Bridge or Barrier: Does the Crusader Self-Propelled Howitzer Have a Weight Problem?

A Monograph
by
Major Steven M. Merkel
Field Artillery

19990804 074

School of Advanced Military Studies
United States Army Command and General Staff College
Fort Leavenworth, Kansas

First Term AY 98-99

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
		MONOGRAPH

4. TITLE AND SUBTITLE
Bridge or Barrier: Does the Crusader Self-Propelled Howitzer Have a Weight Problem?

5. FUNDING NUMBERS

6. AUTHOR(S)
MAJ Steven M. Merkel

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
School of Advanced Military Studies
Command and General Staff College
Fort Leavenworth, Kansas 66027

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Command and General Staff College
Fort Leavenworth, Kansas 66027

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
APPROVED FOR PUBLIC RELEASE
DISTRIBUTION UNLIMITED.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
SEE ATTACHED

14. SUBJECT TERMS	15. NUMBER OF PAGES
Crusader, Howitzer, Fire Support	46
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UNLIMITED

SCHOOL OF ADVANCED MILITARY STUDIES

MONOGRAPH APPROVAL

Major Steven M. Merkel

Title of Monograph: *Bridge or Barrier: Does the Crusader Self-Propelled Howitzer Have a Weight Problem?*

Approved by:

_______________________________ Monograph Director
LTC Mark R. Gilmore, MMAS

_______________________________ Director, School of Advanced Military Studies
LTC Robin P. Swan, MMAS

_______________________________ Director, Graduate Degree Program
Philip J. Brookes, Ph.D.

Accepted this 16th Day of December 1998

ABSTRACT

BRIDGE OR BARRIER: DOES THE CRUSADER SELF-PROPELLED HOWITZER HAVE A WEIGHT PROBLEM? By MAJ Steven M. Merkel, USA, 52 pages.

The American Army's current fleet of self-propelled howitzers is largely outmoded and at its limit, due to space and weight constraints, to be upgraded. This fire power shortfall is the impetus behind development of a new self-propelled howitzer designed to not only overcome current shortfalls but to remain in the Army inventory for the next forty years. The Crusader self-propelled howitzer system is the new cannon currently under development.

The problem is that its weight of 110 tons combat-loaded (fifty-five tons each for the howitzer and the resupply vehicle) simply does not fit nicely with the current vision of agile, quickly deployable forces operating on the future battlefield as described in Joint Vision 2010 and in the Army After Next. In a period of increasing competition for scarce Defense Budget dollars, critics have highlighted the system's reduced transportability due to its weight as marginalizing its value to the Army. In a 6 April 1998 interview in *Army Times* the Chief of Staff of the Army, General Dennis Reimer, defended the Army position in developing the Crusader noting that such "criticism ignored the increased tactical capability of the gun." This monograph examines the question of whether the Crusader's tactical capabilities offset its weight.

The monograph begins with an examination of the Crusader system and the environment in which it is expected to operate. Because any conflict has two sides, the environment is not only considered from an American viewpoint, but also from the view of how threat artillery systems may evolve. The Crusader's tactical capabilities, namely increased force effectiveness, survivability, flexibility, and the ability to support a broader range of missions, are derived from this information.

Finally, the monograph analyzes the Crusader's transportability. While suffering from the same constraints that limit the deployment of any heavy combat vehicle, the Crusader does not appear to represent a significant decrease in transportability from the M109 Paladin, the system it replaces. The monograph concludes that General Reimer was correct in defending the Crusader. Its tactical capabilities do seem to offset its projected weight.

TABLE OF CONTENTS

I. Introduction

> Even the recent introduction of the M109A6 Paladin, for all its apparent attributes, cannot conceal that the last drop of juice has been squeezed from the M109 lemon.[1]

Without a change in its family of self-propelled howitzers, the U.S. Army faces the unenviable and increasingly more likely position of being outgunned by an opponent on the future battlefield. The crux of the Army's problem with its current self-propelled howitzer is that the Paladin and related M109 series of guns is based on a 1950s chassis making it, not only, largely outmoded, but also at its limit of ability to be upgraded with the latest technology.[2] In addition to lacking the mobility to keep up with the M1 Abrams Tank and the M2 Bradley Fighting Vehicle, the Paladin also lacks the lethality of many of today's artillery systems.[3] With a range of thirty kilometers and a rate of fire of four rounds per minute, the Paladin cannot match systems such as the Russian 2S19 self-propelled howitzer, the German PzH2000 system, the South African G6 howitzer, or Great Britain's AS90 self-propelled howitzer. In each case, the Paladin is outmatched in both range and rate of fire.

In addition to lacking the necessary lethality, the Paladin also presents a survivability risk. Increasingly more and more countries are involved in the production or development of artillery delivered high precision munitions.[4] Conceivably, since these munitions offer high "shoot to kill" probabilities, they will become the weapons of choice for tomorrow's counterfire systems. This presents a problem to our current family of self-propelled howitzers as they only carry armor to protect the crew against fragmentation and do not carry sufficient armor to protect the crew from top-attack submunitions.

The fact that the Paladin has reached the limit of its ability to be significantly upgraded exacerbates the Army's problem in finding a solution to overcome its current deficiencies. Due largely to space and weight limitations on its current chassis, simple modifications to the Paladin and M109 family of self-propelled howitzