.

This monograph argues that changes in the nation's military strategy, the continued global proliferation of ballistic missiles and weapons of mass destruction, and the pace of technological improvements to those systems mandate that commanders and planners understand the military significance of ballistic missiles to their tactical battle space. This monograph traces the early history and recent development of ballistic missiles and analyzes nine factors related to their battlefield effectiveness. Included in this analysis is a discussion of chemical, biological, nuclear, fuel-air explosive, and submunition warheads and their effect on tactical operations. The monograph concludes with an examination of the impact of ballistic missiles on tactical forces during force projection operations.

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The spread of ever more sophisticated weaponry--including chemical, biological, and nuclear weapons--and of the missiles capable of carrying them represents a growing danger to international security. This proliferation exacerbates and fuels regional tensions and complicates US defense planning. It poses ever greater dangers to US forces and facilities abroad, and possibly even to the United States itself.[1]

George Bush, *National Security Strategy of the United States*, March 1990

We are threatened by the continued proliferation of advanced conventional arms, ballistic missiles of increasing range, and weapons of mass destruction....[2]

Inevitably, an increasing number of supplier nations will become able to contribute to the proliferation of ballistic missiles and weapons of mass destruction.[3]

As the Patriot demonstrated during the Gulf War, ballistic missile defenses are crucial to protect our troops and allies against madmen or rogue nations.[4]

George Bush, *National Security Strategy of the United States*, January 1993

The proliferation of weapons of mass destruction represents a major challenge to our security.[5]

Weapons of mass destruction--nuclear, biological, and chemical--along with the missiles that deliver them, pose a major threat to our security....[6]

William Clinton, *National Security Strategy of the United States*, July 1994

INTRODUCTION

The Persian Gulf War confirmed the utility of using tactical ballistic missiles as a political terror weapon. Iraq's launching of Scud missiles against Tel Aviv on 18 January 1991 threatened to draw Israel into the war and forced the United States to respond by rushing Patriot Air Defense systems to the region to protect key Israeli population centers. While the political and strategic significance of the 88 tactical ballistic missiles[7] Iraq launched at Israel and Saudi Arabia during the war appears obvious, the tactical effect of these missiles on the battlefield is less apparent.[8]

Despite growing evidence of technological advances in guidance and warhead systems that warrant concern, much of the current literature ignores the operational and tactical impact of ballistic missiles on the battlefield. Even the US Army's most forward looking document, US Army Training and Doctrine Command (TRADOC) Pamphlet 525-5, *Force XXI Operations: A Concept for the Evolution of Full-Dimensional Operations for the Strategic Army of the Early Twenty-First Century*, (1 August 1994), does not address the impact of these weapons on tactical operations. Emphasizing the strategic and political impact of weapons of mass destruction, the pamphlet contends that

> the security challenge having the most serious ramifications for US interests will come from the proliferation of WMD [weapons of mass destruction]. The strategic-political effects of WMD overshadow their military utility. WMD and theater ballistic missiles (TBMs) allow an adversary to extend its operational and strategic reach.[9]

While the extreme physical devastation and psychological dislocation resulting from the use of ballistic missiles and weapons of mass destruction will have far reaching political and strategic effects, their impact on tactical military operations will also be significant. Thus, this monograph breaks new ground and demonstrates why military leaders and planners should pay more attention to the emerging tactical threat from ballistic missiles, unconventional warheads, and weapons of mass destruction.

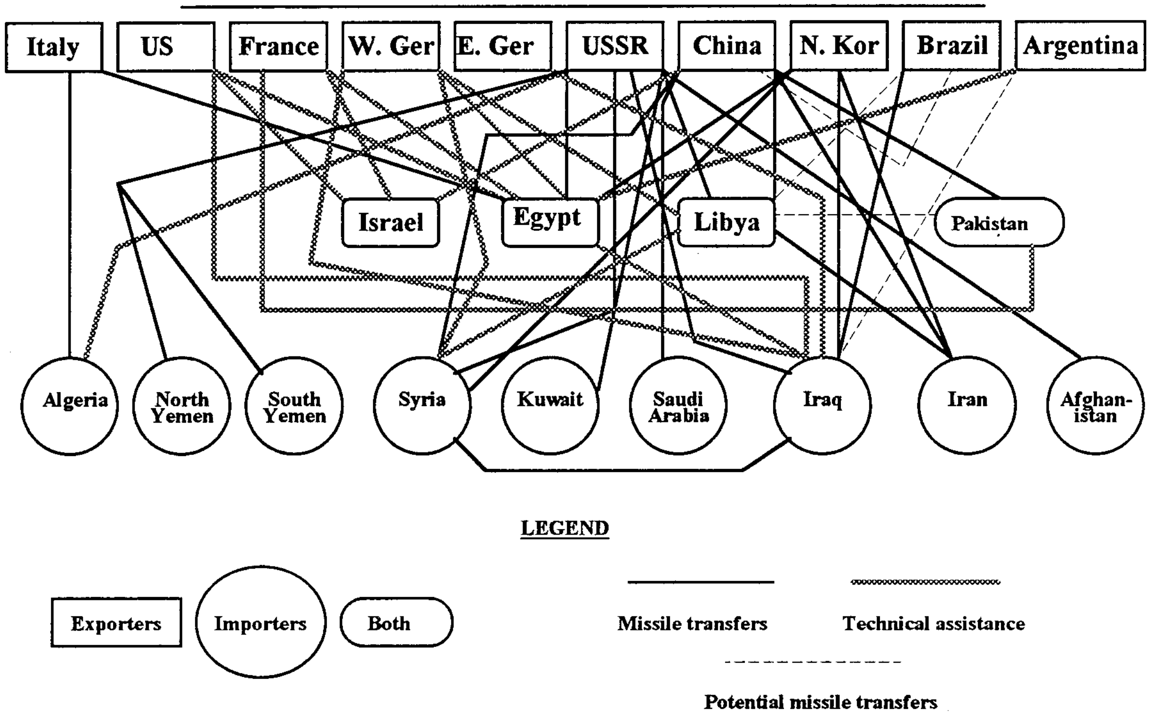
Changes in the nation's military strategy, the continued global proliferation of ballistic missiles and weapons of mass destruction, and the pace of technological improvements to these systems mandate that commanders and planners understand the military significance of ballistic missiles on the tactical battlefield. With the end of the Cold War, the nation's shift from a strategy of forward presence to an increased reliance on force projection operations means that the armed forces will deploy to unstable areas of the world where host nation defense forces may be limited and force protection will be an immediate priority. Within that environment, the proliferation of tactical ballistic missiles among Third World nations combined with the predilection of some leaders to use them against US forces--Libya in 1986 and Iraq in 1991--provides both the means and precedent for a TBM attack on US forces in the future.

While current missile accuracy may limit the effectiveness of a conventionally armed tactical ballistic missile as a point weapon, the addition of a chemical, biological, or nuclear warhead makes the TBM militarily significant regardless of circular error probable (CEP).[10] The improvements in missile accuracy and range that have occurred over the last twenty years will continue, making both conventionally and unconventionally armed missiles an ever increasing threat to tactical forces. Finally, attempts at counter-proliferation may slow, but will not stop the emergence of these evolving weapon systems in the arsenals of developing countries. Several developing nations, including some that are hostile to the United

States, possess indigenous missile and warhead programs that render them relatively impervious to American or international arms control and counter-proliferation efforts. As the following chart demonstrates, some missile producing nations, irrespective of their relationship with the United States, also have export agreements or development partnerships with nations that are either hostile to the United States or embroiled in regional disputes that may involve US forces at some point in the future.[11]

TRANSFERS OF MISSILES AND RELATED TECHNICAL ASSISTANCE

from Industrialized Countries to Developing Countries, 1960-1994



Sources include: Janne E. Nolan, *Trappings of Power: Ballistic Missiles in the Third World,* (Washington: DC: The Brookings Institution, 1991), 18; Martin Navias, *Ballistic Missile Proliferation in the Third World,* (London: Brassey's, 1990), 29-31. For additional references see note[12]

This monograph highlights the history and development of the ballistic missile, surveys the current TBM threat environment, and examines the potential primary and secondary effects ballistic missiles have on the tactical commander's battle space during four phases of force projection operations--deployment and early entry, build up and expansion, decisive operations, and redeployment and post-conflict. To validate the potential TBM threat to tactical units, the threat survey outlines the range, accuracy, and warhead capabilities of contemporary missiles as well as lists the nations most likely to possess them. This monograph employs three criteria to evaluate the primary and secondary effects that a ballistic missile attack may have on the tactical aspects of force projection operations. The criteria are: the potential for increased casualties, the diversion of resources from the main effort in response to a TBM attack or threat of attack, and the degree of disruption (de-synchronization) an attack creates in the commander's battle plan.

CRITICAL CONCEPTS

The discussion of ballistic missile development and current threat environment set the conditions for an informed examination of the effect of these weapons on tactical military operations. Therefore, it is important to define the three concepts--primary effect, secondary effect, and tactical battle space--that form the boundaries of this monograph.

Primary effects are those that occur directly from a missile attack or from the threat of such an attack. In the Persian Gulf War, tactical commanders planned for Scud attacks on their units as they entered the theater, trained in assembly areas, passed through the breach, conducted decisive combat operations, and even as they signed the Armistice at Safwan Air Field. Although the Iraqis did not use their Scuds to attack maneuver forces, the threat of an attack, particularly in view of Iraq's known use of chemical weapons and perceived nuclear potential, compelled tactical commanders to prepare appropriately for their use. A successful attack on the ports, the assembly areas, or the breach may have disrupted Allied actions and greatly increased casualties.

While primary effects demonstrate the first tier, direct impact of ballistic missiles on tactical forces, secondary effects are those tactical effects that devolve indirectly from a friendly response to the political and strategic use or threatened use of ballistic missiles by enemy forces. For example, in the Persian Gulf War, the political impact of Scud attacks on Israel forced General Schwarzkopf to divert 40% of his daily air sorties from attacking Iraqi formations and lines of communication to hunting Scud launchers in the Western Iraqi Desert. His actions represented a major diversion of combat power, extended the air effort by more than a week, and prevented the Army Central Command (ARCENT) from meeting its targeting goals prior to starting the ground war.[13] Moreover, the same attacks required the United States to use a portion of its limited airlift assets to bring Patriot units into Israel and other sites in the theater. In future force projection operations, the 94 C-5A Galaxy and 19 C-141 Starlifter sorties needed to fly a six-battery Patriot battalion into a theater of operations will consume precious amounts of strategic lift and detract from the commander's ability to rapidly build up combat forces or a logistical base.[14]

While most sources acknowledge the political, strategic, and even operational impact of ballistic missiles, the focus of this monograph is on the effect of these weapons on the tactical commander's battle space. Battle space, as defined by the US Army's keystone warfighting doctrine, Field Manual 100-5, *Operations*, is a physical, three-dimensional volume that extends to the maximum capabilities of the commander to acquire and engage the enemy. In examining the impact of ballistic missiles on the tactical commander's battle space, the type, quantity, and capability of the assets at the tactical commander's disposal delimit the area concerned. At the tactical level of war, "corps and divisions fight...battles and engagements." Thus, for the purpose of analysis, this monograph places the upper limit of tactical battle space at the area defined by the capabilities of the assets organic to an army corps; the lower limit extends down to the area associated with a maneuver company.[15]

THE HISTORY, DEVELOPMENT, AND CURRENT STATUS OF BALLISTIC MISSILES

In light of the recent use of ballistic missiles in the Middle East, a mythology has arisen concerning TBMs. Some of the erroneous perceptions include the beliefs: that all missiles are alike; that the Persian Gulf War was the first time ballistic missiles had been used in combat; that they are extremely inaccurate and only good for terrorizing urban populations; and that they are militarily insignificant weapons.[16] An indepth analysis of the history, development, and use of ballistic missiles dispels these misconceptions and highlights their potential impact on the tactical commander's battle space.

Ballistic and Cruise Missiles

Largely due to the intense publicity the use of the "Scud" missile received during the Persian Gulf War, it has become incorrectly the *nom de guerre* for the several models of surface-to-surface missiles present in the world today. In reality, there are two types of surface-to-surface missiles--ballistic missiles and cruise missiles. A ballistic missile is an unmanned, rocket-powered weapon. It receives power from its engines and guidance from the guidance system only in the ascent. In the descent, it follows a ballistic (unpowered and unguided) trajectory. The majority of ballistic missiles are exo-atmospheric.

Conversely, a cruise missile is an unmanned aircraft that uses an air-breathing engine similar to those used in airplanes to propel it. Most modern versions employ inertial guidance systems as well as terrain comparison programs that link television or infrared images of the terrain to computer-generated images of the planned attack route to achieve pinpoint accuracy. Like an aircraft, the cruise missile is endo-atmospheric. Unlike most aircraft, however, the cruise missile provides an extremely small radar cross section and is therefore more difficult for air defense systems to detect and engage.[17]

Early Ballistic Missile History

Although the use of rockets and missiles in war extends back to Tamerlane's Battle of Delhi in 1399, the slow pace of technical advancement resulted in only sporadic employment of these weapons in the ensuing centuries. A brief flurry of interest reemerged around 1800 with the adaptation of an Indian rocket by Sir William Congreve for use by the British Army. In 1806, after setting the town of Boulogne, France afire with his rockets, Congreve proclaimed that, "the rocket is, in truth, an arm by which the whole system of military tactics is destined to be changed." Yet despite Congreve's prophetic comment, the useful development of rockets and missiles as weapons of war had to wait until the twentieth century.[18]

Modern surface-to-surface missiles first saw wartime service with the firing of V-1 and V-2 weapons against London, Paris, Antwerp, Liege, and Brussels during the latter stages of World War II. The V-1 "flying bomb" was a small cruise missile powered by a pulse jet that "buzzed" as it flew. It traveled at speeds up to four hundred miles per hour at altitudes between 3,000 and 5,000 feet and carried a ton of explosive. Early models ranged out to 250 kilometers. Later in 1945, the Germans boosted the range to 400 kilometers by replacing certain portions of the airframe with plywood and reducing the size of the warhead. In a final effort to increase the range of the missile, the

Germans slung the V-1 under a Heinkel-111 airplane, creating the first air-launched cruise missile. The combined range of the aircraft and missile extended to nearly 1300 kilometers. Its rudimentary guidance system kept the V-1 accurate to within 10 kilometers for every 160 kilometers of flight. Although quite inaccurate by modern standards, the V-1 was accurate enough to strike large urban areas such as Greater London.[19]

The V-2 was a single-stage, liquid-fueled ballistic missile equipped with an inertial guidance system. It weighed almost thirteen tons, carried a one ton warhead, and had a range of 350 kilometers. Powered by nearly nine tons of alcohol and liquid oxygen and controlled by gyroscopes or radio signals that moved large graphite vanes located behind the jet, the missile rose vertically for six miles before automatic controls turned it to forty-five degrees for its final climb. Once it attained a speed sufficient to reach its intended range, the engine shut off and the missile flew in a "gigantic parabola" to the target. At its apex, the missile climbed to a height of fifty miles. Its peak speed was four thousand miles per hour; it made the flight from Germany or the Netherlands to London in three or four minutes.[20]

In the last year of the war, the Germans successfully launched 19,395 V-1 cruise missiles and 2,952 V-2 ballistic missiles at cities in England and on the Continent. While Hitler's *Vergeltung* or "retaliation" campaign had little or no strategic effect on the Allied war effort, it did inflict immense physical damage, killing over 13,000 civilians and soldiers, and seriously wounding at least another 25,000.

More importantly, the V-weapons had an immense psychological impact on the populace. Of these missiles, Winston Churchill wrote

> [they] imposed upon the people of London a burden perhaps even heavier than the air-raids of 1940 and 1941. Suspense and strain were more prolonged. Dawn brought no relief, and cloud no comfort....The blind impersonal nature of the missile made the individual on the ground feel helpless. There was little that he could do, no human enemy that he could see shot down.[21]

Interestingly, although both missiles carried the same size warhead, the V-2 caused nearly twice as many casualties as the V-1. The slower speed of the V-1 permitted Allied planes and antiaircraft artillery to intercept it occasionally, while its engine noise served to warn people to take cover. Conversely, the V-2's supersonic speed guaranteed the penetration Allied air space, while its lack of engine noise made the missile's impact a surprise, preventing any manner of early warning or protective action.[22]

General Sir Frederick Pile, Commander of the Anti-Aircraft Command and Britain's leader in the defense against the V-1 and V-2 missiles during World War II, was quite sanguine about the prospects of what he called "robot warfare". He believed that "the bomber which today [1949] necessitates a group of highly trained personnel will in its turn become a robot machine of the rocket-propelled type."[23] While Pile appears to have overstated his case a bit, the continued improvements in ballistic and cruise missiles since World War II may still prove him correct. His associate, Mr. Duncan Sandys, British Minister of Parliament and chairman of Churchill's "Crossbow" Committee on air defense, may have been more on target.

In his post-war report to the British Cabinet Sandys commented,

> "that the advent of the long-range, radio-controlled, jet-propelled projectile has opened up vast new possibilities in the conduct of military operations. In [the] future, the possession of superiority in long-distance rocket artillery may well count for as much as superiority in naval or air power."[24]

Over the last fifty years, what Duncan Sandys hinted at in 1945 has indeed occurred. Ballistic missiles have retained their characteristic ability to penetrate enemy air space, while advances in technology have led to improvements in accuracy and lethality. By the mid-1990s, ballistic missiles have developed to the point where, in some situations, their military utility rivals that of combat aircraft.

Recent Ballistic Missile Development

Despite losing the World War II, the Germans continued to influence missile development into the early stages of the Cold War. After the war, both the United States and the Soviet Union used captured V-weapons (and German scientists) in the early phases of their missile programs. Of the two superpowers, the Soviet Union, through its export of missiles to developing nations, did more to propagate the German ballistic missile legacy.[25]

Of the several potential Soviet missile systems available for export, the SS-1C or Scud-B missile (NATO designation) has become the *sine qua non* of developing ballistic missile programs. It is not without reason that the Scud missile has entered the lexicon of military planners and defense analysts as a synonym for tactical ballistic missile. The Soviet Scud-B is the most widely proliferated surface-to-surface missile in the world today.

As of early 1993, there were twenty-two countries with Scud-B missiles in their arsenals.[26]

Drawing heavily on the original V-2 design, the Soviet Union developed and mass produced the Scud-B in the 1960s for deployment with Soviet and Warsaw Pact forces. In response to requests from the then client states of Syria, Libya, and Egypt, the Soviets developed a special export version (designated R-17E), the first of which reached Egypt in 1973 and was used in the 1973 Arab-Israeli War. The export version had a throw weight of one metric ton (1,000 kg or 2,200 lb), a range of approximately 300 kilometers, and came with the same eight wheeled, high mobility Transporter-Erector-Launcher (TEL) used by the Soviets. Its circular error probable (CEP) ranged between 400-1,000 meters.[27]

Soviet Scud missile exports flourished from the 1970s through the early 1990s. In addition to Egypt, the following countries received Scud missiles from the Soviet Union: Iraq (1974 and again in the mid-1980s), Syria (1974), Libya (1976), and the People's Democratic Republic of Yemen (1979). The greatest transfer and indeed the largest employment of ballistic missiles since World War II took place in the late 1980s when the Soviets shipped approximately 2,000 Scud missiles to Afghanistan for use by the Afghan government against the guerrilla forces.[28]

From this nucleus of primary Scud importers, secondary and tertiary groups of Scud users have emerged. North Korea, for example, acquired Scud-B missiles and Transporter-Erector-Launchers from Egypt in 1981. In 1987, North Korea sent modified Scud-B missiles to Iran for use in the Iran-Iraq "War of the Cities". The North Koreans have since licensed modified Scud-B manufacturing lines in Egypt, Syria, Iraq, Iran, and possibly Cuba. These modified missiles have a slightly longer range--about 320 kilometers with a 2,200 pound warhead. Various sources estimate the accuracy of the modified missile at about 400-1,000 meters, the same as the basic Scud-B.[29]

In addition to building and exporting a modified version of the Scud-B, North Korea also initiated development of three extended-range variants of the missile. This effort took two different paths. The simpler of the two approaches merely made further modifications to the already modified Scud-B. By reducing the size of the Scud-B warhead, the North Koreans increased the range on their Scud Mod C missile to 500 kilometers. They may have also added an improved inertial guidance system to enhance the CEP. In 1990, for potentially as much as $500 million, Iran purchased Scud Mod C missiles and North Korean assistance in converting an Iranian missile maintenance facility to produce indigenous Mod C missiles. North Korea followed up this missile transfer with the sale of Mod C missiles to Syria--about sixty missiles and 12 TELs began arriving in April 1991.[30]

The more difficult of the two approaches North Korea took to increase the range of the modified Scud-B missile involved a complete redesign of the missile system based on "Scud" technology. The estimated range of the Scud Mod D or Nodong 1 missile is between 1,000-1,300 kilometers, a distance that includes all of the Korean peninsula, Kyoto and Osaka in Japan, Beijing and Shanghai, and parts of Russia. The North Koreans had trouble with the accuracy of the Nodong 1 missile and may limit deployment until the Nodong 2 or Scud Mod E missile is available. Reports estimate that the Nodong 2 will have a range between 1,500 and 2,000 kilometers. Unlike the Nodong 1 and its predecessors, the Nodong 2 is either a multi-stage or clustered missile. North Korea's inexperience with these types of missiles may delay fielding of the Nodong 2.[31]

China has followed the example set by the Soviet Union and North Korea in missile development and export sales. The Chinese have greatly expanded their ballistic missile production since their initial foray in the 1960s. Like the North Koreans, the Chinese have pursued two lines of missile production. The CSS/*Dongfeng* line of strategic nuclear missiles, designed for use by the People's Liberation Army, expanded from the CSS-1 deployed in 1967 to include the CSS-2, CSS-3, and CSS-4 (known in China as the DF-3, DF-4, and DF-5). The CSS-2 (DF-3) has a range of 3,000 kilometers and a CEP of 1,000 meters. The Chinese sold a conventional version with a range of 2,700 kilometers to Saudi Arabia in 1987. The CSS-3 (DF-4) and CSS-4 (DF-5) missiles are two-stage, liquid-fueled missiles with ranges of 7,000 kilometers and 10,000 kilometers.[32]

In 1984, the Chinese began a second line of missile production aimed primarily at the Third World export market. The "M" family of missiles are solid-fueled, tactical ballistic missiles. The M-9 is a single-stage missile with computer-aided inertial guidance and terminal control. It carries a 500 kilogram payload, has a range of 600 kilometers, and a CEP of 300 meters. The Chinese have sold the M-9 to Syria and Libya. The M-11 is a two-stage system with the same guidance and payload characteristics as the M-9. It has a range of 300 kilometers. Reports indicated that Pakistan had purchased the M-11 in 1991, but as of October 1994 had not yet received operational missiles from China. Part of this purchase may have included Chinese technical assistance to help Pakistan with its own short-range *Hatf* I (80 km) and medium-range *Hatf* II (300 km) ballistic missile programs.[33]

Of all the missile importers and exporters discussed so far, Iraq has been the most profligate builder, developer, and user of Scud missiles and their derivatives. In the early-1980s, Iraq initiated a missile development program that started with the building of rocket artillery to gain experience and graduated to the modification of imported Scud missiles before the Allied bombing in early 1991 and subsequent United Nations sanctions and inspections combined to shut it down. In 1982, Iraq fired its first Scud-B missile at Iran. The 300 kilometer range of the missile, however, proved inadequate to strike the Iranian capital, Teheran, located 500 kilometers away from the Iraqi border. To overcome this shortfall, the Iraqis modified their Scud-B missiles by lengthening the fuel tanks and lightening the warhead. This resulted in two longer range missiles, the Al Hussein, with a range of 650 kilometers and the Al Abbas, with a range of 950 kilometers. Although they increased the range of their missiles, the Iraqis did nothing to improve their accuracy. This only exaggerated the error already present in the generic Scud-B guidance system (CEP 450 meters). The resultant doubling and trebling of range created a similar effect with respect to circular error probable. The Al Hussein had a 1,000 meter CEP and the Al Abbas fell out at around 1,500 meters.[34]

Over the course of the Iran-Iraq War (1980-88), the two sides fired over 478 Scud-type missiles at each other. Iran fired about 117 North Korean Scud-B missiles at Iraq, while the Iraqis launched a mixture of approximately 361 Scud-B, Al-Hussein, and Al-Abbas missiles. During the Persian Gulf war, Iraq used its Al-Hussein missiles primarily against targets in Israel and its longer range Al-Abbas missiles against Saudi Arabia and Bahrain.[35]

Ballistic Missile Use

YEAR	EVENT	MISSILE	QUANTITY
1944-45	German attacks on Allies	V-2	2,952
1973	Egyptian and Syrian attacks on Israel	Scud	3
1980-88	Iran-Iraq War		478
	Iraq	Scud*	361
	Iran	Scud	117
	"War of the Cites"		
	Iraq	Scud*	189
	Iran	Scud	77
1986	Libyan attacks on US Coast Guard base, Lampedusa Italy	Scud	2
1989-91	Afghan Government use on Mujahideen	Scud	1,228 to 2,000
1991	Iraqi attacks during the Persian Gulf War	Scud*	88
	On Israel		42
	On Saudi Arabia		43
	On Bahrain		3
1994	Yemeni Civil War	Scud	Unknown

*Scud and/or derivative missiles.[36]

Current Ballistic Missile Tactics

Ballistic missiles have been employed in war with increasing frequency. By themselves, however, ballistic missiles are useless. Only when employed as part of a system that includes both targeting and launching mechanisms do ballistic missiles attain any significance. As both Adolph Hitler and Saddam Hussein demonstrated with their selective use of missiles against cities, accurate targeting is not always a prerequisite for successful ballistic missile employment. A launching mechanism, however, is crucial. Without a launcher, ballistic missiles are like bullets without a rifle--they simply cannot get into the air.

Prior to the Persian Gulf War, intelligence analysts used the number of Transporter-Erector-Launchers a nation imported from the Soviet Union as one indicator of that nation's capability to employ its ballistic missile force. As events during Operations Desert Shield and Desert Storm highlighted, however, some nations have ceased relying on imports and begun building an indigenous fleet of launchers. Iraq developed a number of its own Transporter-Erector-Launchers and Mobile-Erector-Launchers (MELs) as well as separate transport vehicles for its Al-Hussein and Al-Abbas missiles. The first TEL was the Al-Waleed TEL, a Saab-Scania tractor-trailer with an erector-launcher assembly similar to the one used on the Soviet supplied Scud-B TEL. Less sophisticated, the MEL consisted of a truck with a simple hydraulically elevated launch rail. Additionally, the Iraqis used fixed launch sites constructed from formed concrete ramps and steel rails and located primarily in the H2/H3 Airfield complexes. They also developed a missile transport vehicle based on a civilian tractor-trailer.[37]

In a TEL supported launch, the Iraqis sent the vehicle to the missile transfer area at the appropriate time to receive the missile from a transport vehicle. From there it proceeded to the pre-surveyed launch site where the missile was fueled and launched. The transport vehicle and all other vehicles returned to "fortified" areas as soon as their tasks were complete. In a MEL supported launch, the MEL and the transport vehicle met at the launch site at the appointed time. Crews transferred the missile from the transport vehicle to the MEL, fueled and launched the missile. As in the TEL supported launch, all support crew and vehicles left the launch site as soon as they had accomplished their specific tasks. These tactics worked well during the Persian Gulf War. Although restricted by Allied air operations to moving only at night, Iraqi missile crews succeeded in launching their missiles and, for the most part, escaped unscathed.[38]

Third World Motivations: Ballistic Missiles vs. Aircraft

The rapid proliferation of ballistic missiles among developing countries over the last decade has spawned a debate about their actual ability to affect the conduct of tactical operations. The issue centers on whether ballistic missiles or combat aircraft represent a more efficient means for developing nations to exercise military power. At first glance, aircraft appear more advantageous. They are reusable, more versatile, and capable of achieving better accuracy than their single-shot ballistic brethren. Ballistic missiles, however, confer prestige and enhance deterrence, two benefits that combat aircraft do not necessarily provide. Moreover, in certain situations, ballistic missiles add more to a nation's warfighting capability than combat aircraft do.[39]

There is by no means unanimity of opinion on this issue. Several analysts hold that ballistic missiles do not carry enough payload nor are they accurate enough to make them cost-effective unless armed with nuclear warheads. This belief dominated superpower thinking about nuclear weapons and ballistic missiles for years, but with advances in technology and the deployment of the US Army's extremely lethal Tactical Missile System (ATACMS) this attitude may change. Others see current utility as limited, but allow that the rapid proliferation of improved positioning and guidance systems and enhanced warhead technologies will add to the usefulness of ballistic missiles on the battlefield. This opinion supports the contention that ATACMS may represent a new stage in ballistic missile development similar to the one presaged by the early Scud missile. Finally, a small minority view holds that ballistic missiles are applicable to today's battlefield.[40]

Although a debate rages over the military utility of ballistic missiles, most analysts agree that any measure of military effectiveness must involve five characteristics: range, payload, accuracy, rate of fire, and speed of delivery. Reliance on these characteristics, however, sanitizes the argument and excludes four other important features that complicate analysis even further: pre-launch survivability, warhead type, cost, and relative ability to employ either missiles or aircraft in actual combat. A careful examination of all nine factors demonstrates that while ballistic missiles do not fly as far as combat aircraft nor carry as much ordnance, their improving accuracy and warhead yield as well as lower cost and greater pre-launch survivability make them a more efficient means of attacking an adversary than combat aircraft. Most importantly, their speed enables ballistic missiles to penetrate enemy air space and deliver ordnance in combat, a task that most Third World air forces have found extremely difficult to accomplish, especially when fighting the United States. Under these circumstances, ballistic missiles are not only a more efficient and effective means for Third World nations to attack deploying US tactical forces, they are often the only means available. This conclusion is not lost on the leaders of developing countries. More than anything else, it drives their procurement of ballistic missiles and constitutes a continuing threat for United States forces during force projection operations.

Range, Payload, and Pre-Launch Survivability

The preponderance of ballistic missiles available to developing countries have relatively short ranges and limited payloads. Their ranges extend from approximately 300-1000 kilometers, while their payloads measure between 1,100-2,200 pounds. Some missiles, including the Israeli Jericho II(1,500 kilometers/1650 pounds), the Saudi Arabian/Chinese DF-3A (2,700 kilometers/4,400 pounds), and the Indian Agni (2,500 kilometers/1,400-2,000 pounds), possess longer ranges and greater payloads. These missiles, however, are still no match for most combat aircraft, especially when air refueling is available to extend an aircraft's combat radius.[41]

Although the majority of ballistic missiles fly much farther and carry far more ordnance than Third World artillery (45 kilometers/220 pounds or less), they pale in comparison with combat aircraft. The average operational payload of an F-16C fighter with a combat radius of almost 1,400 kilometers is 4,000 pounds or roughly the equivalent of two Scud-B missiles (300 kilometers/approx. 2,200 pound payload) or ten Al Hussein missiles (650 kilometers/approx. 400 pound payload). The SU-24 can fly 950 kilometers and carry 6,600 pounds of weapons or the equivalent of three Scud-B or sixteen Al Hussein missiles.[42]

Despite their moderate ranges and payloads, ballistic missiles retain some advantages over combat aircraft. In some geo-strategic situations, range does not matter. During the Iran-Iraq War, "almost every militarily significant target in Iraq [was] within 300 kilometers [or Scud missile range] of Iran".[43] Likewise, during the Persian Gulf War, Iraq used its longer range Al Hussein missiles (650 kilometer) to hit targets in Israel. In the Far East, the South Korean capital of Seoul lies within 45 kilometers of the Demilitarized Zone (DMZ), while the major port city of Pusan, at the southern tip of the Korean peninsula, is only 380 kilometers away from North Korea. Both areas are well within the range of North Korean ballistic missiles.[44]

Moreover, the need for combat aircraft to take off and land from fixed, known facilities limits their pre-launch survivability. Only when conducting a preemptive strike or during an opening attack on enemy territory do aircraft obtain a pre-launch survivability similar to ballistic missiles. For the rest of the conflict, aircraft and the bases from which they fly are at much greater risk than are mobile missile launchers. Conversely, even moderately ranged (300-1,000 kilometers) ballistic missiles possess greater operational flexibility and survivability. The range and mobility of ballistic missiles expand their launch area and increase the difficulty an adversary will have in finding and suppressing them. During the Persian Gulf War, the United States and its allies experienced great difficulty in locating and destroying mobile Iraqi missile launchers. A Congressional report on intelligence achievements during the war concluded that the United States failed to destroy a single mobile launcher. Moreover, the *Gulf War Air Power Survey* commissioned by the United States Air Force concluded that "there is no indisputable proof that Scud mobile launchers...were destroyed by fixed-wing aircraft....the level of effort put into the hunt for the launchers...does not appear to have been very effective...." Even with Coalition aircraft flying Scud patrols over Iraq and in some cases visually identifying the launch flume, the mobile Scud launchers escaped the area before the aircraft could attack them.[45]

Accuracy, Rate of Fire, and Warhead Type

Under the correct conditions, combat aircraft are extremely accurate and capable of dropping unguided, conventional high-explosive bombs within 5 to 15 meters of the target. When equipped with precision-guided munitions, the accuracy of combat aircraft improves to within a few feet of the target. In combat against a similarly equipped enemy armed with modern air defense fighters, surface-to-air missiles, and antiaircraft artillery, however, pilots may have difficulty finding and staying on target long enough to deliver their ordnance accurately. Even in Operation Desert Storm, where Coalition forces had unchallenged command of the air, aircraft accuracy against Iraqi ground forces was initially quite poor. It improved only after pilots decreased their attack and release altitudes and switched to dropping laser-guided bombs.[46] Considering that American and some European aircraft and air forces are undoubtedly the most sophisticated and best trained forces in the world, it is unlikely that for the foreseeable future any Third World country will develop or acquire combat aircraft, precision munitions, and pilots capable of achieving similar pinpoint accuracy either on a target range or in combat. Thus, when comparing aircraft and missiles, one must not blindly accept claims of superior accuracy, but should view them in the context of what is possible during actual combat operations.

Despite the questionable accuracy of Third World aircraft in actual combat, ballistic missiles armed with high explosive conventional warheads are still not as accurate as even degraded combat aircraft. Missile accuracy, however, depends a great deal on the character of the intended target. Most foreign ballistic missiles deployed in the early 1990s use guidance systems developed in the 1960s and 1970s. These missiles are ideal for large soft area targets such as cities, multi-strip air fields, port complexes, and expansive logistics or command and control sites. Used individually, their high explosive warheads have limited utility against separate point targets that require greater accuracy. Still the destructiveness of a conventional Scud-type missile with a 450 meter CEP bears mention. The missile's supersonic speed imparts considerable energy upon impact. The missiles fired during the Iran-Iraq War typically dug craters at least 10 meters across and several meters deep. Even when fired separately their cumulative damage, as experienced for instance by Israel during the Persian Gulf War, is worth note. Over a 43 day period, the nineteen Iraqi missile attacks on Tel Aviv damaged over 4,000 buildings including about 3,900 apartments and homes, 330 public buildings, 20 schools, and over 50 businesses.[47] When fired in salvos--Iraq managed to launch six in one three minute period during the second week of Operation Desert Storm--the high rate of fire intensifies the attack and adds to its overall cumulative effect.[48]

Unfortunately, developing nations will not remain satisfied with 20-30 year old missile technology. Just as they are seeking improved aircraft and surface weapons, Third World countries will endeavor through either indigenous production or foreign purchase to upgrade their missile arsenals.[49] One of the factors motivating these nations to improve the accuracy of their missiles is that the developed nations have demonstrated that it is indeed possible to build both better guidance systems and enhanced conventional and unconventional warheads. In the 1980s, the Soviet Union made great strides in improving the accuracy of their missiles. For example, they replaced the Scud-B (CEP 450 meters) with the SS-23 (CEP 320 meters) and the SS-12 Scaleboard (CEP 650 meters) with a new SS-12M version (CEP 300 meters). There are even reports of a new Scud-D missile with a CEP of 50 meters.[50]

Dramatic advancements in ballistic missile technology should not surprise the leaders of the developed nations. After all, the United States more than doubled the range and reduced the CEP of its medium range ballistic missile tenfold when it replaced the Pershing 1A (CEP 400 meters) with the Pershing II (40 meters).[51] Additionally, the pace of missile development in Third World countries is progressing at a faster rate than it did in the United States and the Soviet Union. Although developing countries on the whole began development of ballistic missiles about 20-25 years after the United States and the Soviet Union, they have benefited from the scientific ground work laid down by scientists in those nations. As a result, the progress over time made by Third World indigenous development programs has more than tripled that of the US and Soviet Union.[52]

Given the availability of advanced guidance technology, missile accuracy will improve significantly over the next decade. While extremely sophisticated guidance technologies like thrust vector nozzles, cryogenic gyroscopes, and antiradiation terminal homing mechanisms remain difficult for developing countries to obtain, Third World countries can purchase low cost alternatives, including GPS/GLONASS receivers and television and infrared comparators, that will enhance the accuracy of their missiles dramatically. With improved accuracy, ballistic missiles will rival combat aircraft in their ability to attack point targets. This will make them an even more attractive option for Third World leaders to use against deploying United States forces.[53]

Another way to enhance the military effectiveness of a ballistic missile is to improve its warhead yield. This is possible through the use of improved conventional submunitions or fuel-air explosives as well as unconventional chemical, biological, or nuclear warheads. Given the lethality of these warheads, concern over accuracy declines, making even 1970s vintage missiles a potent threat to US tactical forces.

Submunitions warheads have been part of superpower arsenals for some time. The Soviets led the way with development of submunitions warheads for their second and third generation missiles, including a Scud runway penetration warhead with forty 12-kilogram submunitions and an anti-personnel warhead with one hundred 5-kilogram submunitions. The United States Army Tactical Missile System (ATACMS) holds up to 1,000 small submunitions and the Multiple Launch Rocket System (MLRS) carries 677 bomblets weighing about one-half pound each. Submunitions are currently available in the Third World either through the sale of former Soviet hardware or through indigenous development and sale of products such as the Egyptian Sakr-80 and the Brazilian Astros II rocket system, both of which have optional submunition warheads.[54]

There are two classes of submunitions, "light" and "heavy", with the dividing line between the two somewhere around 10 kilograms (22 pounds). Assuming a 300 meter CEP, a warhead with 30 "heavy" (40 pound) submunitions would disperse one submunition every 110 meters (360 feet). The same warhead packing 1,000 "light" (1.1 pound) bomblets would land one bomblet every 19 meters (62 feet). Place this dispersion in the context of a force projection operation with United States Air Force aircraft unloading soldiers and materiel at a forward air base. The wingspan of a C-141 Starlifter is 49 meters (161 feet), that of a C-5A Galaxy is 68 meters (223 feet). As the following diagram demonstrates, "heavy" submunitions would theoretically leave these aircraft unharmed, while the dispersion of "light" submunitions guarantees that some aircraft would be hit.[55]

```
   Effect of Submunitions on Aircraft

"Heavy" Submunition    x-----------x
(110 meter dispersion)
C-5A Galaxy               w-------w
  (68 meter)
C-141 Starlifter           w-----w
  (49 meter)
"Light" Submunition    x--x--x--x--x
  (19 meter)
x = submunition          w = aircraft
     impact                   wingtip
        - = 10 meter interval
```

Using the notional air base outlined in figure 1 as a further example, the effects of several types of warheads including both classes of submunitions becomes apparent.[56] In the center of the runway, using a missile with a 300 meter CEP, the effect of a conventional high explosive warhead with a burst radius of 60 meters is minimal. While high explosive warheads will severely damage vehicles, aircraft, and buildings, the limited accuracy of a 300 meter CEP missile requires that several missiles impact before the probability of achieving significant damage occurs. One study conducted by the RAND Corporation concluded that an attacker would need to fire at least twelve ballistic missiles with unitary warheads to attain a fifty percent probability of cratering a runway. Remembering that Iraq managed to salvo six missiles in rapid succession only once during the Persian Gulf War, it seems the odds of achieving the rate of fire necessary to have just an even chance at impairing military operations are small. If the odds are against success with a 300 meter CEP missile, then a glance at the 900 meter CEP circle confirms the view that conventional high explosive ballistic missiles like the Iraqi Al Hussein (1000 meter CEP) are too inaccurate to affect military operations and are better employed as "terror" weapons.[57]

In contrast to the limited effect of conventional high explosive warheads, "heavy" submunitions would impact on several vulnerable areas of the air base, but leave only two of thirty submunitions on the runway. If the aimpoint was the center of the 400 foot wide parking apron, the total would increase to five submunitions. The impact of two rounds would crater the runway, temporarily impeding operations while the runway repair crew patched the holes. On the apron, given the density of aircraft and the likelihood of both primary and secondary explosions of ammunition and fuel, the level of damage would be much higher.[58]

Compared to "heavy" submunitions, "light" submunitions have an even greater destructive potential. Again with the aimpoint at the center of the runway in figure 1, a ballistic missile with a 300 meter CEP armed with "light" submunitions would place 65 of the 1,000 bomblets on the runway. These 1.1 pound bomblets are too small to damage the runway, but could damage aircraft on the runway or nearby taxiways and subsequently impair flight operations. If the same missile aimed for the middle of the apron, 160

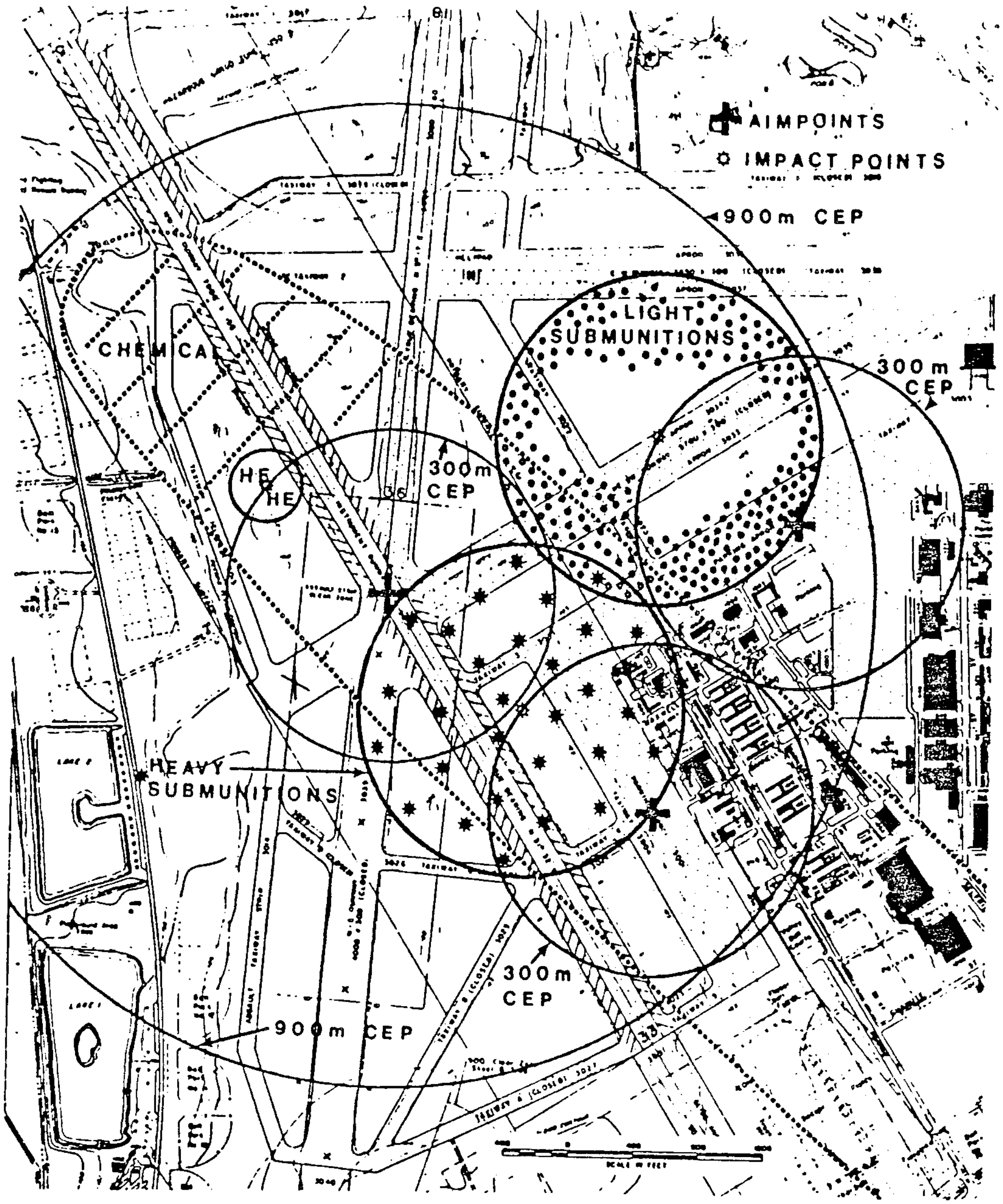


Figure 1

Effects of various ballistic missile warheads
on a United States air base

(Note: by definition only 50 percent of arriving
warheads would impact inside the CEP circle.)

bomblets would impact, inflicting substantial damage on the aircraft parked there and disrupting flight operations for a much longer time. In force projection operations, often only a limited number of fighter and transport aircraft are available for use by tactical forces. The loss of these aircraft either through destruction or the disruption of flight operations may reduce the ground commander's tactical combat power and prevent him from executing his tactical plan.[59]

In addition to submunitions, developing countries are seeking to buy or build chemical warheads for their ballistic missiles. These warheads are not only more lethal than submunitions, they are also more available throughout the Third World. Former Secretary of Defense Richard Cheney testified to Congress in 1991 that by the year 2000, thirty countries will have chemical weapons. Several of these nations, including Egypt, India, Iran, Iraq, Israel, Libya, North Korea, Pakistan, Syria, and Taiwan, are also developing their own ballistic missiles.[60]

The actual lethality of chemical warheads is subject to several factors including the type of agent employed, the weather, terrain, and the degree of protection. Indeed, due to difficulties with the size of particle dispersion and the possibility that the heat of reentry may destroy the chemicals, ballistic missiles may not be the most efficient way to dispense chemical weapons. For some countries, however, they may be the only way to attack deploying forces.[61]

Issues concerning their efficiency notwithstanding, chemically-armed ballistic missiles can seriously impair friendly tactical operations. Two published studies, one conducted in 1985 by the Defense Intelligence Agency and the other done in 1988 by the International Institute for Strategic Studies, concluded that a single Scud-B chemical warhead filled with thickened Sarin nerve agent would create an elliptical pattern almost four kilometers long and 450 meters wide. Within that pattern, the chemical would have lethal effects out to about 300 meters and cause death and illness as far as two kilometers downwind from the initial area of effect. The DIA study concluded that "all unprotected personnel in the area will be casualties."[62]

Figure 1 depicts such an attack on a United States air base. In this scenario, the chemical would cover most of the runway and portions of the apron and taxiway. While the lethality of the attack would decrease the farther away an individual was from the initial area of effect, operational flights from a contaminated runway are extremely hazardous. Most probably, commanders would divert aircraft to another airfield, accepting the inherent reduction in responsiveness and disruption of operations in order to fly from an uncontaminated air strip. This diversion of resources, either fighter aircraft or equipment moved by transports, could potentially deprive the tactical commander of the assets needed to defeat the enemy and would, at a minimum, complicate his planning immensely.

Instead of merely disrupting operations, an attacker intent on creating as many casualties as possible would need a minimum of four missiles to ensure coverage of the area with a potentially lethal dose to all unprotected troops. Figure 2 shows the effect of such an attack on deplaning troops. Unprotected soldiers caught within the first ellipse would die within one minute. In future deployment operations, commanders facing the possibility of a chemically-armed missile attack will need to decide whether to fly their soldiers into theater wearing hot, bulky, restrictive chemical protective clothing or risk suffering the potential consequences.[63]

CW warhead with thickened SOMAN
1500 m burst height
0.72 system reliability

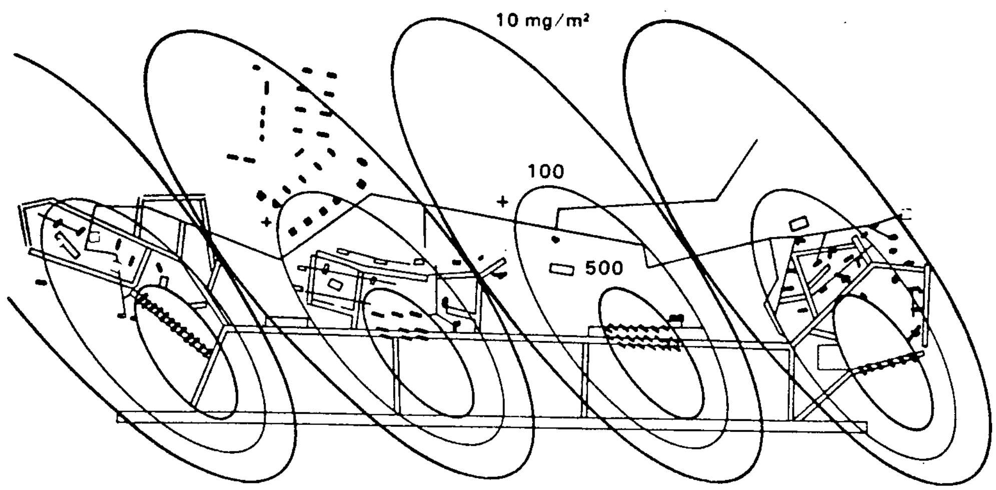


Figure 2
Chemical attack on deplaning troops

If chemical warheads represent an increase in lethality over high explosives and submunitions, biological and nuclear warheads are even more deadly. One analyst noted that in

> ...very rough terms, a relatively small (20-kiloton) nuclear warhead is 10,000 times as destructive as a 1-ton conventional explosive, 10-100 times as deadly as a nerve-agent warhead, but no more deadly than an anthrax warhead used against an unprotected population. Used against a well protected population, nuclear weapons are 100 to 1,000 times more deadly than chemical weapons and about 10 times as deadly as an anthrax warhead.[64]

The tremendous potential lethality of nuclear and biological weapons has motivated several developing countries to either acquire them from external sources or produce them internally. While for years there were only five established nuclear powers--China, France, Great Britain, the United States, and the Soviet Union--the breakup of the former Soviet Union has led to a division of nuclear assets among the new Commonwealth of Independent States.[65] Beyond this initial circle of nuclear states there are some, such as Israel, India, and South Africa, who are believed to possess nuclear weapons already and others who are actively seeking them. This latter group includes Japan, North Korea, Taiwan, South Korea, Pakistan, Brazil, Argentina, Egypt, Iran, Iraq, Libya, and Syria. To put this into perspective, only Japan is known not to possess ballistic missiles.[66]

Similarly, by the year 2000 as many as ten developing countries will be able to deploy biological weapons. Of those nations, eight--Egypt, Iran, Iraq, Israel, Libya, North Korea, Syria, and Taiwan--have ballistic missile programs.[67] To illustrate the magnitude of casualties possible from the impact of a biological warhead, consider a missile armed with 30 kilograms of anthrax spores, a biological pathogen particularly suited for dispersal from missiles and one that Iraq is known to have manufactured at its Salman Pak biological warfare facility. As one analyst noted, depending on the weather conditions and given some assumptions about release, lethal doses to unprotected adults would cover an area of 6 to 80 square kilometers, killing nearly all those affected within a few days. Moreover, anthrax is not contagious and therefore is suitable, like some chemical weapons, for discrete use. In contrast to even the most persistent chemical agents, some of which might pose a continuing hazard for a few weeks, anthrax spores can survive for decades in the soil.[68] While an adversary would not want to use biological warheads on an area he would some day want to occupy, they are ideal for denying territory--an airfield, a port, or an oil refinery--for a significant period of time. The effect of biological warheads on tactical operations is twofold. First, scores of soldiers would die or need evacuation for treatment, thereby depleting the commander's tactical combat power.

Second, the denial of a port of entry into a contingency theater could prevent soldiers from deploying rapidly enough to stop an attacking enemy. Diversion to a secondary port of embarkation would delay operations and carry the potential for increased casualties.

While biological and nuclear warheads represent the epitome of destructive yield, fuel-air explosives are running a close second. Used by the United States in Vietnam and apparently by the Russians in Afghanistan, there is evidence that some Third World countries are developing fuel-air explosives for their ballistic missiles. The basic principle is that the warhead would burst spreading a fuel-air mixture evenly across a wide area. Once dispersed, a detonator ignites the mixture to achieve an explosive effect much like the ignition in a cylinder of a car engine. The benefit of a fuel-air explosion, unlike that of a conventional warhead, is that the blast is spread evenly across a wide area. The peak over-pressure created by a 500 kilogram (1,100 pound) fuel-air explosion reaches 12.8 pounds force per square inch (psig) at a distance out to 130 meters from the outer boundary of the aerosol cloud. At 190 meters, the overpressure is 6 psig. By contrast, in a nuclear explosion, most authorities rate a "severe blast" at 5.2 psig and "moderate blast" at 2.7 psig. Atmospheric tests confirm that an overpressure of 6 psig is enough to destroy steel frame hangars and severely damage fuel storage tanks, while 5 psig will damage and overturn vehicles. Given these effects, it seems reasonable to conclude that a similar explosion would crush US Army command and control shelters, collapse soft-skinned vehicles such as fuel tankers, and cause large casualties among exposed soldiers. In essence, the blast effects of fuel-air explosives match those of a small nuclear bomb.[69]

Cost, Speed, and Ability to Employ in Combat

Advocates of airpower place a great deal of emphasis on the cost-effectiveness of aircraft over ballistic missiles, particularly with respect to unit cost per deliverable ton of ordnance by each system. This argument is overblown and based on a flawed assessment of the degree of penetration and the "reusability" or multi-sortie capacity of combat aircraft. When recalculated using an adversary's predicted ability to employ his aircraft in combat, the cost of aircraft far exceeds that of ballistic missiles, making TBMs a more cost-effective and realistic way for Third World leaders to attack deploying US forces.

Various estimates place the total cost of a single strike aircraft, including pilot training and several years of operations and support, at approximately $40 million dollars. These estimates treat aircraft infrastructure costs--air bases, repair facilities, and training and salaries for highly skilled maintenance personnel--as "sunk" and do not include them in their calculations. Based on a 95 percent probability of penetrating enemy air space, a lifetime total of 20 combat sorties, and a payload of 2.85 tons per sortie, one estimate concluded the cost per deliverable ton of ordnance by aircraft was $700,000.[70]

The same analysis placed the cost of a ballistic missile at $1 million. It properly noted that ballistic missiles provide a nation with a "potent system at much lower investment and infrastructure costs and with less need for highly-trained personnel...."[71] Given a penetration probability of 100 percent and a payload of .80 tons, the estimate figured that it cost $1.25 million per ton of deliverable ordnance. The study concluded that aircraft were more cost-effective than missiles. The author did, however, caveat his conclusions by stating that because nuclear warheads only required one sortie to generate immense destruction, missiles were a more cost-effective way to deliver them.[72]

Due to their accuracy, aircraft are probably better platforms for delivering conventional ordnance, but as discussed above, the accuracy of missiles is improving and the types of warheads are expanding. If nothing else, these factors should drive a re-examination of the calculations. More importantly, when one includes the actual number of combat aircraft needed to defeat ever improving Third World air defense systems and penetrate enemy airspace, the estimated cost per deliverable ton for combat aircraft rises dramatically.

The United States bombing raid on Libya in 1986 is an excellent case study. In Operation El Dorado Canyon, in order to penetrate Libyan airspace safely Navy A-7 and F/A-18 aircraft fired antiradiation missiles at air defense batteries, Navy EA-6 aircraft jammed Libyan air defense radars, F-14 and more F/A-18 fighters flew combat air patrol, and Navy E-2 aircraft provided command and control and early warning. All of these planes as well as the EF-111 aircraft that accompanied the F-111 bombers from England flew only to ensure penetration of Libyan airspace, they had nothing directly to do with bombing Libya.[73] One source indicates that more than 70 aircraft participated in the US Navy's portion of the attack. Of those 70, only 14 were bombers targeting locations in Libya; the rest were there to facilitate penetration or protect the two aircraft carriers used in the attack. Of the 14 A-6E Navy bombers involved, 12 actually dropped bombs.[74]

Using a 5:1 ratio as a rough comparison of participating aircraft to bombers, the cost per ton of ordnance delivered by aircraft rose from $700,000 to $11.36 million or nine times the cost of missiles.[75] While inexact, this example illustrates how the continued improvement of Third World air defense systems will increase the cost of conducting military operations with aircraft to a level where ballistic missiles will one day become cost-effective. If nations improve the accuracy of their missiles and obtain non-conventional warheads, that day may arrive even sooner than expected.

This example pitted the aircraft of the United States Air Force and Navy against the Libyan air defense system. Most analyses of cost-effectiveness follow this trend and cite historic cases of US aircraft in World War II, Korea, Vietnam, and Operation Desert Storm. They conclude that the highest aircraft attrition rate ever achieved over the course of any of these conflicts was 2 percent. This methodology is inappropriate for any analysis of the impact of ballistic missiles on US force projection operations. Using the attrition rate of US aircraft in a cost-benefit analysis of aircraft and missiles inverts the factors and skews the results. A more appropriate scenario examines the cost-effectiveness of Third World aircraft attacking an area defended by US Air Force and Navy aircraft and US Army air defense artillery. While no such studies have been conducted, several analysts have postulated about the percentage of aircraft attrition necessary to make ballistic missiles more cost-effective than aircraft. The figures run anywhere from 9 percent to 50 percent depending on the type and range of the missile.[76]

In the Persian Gulf War, the most recent conflict between a Third World air force and US armed forces, no enemy aircraft overflew United States or Coalition forces. The US and her allies had air supremacy then and are likely to continue to have it in any conflict in the foreseeable future. This would seem to drive the virtual attrition rate of Third World aircraft facing a US led deployment to well above 50 percent. In other words, the likelihood that an adversary would test his air force against that of the United States is small. Moreover, if he were to do so, the probable attrition rate of his aircraft would easily exceed 50 percent. Thus, in planning an attack on US forces, a

Third World adversary would probably find it more cost-effective to launch ballistic missiles instead of combat aircraft. While this may seem extreme, it was essentially Iraq's strategy during the Persian Gulf War. The Iraqis understood that the speed of their missiles gave them a chance at penetrating Coalition air space, something their air force could never do. At the very least, given the continued asymmetry between US and Third World air forces, it is reasonable to expect a potential adversary to employ a mixture of missiles and aircraft--maybe more missiles than aircraft--against deploying US forces. This expectation, combined with the likelihood that any future foe will have improved the accuracy and yield of his ballistic missiles, poses an ever increasing threat to deploying tactical forces.

Third World Missile Status

The ballistic missile threat to US tactical forces is real and quantifiable. Table 1 outlines this threat by nation and type of missile. All references to range, payload, and CEP are approximate and based on unclassified information.[77] While this threat information is as comprehensive as possible, limited access to a number of countries on the list prevents a complete and exact indexing of ballistic missile capabilities. Moreover, for reasons of deterrence, most nations may prefer to leave others guessing as to the actual extent of their capabilities. Nonetheless, this index highlights several trends in the emerging missile threat to US forces.

The most obvious trend is the spread of Scud and Scud-derivative missiles throughout the Third World. This is attributable to the proliferation begun by the Soviet Union and carried on since its collapse by nations such as Iraq and North Korea. Of particular note is the emergence of Chinese missiles in several developing countries. This indicates how effective the Chinese have become in marketing their more modern "M" series missiles and may demonstrate the viable limits of Scud-derivative proliferation.

Another notable characteristic concerns the range of most missiles. The majority of ballistic missiles have ranges under 1,000 kilometers. When equipped with improved guidance systems and warheads, these missiles will possess the range, accuracy, and lethality to pose a militarily significant threat to tactical units. Similarly, the majority of missile payloads can carry over 1,100 pounds. This is the minimum weight believed necessary to transport a nuclear warhead and may serve as an indicator of the direction some missile programs may follow in the future. Finally, a variety of warheads ranging from conventional high explosives and submunitions to unconventional chemical and nuclear munitions are already available to several developing countries. This proliferation of warhead technology underscores the potential threat to US forces employed in future force projection operations from ballistic missiles of ever increasing range, accuracy, and lethality.

THIRD WORLD BALLISTIC MISSILE INDEX

NATION	MISSILE	RANGE (kms)	PAYLOAD (pounds)	CEP (meters)	WARHEAD
AFGHANISTAN	Scud B	300	2200	400-1000	conv/chem
ALGERIA	Frog-7	70	960	400	conventional
ARGENTINA	Alacan	200	1100		
BRAZIL	MB/EE-150	150	1100		
	MB/EE-600	600			
	MB/EE-1000	1000			
	SS-300	300	2200		
CHINA	8610 (M-7)	180	1100		
	M-9	600	1100	300	conventional
	M-11	300	1100	300	conventional
	CSS-2/DF-3	3000	3000	1000	conv/nuclear
	CSS-3/DF-4	7000	2200		nuclear
	CSS-4/DF-5	10,000			nuclear
EGYPT	Scud B	300	2200	400-1000	conv/chem
	Scud C	500	1500	<Scud B	conv/chem
	Sakr-80	80	440		conv/submun
	Vector	600	1000		
INDIA	Privthi	250	1000		
	Agni	2500	1500-2000	50	
IRAN	Ognab	40	660		conventional
	Nazeat	130			
	Scud B	300	2200	400-1000	conv/chem
	Scud Mod C	500	1500	<Scud B	conv/chem
IRAQ	FROG-7/Laith	70	960	400	conventional
	Scud B	300	2200	400-1000	conv/chem
	Al Hussein	650	1100	1000	conv/chem
	Al Abbas	950	660	1500	conv/chem
LIBYA	Frog 7	70	960	400	conventional
	Scud B	300	2200	400-1000	conv/chem
	Al Fatah	950	1100		
	M-9	600	1100	300	conventional
NORTH KOREA	Scud Mod B	320	2200	400-1000	conv/chem
	Scud Mod C	500	1500	<Scud B	conv/chem
	Nodong 1	1000	2200		conv/chem
	Nodong 2	1500-2000			conv/chem
PAKISTAN	Hatf I/IA	80-100	1100		
	Haft II	300	1100		
	Haft III	600	1100		
	M-11	300	1100	300	conventional
SAUDI ARABIA	CSS-2/DF-3	2700	3000	1000	conventional
SYRIA	Frog 7	70	960	400	conventional
	Scud B	300	2200	400-1000	conv/chem
	Scud Mod C	500	1500	<Scud B	conv/chem
	M-9	600	1100	300	conventional
	SS-21	120	1000	30	conv/chem
YEMEN	Frog 7	70	960	400	conventional
	Scud B	300	2200	400-1000	conventional
	SS-21	120	1000	30	conventional

Table 1

THE EFFECT OF BALLISTIC MISSILES ON TACTICAL BATTLE SPACE

Since their employment in World War II, ballistic missiles have improved in range, accuracy, and warhead capacity to the point where they now pose a significant threat to tactical units. Although some examination of the impact of ballistic missiles on deployed forces occurred coincident to the discussion of their history and development, the following analysis specifically highlights the primary and secondary effects of ballistic missiles on the tactical commander's battle space during the deployment and early entry, build up and expansion, decisive operations, and redeployment and post-conflict phases of force projection operations. While anticipating continued ballistic missile development and the increased availability of advanced conventional and unconventional warheads, this analysis employs potential North Korean and Persian Gulf conflict scenarios as a backdrop for discussion. It superimposes events from the past on concerns of the present and technical developments from the immediate future to produce a vision of how a potential enemy might employ tactical ballistic missiles against US forces. With respect to the emerging threat from ballistic missiles and weapons of mass destruction, "Third World" does not mean third rate. In the context of force projection operations, a ballistic missile attack can have a militarily significant effect on tactical forces and in some cases, seriously damage their chances for success on tomorrow's battlefield.[78]

Deployment and Early Entry

United States forces are most vulnerable during the deployment and early entry phase of force projection operations. An enemy may be unwilling or unable to employ ground or air forces against deploying units, but can attack ports of debarkation with ballistic missiles from secure locations hundreds of kilometers away from the entry area.

During this phase, an enemy will attempt to prevent or delay US forces from entering the theater by using his ballistic missiles to attack ports, air fields, and logistics bases.[79]

The primary effect of such an attack would be to close the air field or port at least temporarily while surviving personnel treated casualties and removed debris. If the enemy employed submunitions in his attack, there is the likelihood of increased damage to arriving aircraft resulting in additional casualties and debris. In the case of a chemical attack on an air field, the number of casualties would increase, while the damage to facilities would decrease. Moreover, the presence of a chemical agent will limit flight operations and slow the inprocessing of newly arriving combat forces. In a scenario where the commander needed to transition forces rapidly from arrival in theater to combat operations, such an attack risks disrupting the flow of troops, upsetting the commander's tempo of operations, and potentially invalidating his plan. If the attack occurred on a tactical air field, the damage to aircraft would reduce the available sorties and disrupt the tempo of air operations. The loss of tactical aircraft would impact on the ability of the commander to attack enemy ground troops, interdict their supply lines, hunt for ballistic missile launchers, and protect his air space.

Likewise, a chemical attack on port facilities in the rear area would cause a large number of casualties, particularly among unprotected civilians. Consider the impact an Iraqi chemical attack on the port of Jubayl might have on the psyche of the civilian stevedore work force during a future Persian Gulf War. Even if most survive the initial attack, it is doubtful that many would return to work the next day. During the Persian Gulf War, Scud attacks on Jubayl and Dammam caused four civilian ship captains to pull back out to sea, delaying the unloading of combat elements of the much needed VII Corps. Similar delays during future deployments could mean the difference between victory or defeat in a rapidly progressing operation.[80]

In addition to their political and strategic impact, the use or threat of use of ballistic missiles on the air fields, ports, or population centers of an allied nation supporting US forces would have serious secondary tactical effects. The most obvious example involves the Iraqi attacks on Israeli population centers during the Persian Gulf War. These attacks risked bringing Israel into the war and destroying the Allied Coalition's political and military structure. This would have changed the correlation of forces, possibly requiring a revising of the operations plan, and left US forces vulnerable to attack from formerly allied nations like Syria. Concern over similar attacks into Turkey and the resultant potential for lost basing rights drove military planners to send Patriot batteries to Turkey to intercept any incoming Iraqi Scud missiles.[81]

The loss, through either missile attack or intimidation, of an intermediate staging base or the forward portion of a communications zone located in an allied nation would degrade significantly the commander's ability to bring forces and supplies into theater and execute his war plan. One nation particularly vital to US military deployments in Asia is Japan. An attacking North Korean force, however, could range the coast of Japan with Scud Mod C missiles from positions just south of Seoul, South Korea. Even worse, using the Nodong 1 missile (1,000-1,300 kilometer range), the North Koreans can reach Osaka and Tokyo from locations outside their capital of P'yongyang. While it is unlikely that the Japanese would prevent US forces from staging out of Japan, improvements in North Korea's missile program and the potential for such an attack compelled the Japanese to purchase the Patriot missile system from the United States. Concern over assured access to bases in Japan obliged the US to agree to sell the Patriot missile system--a system based highly advanced computer and aerospace technology--to Japan, a competitor in the global computer and aerospace industry. Moreover, in the event of war, the political pressure to destroy mobile launchers and alleviate the threat of missile attacks on Japan will force a diversion of aircraft and intelligence assets in a situation reminiscent of the Persian Gulf War. Compared to the relatively flat sands of Iraq, however, the mountainous terrain in Korea will make it even more difficult to find the launchers. This difficulty will cause an even greater diversion of air assets away from attacking ground formations than occurred during the "Great Scud Hunt" in the Persian Gulf War. Given the remote nature of the Korean theater of operations and the expected rapidity of a North Korean attack, any diversion of assets away from stopping a North Korean offensive could prolong the conflict, lead to increased casualties, and limit the ability of tactical commanders to achieve victory on the battlefield.[82]

Build up and Expansion

During the build up and expansion phase of force projection operations, an enemy will continue to attempt to disrupt the deployment of forces into the theater with missile attacks on ports, air fields, logistics bases and tactical assembly areas. To deter, or if necessary defeat, such an attack by North Korea, General Gary Luck, the commander of United States forces in South Korea, asked that a Patriot battalion deploy to Korea in the spring of 1994. Concerned with protecting the vital assets he needed for the initial fight as well as maintaining the flow of reinforcements and supplies into Korea in the event of a North Korean attack, General Luck positioned the arriving Patriot batteries at key air fields and ports on the peninsula.[83] At the tactical level the primary effects of such an attack would be the likely desynchronization of the commander's operation due to a lack of combat troops and equipment necessary to accomplish key parts of his plan as well as an increase in casualties.

A ballistic missile attack on large logistics sites and tactical assembly areas would have a similar effect. During Operation Desert Storm, the commander of the Patriot-Hawk air defense task force assigned to protect VII Corps expressed the importance of preventing such an attack. As part of his Commander's Intent, Lieutenant Colonel Lawrence Dodgen wrote

> ...the enemy's greatest threat is his ability to upset the timing of the operation or to contaminate/damage critical elements of the Corps by missile...attack. While in TAA [tactical assembly area] Juno, Patriot is to protect the force from attack with logistics, 11AB [11th Aviation Brigade], and command and control as the priorities. Early positioning of HIMAD [high to medium air defense] forces allows for rapid logistics build up....[84]

Lieutenant General Paul Funk, commander of the US Army's III Corps, confirmed this danger with respect to his unit's potential deployment to South Korea to thwart a future North Korean attack. He commented that given the restricted nature of the terrain in Korea, a ballistic missile attack had more potential lethality than one might face in Saudi Arabia. He emphasized that the lack of room in Korea to disperse his maneuver forces and logistics sites left them at risk.[85] Depending on the type of warhead employed, a successful missile attack in this situation could cause heavy casualties, destroy or contaminate countless supplies, and render scores of soft-skinned vehicles inoperable.

During this phase, a missile attack on political, strategic, or operational targets poses significant secondary effects for tactical forces. The loss of an intermediate staging base for soldiers and supplies would limit the commander's ability to execute his tactical plan. Furthermore, as in the Iraqi Scud attacks on Israel, the diversion of air assets to find and suppress the mobile launchers could delay the onset of offensive operations. The attacks on Israel caused the diversion of not only combat aircraft, but also the Joint Surveillance Target Attack Radar System (JSTARS) from its coverage of the ongoing ground battle at Khafji to hunt for Scuds in Western Iraq. In an attempt to allay Israeli concerns, political leaders in Washington, DC directed General Schwarzkopf to move one of only two JSTARS aircraft in Saudi Arabia. The issue is not whether the decision was correct, but that the launching of Scuds at Israel had important tactical side effects, including blinding the ground commanders as to what was occurring during the first ground battle of the Persian Gulf War.[86]

Just as an attack on a logistical base or assembly area in VII Corps or III Corps would create problems for the corps commander, so too would an attack on a theater level facility. A successful missile attack on King Khalid Military City and Log Base Bravo during the Persian Gulf War would have amounted to piercing what Lieutenant General John J. Yeosock, the Third Army Commander, considered his operational center of gravity. Consequently, the 11th Air Defense Artillery Brigade positioned Patriot batteries there to protect those vital Third Army assets. The tactical effects of a successful attack would have rippled throughout the command, severely interrupting the movement of forces and supplies west in preparation for the ground attack, and disrupting both the XVIII Corps and the VII Corps plans.[87]

Decisive Operations

The objective of the commander during combat operations is to achieve a quick, decisive victory with minimal casualties. A successful ballistic missile attack during this phase can prevent the commander from achieving his goal. During decisive operations, when combat forces are moving and fighting, the enemy will use his ballistic missiles to interdict the friendly movement of troops and supplies and attack friendly forces as they congregate to pass through choke points on the battlefield.

During the Persian Gulf War, an ideal time for the Iraqis to attack friendly maneuver forces with ballistic missile attacks would been have as VII Corps breached Iraqi front line positions on 24 February 1991. In a post-war conversation, General Frederick Franks Jr., the VII Corps commander during Operation Desert Storm, expressed particular concern about chemically-armed ballistic missiles landing on his soldiers "in the breach," especially if Iraqi minefields slowed their penetration.[88] To counter this threat, VII Corps ordered two Patriot batteries from the Corps Patriot battalion to the breach site to provide defense against ballistic missiles.[89]

For soldiers hit with such an attack, the effects would have been devastating. One participant asked about the likely effect of a chemical attack on breaching forces commented that the soldiers in Abrams tanks and Bradley infantry fighting vehicles might have survived thanks to the over pressurization of the chemical protection system installed on those vehicles, but that soldiers in other vehicles would have been contaminated. This assumes that the tank and infantry squads riding with their hatches open had been warned in time to close their hatches and activate their overpressure systems before entering the contaminated area.[90]

Moreover, in at least one battalion, staff officers and headquarters personnel following the combat forces through the area stopped and dismounted their vehicles to survey the situation. As they gathered together, a senior non-commissioned officer commented that they were all vulnerable to an attack by indirect fire. If that fire had been from ballistic missiles armed with fuel-air explosives, the battalion staff would have been killed and all of the light-skinned vehicles--command and control shelters, supply vehicles, and fuel tankers--destroyed. Such an attack would have decapitated the battalion, removing most of the unit's planning personnel. Additionally, the loss of vehicles, particularly fuel vehicles, would have forced that battalion to run out of fuel. While the 1st Infantry Division had spare combat vehicles to replace destroyed tanks and infantry fighting vehicles, it did not have any additional fuel tankers. Thus, while there may have been enough bulk fuel within the 1st Division and VII Corps, the inability to distribute that fuel to front line units risked disrupting the Division and Corps battle plans.[91]

In certain situations, the political or strategic use of ballistic missiles by the enemy may also have the secondary tactical effect of inhibiting the movement of reinforcements and supplies to critical points on the battlefield. Consider the case of a war in Korea, where political considerations will force the Combined Forces Command (CFC) to defend the approaches to Seoul. To do so, the CFC may need to move forces and supplies in and around Seoul. A North Korean missile attack on Seoul, regardless of whether it carried chemical munitions, would affect the populace psychologically to the point where the ensuing mass exodus of refugees would clog the vital road networks needed by the military forces. This phenonenon was evident in Teheran during the Iran-Iraq War and in Tel Aviv throughout Operation Desert Storm. Seoul is the fourth most populous city in the world with a projected population of almost 22 million people by the year 2000. It has a population density of 49,101 people per square mile or five times that of Tel Aviv. If North Korea lived up to the pledge one of its diplomats made in April 1994, to turn Seoul "into a sea of fire," the consequent exodus could easily overcome efforts by Korean authorities to control it. Furthermore, if the North Koreans used chemical munitions on Seoul, the immense congestion in the city portends massive casualties, potentially drawing US and South Korean medical and logistical personnel and supplies away from the front to provide disaster relief.[92]

Redeployment and Post-Conflict

Although most significant combat activities will have ceased as US forces transition into the reconstitution and post-conflict phase of force projection operations, an enemy may still launch a "last ditch" missile attack against US forces. In this event, an enemy would target large facilities and collections of soldiers such as ports, air fields, and assembly areas. The impact of a ballistic missile attack during this phase would have a debilitating psychological as well as physical effect on tactical forces. While the congestion of departing forces suggests the potential for higher casualties, the shock of such an attack might far outweigh the physical effects of the bombardment. A successful ballistic missile attack on a victorious army may call into question the concept of victory, undermine the political rationale for initially deploying forces, and put future deployments at risk. An attack with weapons of mass destruction could damage or contaminate port and air field facilities, delaying or preventing the redeployment of US forces. Given that the national military strategy envisions fighting two nearly simultaneous major regional contingencies, the inability to redeploy forces from one theater to another rapidly could jeopardize the chances for tactical, operational, and strategic success in the second major regional contingency.

CONCLUSION

Ballistic missiles and weapons of mass destruction represent a credible tactical threat to US forces engaged in force projection operations. The proliferation of improved missile guidance, propulsion, and warhead technologies among Third World nations will only serve to increase the lethality of this threat to US forces in the future. As nations improve the quality and quantity of their missile arsenals, missiles will assume ever increasing utility over combat aircraft. In a conflict with the United States, the power of the US Air Force and Navy to ground any enemy air force will reinforce this belief, tempting an adversary to use his ballistic missile arsenal to best advantage. Moreover, after a slow, but continuous expansion of the use of ballistic missiles in combat, the precedent for an attack on US forces has been set. The Libyan attacks in 1986 represented a meager, but determined attempt to strike back at the United States for its air raids earlier that year. The attacks by Iraq during the Persian Gulf War, however, opened the door for similar large scale attacks in the future. The expected advancements in missile and warhead technology will permit foes to strike at US forces from longer distances with greater accuracy and lethality. If successful, these attacks will have a militarily significant effect on the conduct of the deployment and early entry, build up and expansion, decisive operations, and redeployment and post-conflict phases of force projection operations.

Tactical commanders from battalion to corps must understand and appreciate the devastating effect of attacks by ballistic missiles and weapons of mass destruction on their battle space. These attacks could delay or prevent the entry of forces into the theater of operations, slow the movement of soldiers and equipment from ports and air fields, disrupt the timing and synchronization of decisive operations, necessitate the diversion of essential resources, and cause innumerable casualties. A successful ballistic missile attack could invalidate the concept of "decisive victory with minimal casualties" and undermine the potential for success in future force projection operations. Therefore, commanders must incorporate the threat from ballistic missiles and weapons of mass destruction into their tactical plans or suffer the attendant consequences.

ENDNOTES

[1]George Bush, *National Security Strategy of the United States,* March 1990 (Washington, DC: Government Printing Office, 1990), 9.

[2]George Bush, *National Security Strategy of the United States,* January 1993, (Washington, DC: Government Printing Office, 1993), 1.

[3]Ibid., 16.

[4]Ibid., 17.

[5]William J. Clinton, *A National Security Strategy of Engagement and Enlargement*, July 1994, (Washington, DC: Government Printing Office, 1994), i.

[6]Ibid., 11.

[7]During the Persian Gulf War, Iraq launched 88 Scud-B/Al-Hussein missiles at Saudi Arabia(43), Israel(42), Bahrain(3). See Thomas A. Keaney and Eliot A. Cohen, *Gulf War Air Power Survey Summary Report*, (Washington, DC: Government Printing Office, 1993), 84. Additionally, during the first three days of the ground operation (21-23 February 1991), the Iraqis fired a combination of 91 Brazilian-made Astros II and FROG-7 rockets at Allied forces in Saudi Arabia and Kuwait. See Joseph S. Bermudez, Jr. "Iraqi Missile Operations During Desert Storm," *Jane's Soviet Intelligence Review*, 3, no. 3. (March 1991): 131-135; Bermudez, "Iraqi Missile Operations During Desert Storm--Update," *Jane's Soviet Intelligence Review*, 3, no. 5. (May 1991): 225.

[8]Ballistic missile attack and defense is a relatively new field of study. It was an outgrowth of the study of nuclear theory, emerging in the mid-1980s with a focus on NATO and the Warsaw Pact. As the US and Soviet Union began eliminating entire classes of nuclear weapons, defense analysts started to study the effects of short range, conventional ballistic missiles on the battlefield. With the end of the Cold War and evidence of missile proliferation in the Third World, study has turned to ballistic missile production and use by developing countries.

The use of ballistic missiles in both the Iran-Iraq War and the more recent Persian Gulf War reinforced this trend. Currently, this field of study is dominated by defense analysts and think tank employees who focus primarily at the political and strategic level of war. As an adjunct to the field of ballistic missile study, there has emerged a parallel concern over the use of weapons of mass destruction. The two issues are normally addressed together in the same publications. Some of the major works are: Janne Nolan, *Trappings of Power: Ballistic Missiles in the Third World*, (Washington, DC: The Brookings Institution, 1991); Martin Navias, *Ballistic Missile Proliferation in the Third World,* (London: Brassey's, 1990) and *Going Ballistic: The Build-up of Missiles in the Middle East,* (London: Brassey's, 1993); and W. Seth

Carus, *Ballistic Missiles in the Third World: Threat and Response,* (New York: Praeger Publishers, 1990).

Due to the focus on political and strategic issues surrounding ballistic missiles and weapons of mass destruction, solutions tend toward arms control agreements such as the Nuclear Non-Proliferation Treaty and the Treaty of Tlateloco as well as export control agreements such as the Missile Technology Control Regime and away from active defenses against attack. As recent events involving North Korea's nuclear arsenal demonstrate, however, arms control agreements can be surreptitiously ignored or openly abrogated. Moreover, as the proliferation of missile and warhead technology shows, the actual enforcement of restraints on technology transfer is a complicated and challenging matter.

[9]TRADOC Pamphlet 525-5, *Force XXI Operations: A Concept for the Evolution of Full-Dimensional Operations for the Strategic Army of the Early Twenty-First Century,* (1 August 1994), 2-7.

[10]Circular error probable or circle of equal probability(CEP) is the distance from the intended target in which 50% of the missiles will probably land.

[11]In the last ten years, several nations have established missile partnerships. Iraq, Egypt, and Argentina joined together to develop the Condor II ballistic missile. Iran received North Korean help to modify Soviet Scud missiles. Taiwan, South Africa, and China supposedly received aid from Israel. In turn, China sold DF-3A missiles to Saudi Arabia and offered to develop missile prototypes for Middle Eastern nations willing to underwrite the cost. Brazil and China formed a joint venture to develop space-launch vehicles. One spinoff from this relationship is the development of a ballistic missile with export potential. Also, Libya has approached Brazil, Pakistan, and others in an effort to buy missiles and missile technology (Nolan, 18). For a incisive analysis of Third World defense investment, ballistic missile production, and technology transfer see Janne E. Nolan, *Trappings of Power: Ballistic Missiles in the Third World,* particularly chapters 2, 3, and 5.

[12]Joe Bermudez, Jr. "Ballistic Ambitions Ascendant: North Korea's Ballistic Missile Program," *Jane's Defence Weekly,* 10 April 1993, 20-21; Joseph S. Bermudez, Jr. "Iraqi Missile Operations During Desert Storm," *Jane's Soviet Intelligence Review,* 3, no. 3. (March 1991): 131-135; Richard A. Bitzinger, "Arms to Go: Chinese Arms Sales to the Third World," *International Security,* vol 17, no. 2 (Fall 1992): 84-111; John Wilson Lewis and Hua Di, "China's Ballistic Missile Programs: Technologies, Strategies, Goals," *International Security,* vol 17, no. 2 (Fall 1992): 5-41; Barbara Starr, "USA Links Chinese Ties to Missile Exports," *Jane's Defence Weekly,* (15 October 1994): 6.

[13]"The Great Scud Hunt" also required the use of scarce intelligence assets and the creation of a special 877-man Joint Special Operations Task Force (JSOTF) to find mobile Scud launchers. See Robert

H. Scales, *Certain Victory: The US Army in the Gulf War*, (Fort Leavenworth, KS: CGSC Press, 1994), 184-187.

[14]The data on airlift sorties assumes a six-battery Patriot battalion, eight launchers per battery, and a battalion headquarters. Data was provided by the Directorate of Combat Developments, US Army Air Defense Artillery School and Center, Fort Bliss, Texas. Adjusting these figures to their C-141 equivalent (multiply the number of C-5As by a factor of 2.5), the cost in air lift becomes apparent. To move the Patriot battalion in question would require approximately 254 C-141 equivalent sorties or 31% of what it took to move the entire 82d Airborne Division (832 C-141 sorties) to Saudi Arabia for Operations Desert Shield and Desert Storm. For airlift data on the 82d Airborne Division, see Scales, *Certain Victory*, 50-51.

[15]US Army, Field Manual 100-5, *Operations* (hereafter cited as FM 100-5), (Washington, DC: Department of the Army, 1993), 6-2, 6-12. See also TRADOC Pamphlet 525-5, 3-8. With advances in technology, information age information reporting, and compressions in time-space relationships, defining battle space by levels of command, size of units, types of units, or types of equipment may become obsolete or at best confusing. In certain circumstances, events may be defined as either strategic, operational, or tactical based on their effect or contribution to achieving strategic, operational, or tactical objectives. Commanders at every level must be aware that in a world of constant, immediate communications and advanced, long range weaponry, any single event may cut across the three levels of war. See Joint Publication 3-0, *Doctrine for Joint Operations,* (Washington, DC: The Joint Staff, 1993) II-1.

[16]During the Persian Gulf War, the author participated in a radio talk show on military affairs and discussed ballistic missile and anti-missile (Patriot) operations. The conclusions about misperceptions are drawn from that experience as well as discussions with some senior military officers in the ensuing three years.

[17]W. Seth Carus, *Ballistic Missiles in the Third World: Threat and Response*, 2; Robert Shuey and others, *Missile Proliferation: Survey of Emerging Missile Forces,* (Washington, DC: Congressional Research Office, 1988), 1n.

[18]Cited in Bernard and Fawn Brodie, *From Crossbow to H-Bomb,* 1st Midland ed., (Bloomington, IN: Indiana University Press, 1973), 44 and 127.

[19]The air-launched V-1 was less accurate than the ground-launched version. Instead of launching from a known location on the ground, it relied on the location of the aircraft for its initial positioning. Due to the heavy losses inflicted on the Luftwaffe by Allied bombers and fighters, most air-launches occurred at night over the North Sea with pilots counting on their instruments (and their nerves) to get them to the right spot in the air. Headquarters, United States Forces European Theater, *Report of the General Board, Study #38*, 38-40 cited in R.J.

Backus, "The Defense of Antwerp Against the V-1 Missile," (M.A. thesis, Command and General Staff College, 1971), 10; M. C. Helfers, *The Employment of V-Weapons by the Germans in World War II*, Office of the Chief of Military History, (Washington, DC: Department of the Army, 1954), 37; Winston Churchill, *The Second World War: Triumph and Tragedy,* (Boston: Houghton Mifflin Company, 1953), 39; See also Kenneth P. Werrell, *The Evolution of the Cruise Missile,* (Washington, DC: Government Printing Office, 1985).

The British employed a three-tiered strategy--passive defense, active defense, and attack operations--in their fairly successful defense of London from the V-1. They used air raid alerts and deep air raid shelters to safeguard the people: antiaircraft artillery, fighter aircraft, and barrage balloons to stop the incoming missiles; and bombers to strike the V-1 launch sites, storage areas, and factories. Of the more than 7,500 missiles fired at London, only about 2,400 got through the defenses. Total civilian casualties were 6,184 killed and 17,981 seriously wounded. There is no record for the number of wounded that did not require hospitalization. At least 75,000 homes were destroyed. For more on the British battle against the V-1, see Winston Churchill, *Triumph and Tragedy*, 38-49; General Sir Frederick Pile, *Ack-Ack: Britain's Defence Against Air Attack During the Second World War,* (London: George G. Harrap & Co., 1949), 311-368; and R.J. Backus, "The Defense of Antwerp Against the V-1 Missile," 12-21.

[20]Churchill, *Triumph and Tragedy,* 49-52; Pile, *Ack-Ack*, 386-388. System Planning Corporation, *Ballistic Missile Proliferation: An Emerging Threat*, (Arlington, VA: System Planning Corporation, 1992), 5.

[21]Churchill, *Triumph and Tragedy*, 39.

[22]The V-1 campaign began on June 13, 1944 and occured in three phases. From June 13 - September 5, 1944, the Germans launched missiles from northern France. From September 15, 1944 - January 15, 1945, they used the Heinkel 111 to air launch V-1s at London. V-1 attacks resumed on March 3, 1945 and continued until 29 March, when the British antiaircraft artillery downed the last missile. During the V-1 campaign, the Germans successfully launched 7,558 missiles at London, 8,696 at Antwerp, and 3,141 at Liege. The V-2 campaign began on September 8, 1944 and continued until the Allies liberated the launching area near The Hague in April 1945. During the V-2 campaign, the Germans launched 1,190 missiles at London, 1,610 at Antwerp, 151 at Brussels, and one at Paris. British casualties totaled 6,184 killed and 17,981 seriously wounded from V-1 attacks and 2,724 killed and 6,467 seriously wounded from V-2 attacks. The V-2 attacks on Belgium totaled 4152 killed. Churchill, *Triumph and Tragedy*, 48-55; Backus, "The Defense of Antwerp Against the V-1 Missile," 12-14.

[23]Pile, *Ack-Ack,* 392.

[24]Sir Duncan Sandys quoted in Churchill, *Triumph and Tragedy*, 55. In one aspect, however, Sir General Pile was correct. He wrote that in the future air defense will have no "human element." "The target, whether bombers or rocket plane, will be picked up automatically; the

defence rockets will be fired at them at the most suitable moment--also automatically--and controlled automatically." Today, due to the immense speed with which tactical ballistic missiles approach a target, air defense officers manually enter targeting parameters into the Patriot missile system computer and then turn the system on automatic. The Patriot system radar tracks the incoming missile, while the computer selects the optimum engagement time, fires the Patriot missile, and directs the missile toward the TBM. After the initial programming, the defense is without a "human element." See Pile, *Ack-Ack*, 392. Some American scientists shared Pile's view. Among them was Dr. Hugh L. Dryden, a scientist evaluating the state of American science and technology after the war. Dryden believed that the state of missile development in 1945 mirrored that of aircraft at the end of World War I. Of this latent potential, he wrote, "The brief experience in the tactical use of guided missiles in this war indicates that another war will probably be opened by the descent in large numbers of missiles launched from distances perhaps on the order of 1,000 to 3,000 miles on an unsuspecting and unprepared country." In light of the performance of US cruise and Iraqi ballistic missiles in the Persian Gulf War, he may not have been far off. Hugh L. Dryden, *Present State of the Guided Missile Art*, "Toward New Horizons," vol. VI-1, (A Report Prepared for the Scientific Advisory Group, Army Air Forces, 1945), 1 cited in Gary R. Akin, "Evolution and Development of Cruise Missiles: Technology for War," *Air Power History* vol 38, no. 2 (Summer 1991), 44.

[25]This comment requires at least one caveat. Specifically, the Germans were not shy about lending their expertise after the war. With German help, Egypt became the first developing nation to begin its own missile program. With extensive assistance from German engineers, the Egyptians deployed a family of liquid-propellant missiles as early as 1963. They never fired the missiles and when the Germans were forced from Egypt, the program collapsed. System Planning Corporation, *Ballistic Missile Proliferation: An Emerging Threat*, 5-6.

[26]The following nations possess Scud-B missiles: Afghanistan, Algeria, Azerbaijan, Belarus, Bulgaria, Czech Republic, Egypt, Georgia, Hungary, Iran, Iraq, Kazakhstan, North Korea, Libya, Poland, Romania, Russia, Slovakia, Syria, Ukraine, Vietnam, and Yemen. Duncan Lennox, "Missile Race Continues," *Jane's Defence Weekly*, 23 January 1993, 20.

[27]The Soviets first supplied FROG rockets in the 1960s and 1970s, sending FROG 7s to Egypt (1968), Iraq and North Korea (1969), Syria (1973), Algeria (1975), Libya (1978), The Peoples' Democratic Republic of Yemen [PDRY] (1979), and Kuwait (late 1970s). Scud exports began in the 1960s and continue into the 1990s. See Martin Navias, *Going Ballistic: The Build-up of Missiles in the Middle East*, 63-64.

The Scud-B CEP varies according to source consulted. For example, Duncan Lenox, "Iraq's Scud Progrmme-the Tip of the Iceberg," *Jane's Defence Weekly*, 12 March 1991, 303, lists it at 450 meters, while Janne E. Nolan, *Trappings of Power*, 67-68 carries it at 980 yds. Martin Navias, *Going Ballistic*, 13 lists the Scud-B at 400-500 meters CEP. This monograph assumes a CEP of 450 meters.

[28]Martin Navias, *Going Ballistic*, 63-64, 140-142 contends that goverment forces fired somewhere between 1,228 and 1,554 (possibly even all 2,000) Scuds at the Mujahideen.

[29]Joe Bermudez, Jr. "Ballistic Ambitions Ascendant: North Korea's Ballistic Missile Program," 22; System Planning Corporation, *Ballistic Missile Proliferation: An Emerging Threat*, 16; Joe Bermudez, Jr., "Syria's Acquisition of North Korean 'Scuds'," *Jane's Intelligence Review*, vol 3, no. 6 (June 1991): 249-251.

[30]One indication of the status of the North Korean economy and the importance of Iranian financing is the report that Iranian forces received their new missiles even before North Korea fielded them in its own army. Joe Bermudez, Jr., "Ballistic Ambitions Ascendant: North Korea's Ballistic Missile Program," 22; Syria reportedly paid for the missiles it received from North Korea with part of the $2 billion it received from Saudi Arabia for its participation in the Persian Gulf War. Joe Bermudez, Jr., "Syria's Acquisition of North Korean 'Scuds'," *Jane's Intelligence Review*, 249-251. Iran also may have received North Korean assistance in manufacturing a chemical warhead for their new missile. See Martin Navias, *Going Ballistic*, 80-81. Navias also reports that in October 1991 the United States warned Israel not to attack a North Korean cargo ship, the Mopu, which they believed was carrying the Scud Mod C missiles. The US feared that an Israeli attack might have damaging implications for the upcoming Madrid summit.

[31]An indicator as to the extent of continued Russian (and ultimately German) influence over ballistic missile development, Russia recently prevented a number of missile designers from travelling to North Korea. These designers were from the Makeyev design bureau responsible for "Scud" design and, according to Joe Bermudez, Jr., have addressed North Korea's multi-staging or clustering problems. Joe Bermudez, Jr. "Ballistic Ambitions Ascendant: North Korea's Ballistic Missile Program," 22.

[32]System Planning Corporation, *Ballistic Missile Proliferation: An Emerging Threat*, 14; After an early interest in tactical range ballistic missiles, the Chinese turned to strategic range weapons in an effort to deter the superpowers, the United States before the 1970s and the Soviets after the late 1960s. Only in the mid-1980s when they became aware of the export potential of TBMs did the Chinese turn to making and marketing short range ballistic missiles. Interestingly, in reflection of their interests over time, the Chinese designed the *Dongfeng* series of missiles to strike specific strategic targets, the DF-2 (Japan), DF-3 (Philippines), DF-4 (Guam), and DF-5 (the continental United States). This designation determined the range of the missile. Conversely, with their eye on the Third World export market, the Chinese named the "M" family of missiles to correspond to the English word "missile". Perhaps the best description of the Chinese missile program is John Wilson Lewis and Hua Di, "China's Ballistic Missile Programs: Technologies, Strategies, Goals," *International Security*, vol 17, no. 2 (Fall 1992): 5-41. See also Barbara Starr, "USA Links Chinese Ties to Missile Exports," *Jane's Defence Weekly*, (15 October 1994): 6; and Yan

Kong and Tim McCarthy, "China's Missile Bureaucracy," *Jane's Intelligence Review*, vol 5, no. 1 (1 January 1993): 36-41.

[33]The M-9 and M-11 missiles, when used by the PLA, are known as the DF-15 and DF-11. In addition to the M-9 and M-11, there have been reports of other "M" series missiles--the M-7, M-8, M-12, or M-18--under production, including one supposedly with a range of 1,000 kilometers. System Planning Corporation, *Ballistic Missile Proliferation: An Emerging Threat*, 15; John Wilson Lewis and Hua Di, "China's Ballistic Missile Programs," 10-11.

With respect to tactical ballistic missiles and weapons of mass destruction, China's arms exports go beyond merely selling surface-to-surface missiles. In 1989, they sold Iraq and Pakistan magnets used in high-speed centrifuges to make weapons-grade uranium. In 1990, the Chinese sold lithium hydride to Iraq and Libya. The chemical has potential uses in the manufacture of nerve agents, missile fuel, and nuclear weapons. In 1991, they provided Algeria and Iran with advice on how to match nuclear weapons with air and missile delivery systems. Moreover, they are reportedly aiding these nations in developing nuclear weapons programs, including building a plutonium reactor in Algeria. For the extent of Chinese arms sales, see Richard A. Bitzinger, "Arms to Go: Chinese Arms Sales to the Third World," *International Security*, vol 17, no. 2 (Fall 1992): 84-111.

[34]Martin Navias, (*Going Ballistic*, 101-105; Duncan Lennox, "Iraq's 'Scud' Programme--The Tip of the Iceberg," *Jane's Defence Weekly*, (2 March 1991), 301-303.

[35]Duncan Lennox, "Iraq's 'Scud' Programme," 301; Joe S.Bermudez, Jr. "Iraqi Missile Operations During Desert Storm," 132.

[36]For V-2 figures, see Churchill, *Triumph and Tragedy,* 39; For Persian Gulf War figures, see Thomas A. Keaney and Eliot A. Cohen, *Gulf War Air Power Study Summary Report*, 84; For other figures, see Martin Navias, *Going Ballistic*, 128-172.

[37]Bermudez, "Iraqi Missile Operations During Desert Storm," 131-135.

[38]The Iraqis used standard operating procedures developed during the Iran-Iraq War for ballistic missile operations. Prior to missile transfer to the TEL or MEL, the procedures are believed to progress in the following order: The launch order is given, presumably from Saddam Hussein directly, containing the launch time, position, and target. Crews at the appropriate missile storage facility prepare the missiles, mating the warhead, calibrating the guidance system, and conducting last minute checks. Concurrently, commanders alert the missile transport vehicles as to the number of missiles to move and the location of the missile transfer area or launch area. Ibid., 131-135.

Keaney and Cohen in the *Gulf War Air Power Study Summary Report*, 84-90, conclude that Coalition air power failed to destroy a single mobile Scud launcher. Scales, *Certain Victory*, 184-187, implies, but does not confirm, that a Special Forces called F-15E strike destroyed at least one mobile launcher.

[39]While the issues of prestige and deterrence are outside the scope of this monograph, they nonetheless form part of the motivation for developing nations to acquire ballistic missiles. As a symbol of a nation's military might and technical prowess, ballistic missiles enhance national prestige and stature among other developing nations. In a certain sense, the possession of ballistic missiles replicates the political prestige associated with the possession of battleships earlier in the twentieth century. In that regard, the concept of actual military utility may in fact give way to the perception of the same. Moreover, actual usefulness may yield to the need of some developing countries to demonstrate an industrial strength and wherewithal equal to that of developed nations. Brazil and South Africa are two examples of nations where the possession of ballistic missiles holds only limited military utility yet provides a symbol of strength and technical capability. Additionally, the ability to manufacture missiles and other military hardware magnifies the symbolic value attributed to possession. Indigenous manufacturing not only showcases a nation's technical sophistication, but it also highlights that country's military self-sufficiency and apparent independence from foreign political influence. For a further explanation of these and other benefits of ballistic missile ownership and indigenous production see, Andrew W. Hull, "Motivations for Producing Ballistic Missiles and Satellite Launch Vehicles," *Jane's Intelligence Review*, vol 5, no. 2 (February 1993): 86-89; John R. Harvey, "Regional Ballistic Missiles and Advanced Strike Aircraft: Comparing Military Effectiveness," *International Security*, vol 17, no. 2, (Fall 1992): 77; Martin Navias, *Going Ballistic*, 10; Bruce E. Arlinghaus, "Social versus Military Development: Positive and Normative Dimensions," in James Everett Katz, *Arms Production in Developing Countries*, (Lexington, MA: D.C. Heath and Company, 1984), 39-50; and Michael Brzoska and Thomas Ohlson edited, *Arms Production in the Third World*, Stockholm International Peace Research Institute, (London: Taylor and Francis, 1986).

While prestige may motivate some nations to acquire ballistic missiles, their popularity among developing nations stems as much from their deterrent value as any other factor. The deterrent value of ballistic missiles, especially when armed with unconventional warheads, far exceeds that of combat aircraft. All the Middle East nations that possess missiles do so in part due to their deterrent value. Iraqi dictator, Saddam Hussein, explicitly referred to the deterrent value of ballistic missiles when he commented that peace was possible only when both the Arabs and Israelis each had "one missile, so neither can use it." For more on the deterrent value of ballistic missiles see, Martin Navias, *Going Ballistic*, 48.

[40]Cordesman and Wagner, *The Lessons of Modern War: Volume II: The Iran-Iraq War*, 503; John R. Harvey, "Regional Ballistic Missiles and Advanced Strike Aircraft: Comparing Military Effectiveness," 43; and Steve Fetter, "Ballistic Missiles and Weapons of Mass Destruction: What is the Threat? What Should be Done?" *International Security*, vol 16, no. 1, (Summer 1991), 5-42, all believe that aircraft are more cost-

effective that ballistic missiles. Thomas L. McNaugher, "Ballistic Missiles and Chemical Weapons: The Legacy of the Iran-Iraq War," *International Security*, vol 15, no. 2 (Fall 1990) goes even further claiming that "...it might be useful to encourage states to buy missiles rather than bombers, since doing so would be a relative waste of money, leaving fewer resources available for war" (33). Martin Navias, *Going Ballistic,* 7-18, presents a more balanced opinion. Janne E. Nolan, *Trappings of Power*, 63-97, concludes that by traditional measures of utility--accuracy, payload, and quantity available--ballistic missiles have limited military significance, but with the continued proliferation of advanced technology, especially global positioning data and improved guidance systems, that may change. W. Seth Carus, *Ballistic Missiles in the Third World: Threat and Response*, 27-39, believes that ballistic missiles have capabilities that make them potentially useful as conventional weapons.

The current version of ATACMS ranges to 150 kilometers and carries up to 1,000 anti-personnel, anti-materiel mines. One planned improvement to the ATACMS will double the range to 300 kilometers, but reduce the payload. Another planned version will employ Brilliant Anti-Tank Munitions (BAT) to kill armored vehicles at extended ranges. At a test conducted at White Sands Missile Range, New Mexico in December 1994, the US Army fired an ATACMS 428 kilometers. The ATACMS has an unclassified CEP of approximately 15 meters.

[41]W. Seth Carus, *Ballistic Missiles in the Third World: Threat and Response*, 31-32; Janne E. Nolan, *Trappings of Power*, 65, makes a very cogent point about the ability of inflight refueling to extend the range of combat aircraft. This is especially true when one remembers Operation El Dorado Canyon, the 1986 raid on Libya, where US F-111 combat aircraft took off from England, flew around France and Spain, bombed Libya and returned without landing. The F-111 aircraft refueled four times in the air between takeoff and landing in England.

[42]The initial idea for comparing the payloads of aircraft and missiles came from work done by Navias, Carus, and Nolan. The combat radii and payloads of aircraft, however, vary not only by country and by source, but also are interpreted differently by the various authors when comparing aircraft and missiles. The combat radii and payloads used in this monograph came from Mark Lambert, ed., *Jane's All the World's Aircraft, 1993-1994*, (Alexandria, VA: Jane's Information Group, Inc, 1993), F-16C (page 512), SU-24 (310). The payload of an Al Hussein missile is also up for debate. W. Seth Carus and Janne Nolan contend it is about 190 kilograms (418 pounds), while Martin Navias places it at 500 kilograms (1,100 pounds). This monograph uses the Carus/Nolan estimate of about 400 pounds.

[43]W. Seth Carus, *Ballistic Missiles in the Third World: Threat and Response*, 32.

[44]John R. Harvey, "Regional Ballistic Missiles and Advanced Strike Aircraft: Comparing Military Effectiveness," 62.

[45]John R. Harvey in "Regional Ballistic Missiles and Advanced Strike Aircraft: Comparing Military Effectiveness," contends that aircraft and missiles have the same pre-launch survivability. "For simplicity assume that the pre-launch survivability of both aircraft and missiles is 1.0" (p. 65). For states sharing a common border, he is probably correct that the warning time for missiles and aircraft is about equal. During the Persian Gulf War, the Israelis had approximately 5 minutes warning time of incoming Al-Hussein missiles launched from the H3 air base in Iraq. A modern combat aircraft flying at Mach 2.0 could cover the same distance in about the same time. During a preemptive air strike against a neighboring state, Harvey's assumption of pre-launch survivability appears correct.

Unless the first strike prevents all retaliatory action by the defender, however, the pre-launch survivability of missiles and aircraft is not equal. As the US and Coalition forces discovered during the Persian Gulf War, finding and destroying mobile missile launchers is much more difficult than striking fixed launching facilities or airfields. For a specific assessment of the United States inability to find and destroy mobile launchers during the Persian Gulf War, see the section entitled "The Great Scud Chase," Congress, House, Committee on Armed Services, Subcommittee on Oversight and Investigations, *Report on Intelligence Successes and Failures in Operations Desert Shield/Storm*, 103d Cong., 1st Sess., August 16, 1993, Committee Print 5, p. 11-12. This section of the report concludes that there was no "hard evidence" that Allied forces destroyed even a single mobile missile launcher despite the continuous use of combat air patrols consisting of JSTARS and F-15E strike aircraft. The United States Air Force came to the same conclusion in its Gulf War Air Power Survey. See Thomas A. Keaney and Eliot A. Cohen, *Gulf War Air Power Survey Summary Report*, 83-90. Obviously, even for the world's most sophisticated military equipped with superior intelligence gathering and strike capabilities, this task was far from "simple". Summarizing the problems posed by ballistic missiles, General Charles A. Horner, the CENTCOM Air Component Commander during the Persian Gulf War, wrote in a recent article, "...I grossly underestimated [the Scud's] impact as a political terror weapon and the resources we would have to expend to counter it. The capability of that antiquated weapon to hamstring modern warfare shocked me. Proliferation of fielded and emerging ballistic missiles with vastly improved capabilities will only exacerbate the problem for future warfighting commanders." General Charles A. Horner, "Space Systems Pivotal to Modern Warfare," *Defense 94*, no. 4.: 20-29.

[46]Such was the case in Vietnam during Operation Rolling Thunder when, to cite an extreme example, the US Air Force and Navy flew 350 sorties against the Thanh Hoa bridge in North Vietnam from 1965-68 and failed to cause any major structural damage. Accuracy improved, when during Linebacker I (May-October 1972), the Air Force flew F-4s with laser-guided bombs against the same target and destroyed it without suffering any aircraft losses. Even with laser-guided bombs, it still required 26 F-4 sorties to destroy the bridge. Glenn Griffith and others, "The Tale of Two Bridges," *The Tale of Two Bridges and the Battle for the Skies over North Vietnam*, ed. by A.J.C. Lavalle, (Washington, DC: Government Printing Office, 1976) cited in Thomas A.

Keaney and Eliot A. Cohen, *Gulf War Air Power Survey Summary Report,* 243. See Keaney and Cohen, pages 102-106, for an explanation of early aircraft difficulties in targeting accuracy during the Persian Gulf War.

[47]Information on the V-2 tests and size of craters from W. Seth Carus, *Ballistic Missiles in the Third World: Threat and Response*, 35. Information on the damage to Tel Aviv during the Persian Gulf War from Martin Navias, *Going Ballistic*, 154.

[48]Thomas A. Keaney and Eliot A. Cohen, *Gulf War Air Power Survey Summary Report,* 88.

[49]Concern over technology transfer by developed countries formed the basis for the Missile Technology Control Regime (MTCR). Formalized in 1987 between Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States, the agreement asks signatories to restrict voluntarily the export of missile-related exports and dual-use technology applicable to missile programs. The MTCR applies controls to technologies that would contribute to the capability of unmanned delivery of a payload of at least 1,100 pounds (the minimum size scientists believe necessary for a nuclear warhead) across a distance of at least 300 kilometers. Membership has grown from the initial seven nations to eighteen, adding Spain, Australia, Belgium, Luxembourg, the Netherlands, Denmark, Austria, Sweden, Norway, New Zealand, and Finland. Portugal and Israel may join soon. While the MTCR is an encouraging step toward counter-proliferation, it will not stop some nations--Libya, North Korea, Iran, Iraq, India, Pakistan, or China--from pursuing ways to improve the accuracy and yield of their missiles or from selling those improvements to others. Access by rogue nations to more accurate and lethal missiles will increase the potential danger to US tactical forces deployed in future force projection operations.For more on MTCR see, Janne E. Nolan, *Trappings of Power.*

[50]System Planning Corporation, *Ballistic Missile Proliferation: An Emerging Threat*, 67, makes reference to a new model Soviet/Russia Scud (possibly the Scud D) with a 50 meter CEP. Although they are not signatories to the MTCR, the Soviets in 1990 appeared to have scaled back their missile exports and denied a Syrian request for SS-23 missiles. The new Russian regime or maverick elements within its underfunded military, however, may be willing to do anything for cash to include selling highly accurate ballistic missiles or advanced guidance components. W. Seth Carus, *Ballistic Missiles in the Third World: Threat and Response*, 15 and 34. Carus also makes mention of the Agni missile under development in India with a CEP of 50 meters.

[51]International Institute for Security Studies, *The Military Balance, 1988-1989,* (London: International Institute for Security Studies, 1988), 210.

[52]Using the comparative data provided in System Planning Corporation, *Ballistic Missile Proliferation: An Emerging Threat*, 67-68, and calculating the slope of development, the author arrived at the following conclusions about the pace of ballistic missile development.

The US achieved an increase in effective range of 50 meters per year during the first phase of its ballistic missile development. The Soviet Union, after a slow period from the mid-1950s to the mid-1960s where it achieved only a 25 meter per year increase, caught up with the US and maintained a parallel development of 50 meters per year. France and Great Britain together achieved an increase of only 18.5 meters per year from the early 1970s to the early 1990s. Finally, after a slower first phase of growth from 1987 to 1990 where they achieved 100 meters per year, developing countries have progressed rapidly attaining between 160-200 meters per year of effective range on the ballistic missiles. While these figures depict the pace of development with respect to effective range of relatively short range missiles, they should also serve as an indicator of what developing countries are capable of with respect to improving accuracy and enhancing warhead effects.

[53]For an excellent explanation of this issue, see System Planning Corporation, *Ballistic Missile Proliferation: An Emerging Threat*, 61. In addition to developing more modern guidance mechanisms, missile owners may improve accuracy by using commercially available satellite data to enhance missile targeting. Satellite navigation data will reduce the uncertainty of both mobile missile launcher and target positioning, a long time problem for all surface-to-surface artillery calculations. Furthermore, commercial imagery from, for example French SPOT satellites, could provide added target location and battle damage assessment. John E. O'Pray, "Regional Power Ballistic Missiles: An Emerging Threat to Deployed US Forces?," (Thesis, Air War College, Air University, Maxwell Air Force Base, AL, 1990), 8.

[54]System Planning Corporation, *Ballistic Missile Proliferation: An Emerging Threat*, 67; John E. O'Pray, "Regional Power Ballistic Missiles: An Emerging Threat to Deployed US Forces?," 85; David Rubenson and Anna Slomovic, *The Impact of Missile Proliferation on US Power Projection Capabilities,* (Santa Monica, CA: Rand, 1990), 13. Iraq used the Astros II during the Iran-Iraq War and Brazil has sold the Astros II to Libya.

[55]John E. O'Pray, "Regional Power Ballistic Missiles: An Emerging Threat to Deployed US Forces?," 83-86.

[56]The following discussion concerning the effects of submunitions and chemical warheads on a notional airbase summarizes an argument made by John O'Pray in Chapter 5 of "Regional Power Ballistic Missiles: An Emerging Threat to Deployed US Forces?." O'Pray used Maxwell Air Force Base, Alabama as his model. It is a standard, unhardened airbase similar to those that US forces might deploy to in response to regional contingencies.

[57]David Rubenson and Anna Slomovic, *The Impact of Missile Proliferation on US Power Projection Capabilities,* 17.

[58]John E. O'Pray, "Regional Power Ballistic Missiles: An Emerging Threat to Deployed US Forces?," 84, cites an example from Vietnam where a single explosion at Bien Hoa destroyed 14 aircraft and damaged 30

more. It also caused several fires and secondary explosions in fuel and ammunition storage facilities.

[59]John E. O'Pray, "Regional Power Ballistic Missiles: An Emerging Threat to Deployed US Forces?," 86-87.

[60]Secretary Cheney cited in Martin Navias, *Going Ballistic*, 14. List of nations with ballistic missile and chemical programs from W. Seth Carus, *Ballistic Missiles in the Third World: Threat and Response*, 7 and System Planning Corporation, *Ballistic Missile Proliferation: An Emerging Threat*, 72-74. Of particular note, former Director of the Central Intelligence Agency, William Webster, stated that Libya's Rabta chemical plant may be "...the single largest chemical-warfare-agent production plant in the Third World," but that Iraq has several production sites with a total capacity that exceeds Libya's. William Webster cited in John E. O'Pray, "Regional Power Ballistic Missiles: An Emerging Threat to Deployed US Forces?," 75.

[61]Martin Navias, *Going Ballistic*, 15-16, outlines some of the difficulties in using chemical warheads on ballistic missiles.

[62]*Soviet Chemical Weapons Thrust*, Report No. DST-1629F-051-85, (Washington, DC: Defense Intelligence Agency, 1985) 8, cited in John E. O'Pray, "Regional Power Ballistic Missiles: An Emerging Threat to Deployed US Forces?," 78; International Institute for Strategic Studies, *The Military Balance*, (London: International Institute for Strategic Studies, 1988), 248; Robert D. Orton and Robert C. Neumann, "The Impact of Weapons of Mass Destruction on Battlefield Operations," *Military Review*, vol 73, no. 12. (December 1993): 64-72, offers soldier's perspective of the impact of WMD on battlefield operations.

[63]Figure 2 was taken from David Rubenson and Anna Slomovic, *The Impact of Missile Proliferation on US Power Projection Capabilities*, 23. The measure of thickened Soman should be in milligrams per cubic milliliter of air (mg/m^3) and not mg/m^2 as depicted. The inner elipse would contain 500 mg/m^3, the second elipse 100 mg/m^3, and the third elipse 10 mg/m^3. The lethality of chemical agents is normally stated in terms of LCt_{50}, which is the product of the concentration of the agent in air in milligrams per cubic meter (mg/m^3), multiplied by the length of exposure in minutes that would result in death to fifty percent of the unprotected people exposed. For example, the LCt_{50} of Soman is 100 mg min/m^3, meaning that exposure to a concentration of 10 mg/m^3 for 10 minutes or 100 mg/m^3 for 1 minute would be fatal to half those exposed. An incapacitating dose of Soman is 75 mg min/m^3. A median lethal dose to soldiers in chemical protective garments is 10,000 mg min/m^3. Thus, in this scenario, troops wearing MOPP 4 and caught in the first elipse would begin to die within 20 minutes of exposure. At a time when US Army doctrine is based on "decisive victory with minimum casualties" a chemical attack on deploying soldiers could result in instant political and strategic defeat. The chemical dosage data outlined above came directly from Steve Fetter, "Ballistic Missiles and Weapons of Mass Destruction: What Is the Threat? What Should be Done?," 17-18.

[64]Steve Fetter, "Ballistic Missiles and Weapons of Mass Destruction: What Is the Threat? What Should be Done?," 27. This assumes a missile with a 1 ton (2,200 pound) payload aimed at a large city with an average population density of 30 per hectare or 13 persons per acre of land.

[65]The top-secret United States operation to remove nearly 1,100 pounds of weapons-grade uranium from Kazakhstan in 1994 dramatizes the potential for theft or sale of nuclear materials from these nations. Project Sapphire removed 1,400 stainless steel containers of weapons-grade uranium from a remote site in Kazakhstan. The nearly half-ton of material was enough to make two or three dozen nuclear bombs. Secretary of State Warren Christopher stated that there was enough material in the cache "to start a substantial nuclear weapons arsenal if it had fallen into the hands of a rogue state." The operation had the full cooperation of the government of Kazakhstan. "Under Cover of Darkness, Nuclear Cache is Taken Away," *Kansas City Star*, 24 November 1994, A-10.

[66]For reasons of deterrence, fear of sanctions, and protection of sovereignty, many nations do not disclose their nuclear status. As a result, the list of states already possessing nuclear weapons and those who are actively seeking them is open to interpretation and varies by source. This list was taken from System Planning Corporation, *Ballistic Missile Proliferation: An Emerging Threat*, 71.

[67]W. Seth Carus, *Ballistic Missiles in the Third World: Threat and Response*, 7.

[68]Steve Fetter, "Ballistic Missiles and Weapons of Mass Destruction: What Is the Threat? What Should be Done?," 24-26. One example cited by Fetter as to the effect of anthrax bombs was the testing of such bombs by the US, Britain and Canada on Guinard Island during World War II. The island was declared safe again in 1988 after burning the heather and treating the ground with formaldehyde.

[69]Chris Bellamy, *The Future of Land Warfare*, (New York: St. Martin's Press, 1987), 186-187; Data on overpressure effects obtained from John E. O'Pray, "Regional Power Ballistic Missiles: An Emerging Threat to Deployed US Forces?," 89.

[70]John R. Harvey in "Regional Ballistic Missiles and Advanced Strike Aircraft: Comparing Military Effectiveness," 49-66.

[71]Ibid., 64.

[72]Information drawn from Ibid, 49-66. For Harvey's comments on the utility of ballistic missiles for nuclear delivery see, pages 43, 67, and 74.

[73]Description of aircraft used in the raid and their roles obtained from James A. Winnefield and Dana J. Johnson, *Joint Air Operations: Pursuit of Unity in Command and Control, 1942-1991*, (Annapolis, MD: Naval Institute Press, 1993), 87.

[74]The number of US Navy aircraft participating in the attack (70) and the number tasked to drop bombs (14) obtained from, Memorandum, W. Seth Carus to Janne E. Nolan, cited in Janne E. Nolan, *Trappings of Power*, 70. W. Hay Parks, "Crossing the Line," *US Naval Institute Proceedings* vol 112, (November 1986), 51, indicates that two A-6E aircraft aborted, but does not give a reason. Additionally, 24 F-111s and 5 EF-111s departed England. Six F-111s and 1 EF-111 were spares and dropped off after the first air-refueling. Eleven F-111s dropped bombs; one crashed into the Mediterranean Sea. Additional support aircraft included 28 KC-10/KC-135 tankers, six A-7s and six F/A-18s firing Shrike and HARM missiles at Libyan air defense radars, at least two E-2C command and control aircraft, and an undisclosed number of F-14s and F/A-18s flying MIG Combat Air Patrol over the two US aircraft carriers, the *America* and the *Coral Sea*. For more on US Air Force participation, see Robert E. Venkus, *Raid on Qaddafi*, (New York: St. Martin's Press, 1992).

[75]Harvey uses series of complex calculations to arrive at his conclusions. This monograph does not seek to replicate his calculations. Instead, it uses the basic mathematics provided by Harvey in Table 3, Nominal Parameters for Missile-Aircraft Cost Comparison, located on page 66 of his article. The following is a summary of how this author arrived at the cost per deliverable ton using a ratio of 5 participating aircraft to every one actual bombing aircraft. Assume Pre-Launch Survivability (PLS) is still 1.0. Divide the Defense Penetration Probability (PP) used by Harvey for aircraft (.95) by 5 to get .19 probability of penetration. The formula for determining the average number of sorties before an aircraft is lost is $(N_S)=1/(1\text{-}PLS*PP)$. Substituting numbers, $N_S=1/(1\text{-}1.0*.19)$ or $N_S=1/(.81)=1.2345679$ sorties before the aircraft is lost. Take N_S along with the Tons Delivered Per Sortie (T_{AV}) given by Harvey as 2.85 tons, and use them in the following equation for Cost Per Delivered Ton (CPT): $CPT=Cost/(N_S*T_{AV})$. Using actual numbers, CPT=$40 million/(1.23*2.85 tons). This translates into: CPT=$40 million/3.52 tons or CPT=$11.36 million per ton of delivered ordnance. For more information see, John R. Harvey "Regional Ballistic Missiles and Advanced Strike Aircraft: Comparing Military Effectiveness," *International Security*, vol 17, no. 2, (Fall 1992): 66. An even simpler calculation would be to multiply the $700,000 cost per deliverable ton by a factor of 5 for a total of $3.5 million per deliverable ton or nearly three times more costly than missiles.

[76]Harvey and Fetter both use historical evidence of US losses to bolster their argument, although Harvey also discusses the 1973 Yom Kippur War and the 1982 Falklands War. Harvey uses a crossover point of 9 percent in his argument. Fetter (page 9) calculates 35 percent for a single-stage missile and 25 percent for a two-stage missile. Uzi Rubin, "Iraq and the Ballistic Missile Scare," *Bulletin of the Atomic Scientists,* October 1990 cited in Martin Navias, *Going Ballistic,* 12, argues for 50 percent.

[77]Martin Navias, *Going Ballistic*, 33; Martin Navias, *Ballistic Missile Proliferation in the Third World*, 29-31; System Planning Corporation, *Ballistic Missile Proliferation: An Emerging Threat*, 55; Duncan Lennox, Missile Race Continues," *Jane's Defence Weekly*, (23 January 1993): 18-21; and "World Missiles," *Defense and Foreign Affairs Strategic Policy*, (March 1991): 23.

[78]Primary tactical effects are those that occur directly from a missile attack or threat of such an attack. Secondary effects are those tactical effects that devolve indirectly from a friendly response to the political and strategic use of ballistic missiles by enemy forces.

[79]Louis C. Wagner, Jr., "Theater Missile Defense," *Army* vol. 44, no. 11, (November 1994): 26; US Army Air Defense Artillery School, "Draft Concept for Integrated Air Defense Artillery Operations," (Fort Bliss, TX: Combat Developments Directorate, 13 June 1994), 23.

[80]Michael W. Ellis and Jeffrey Record, "Theater Ballistic Missile Defense and US Contingency Operations," *Parameters* vol. 22, no. 1, (Spring 1992): 20; Rick Atkinson, *Crusade: The Untold Story of the Persian Gulf War*, (New York: Houghton Mifflin, 1993), 256-257.

[81]Ibid., 18.

[82]The issue of a North Korean missile attack and the potential for the ballistic missile intimidation of Japan were discussed by the author and LTC Keith McNamara, Assistant Director of Combat Developments, US Army Air Defense Artillery School, Fort Bliss, Texas during a meeting at Fort Leavenworth, Kansas in August 1994.

[83]Conversation with LTC Keith McNamara, Ibid. The Patriot battalion was the 2-7 ADA stationed at Fort Bliss, Texas. That battalion is part of an all Patriot Air Defense Brigade charged with providing tactical ballistic missile protection to echelon above corps (EAC) units. One of the Patriot batteries that deployed to Korea positioned outside of Osan Air Base. The other locations were not disclosed to the author.

[84]Gulf War Collection, SSG AAR 3-042, SG Historian Group VII Corps. (S/Unclass) Part 3, Chronology and Documentation, Volume 4, Documentation: Tab B, VII (US) Corps Operations Order (OPORD) 1990-2 (Operation Desert Sabre), Annex M (Air Defense), (U) (hereafter cited as GWC Operation Desert Saber): 3. The task force designation was TF 8-43 ADA. It consisted of a four-battery Patriot battalion and two Hawk batteries.

[85]Lieutenant General Funk made these comments in response to a question the author asked him during a briefing at the School of Advanced Military Studies, Fort Leavenworth, Kansas on 13 October 1994.

[86]U.S. Congress, House, Committee on Armed Services, Subcommittee on Oversight and Investigations, *Report on Intelligence Successes and*

Failures in Operations Desert Shield/Storm, 103d Cong., 1st Sess., August 16, 1993, Committee Print 5, p. 11.

[87]In a meeting with Colonel Joseph Garrett, Commander of the 11th Air Defense Artillery Brigade, and Lieutenant Colonel Jeff Gault, Deputy Commander, prior to the movement of XVIII Corps west, Lieutenant General Yeosock called King Khalid Military City and Logistics Base Bravo his operational center of gravity. Colonel Gault related these comments to the author during a meeting at Fort Leavenworth, Kansas on 13 August 1994.

[88]On 6 October, 1994 at Fort Leavenworth, Kansas, the author questioned General Franks on how the threat of a ballistic missile attack complicated his planning during Operation Desert Storm. He commented that he was particularly concerned with chemical rounds landing on his forces while they were breaching Iraqi positions and potentially caught up in a minefield. He also mentioned that he felt tactical ballistic missiles were particularly dangerous during early entry operations. He concluded by stating that the Army must always possess its own means of self-defense against ballistic missiles.

[89]GWC (Operation Desert Saber), A-7.

[90]Major Michael Alexander made these observations to the author on 16 November, 1994 at Fort Leavenworth, Kansas. Major Alexander was a Headquarters Company commander in the 2d Brigade, 1st Infantry Division during Operation Desert Storm.

[91]This paragraph is based on comments by Major Alexander to the author on 16 November, 1994.

[92]Data on the population size and density of Seoul obtained from *The World Almanac,* (New York: Pharos Books, 1992), 881. Incidentally, Pusan, while having a smaller total population (5 million) has almost twice the population density (92,735) as Seoul. An attack on Pusan during any phase of the war risks closing its main arteries for the duration of the conflict. The comment by a North Korean diplomat is attributed to Park Young Su. It was made at Panmunjom in March 1994. Quoted in *ADA (Air Defense Artillery),* (July-August 1994), 1.

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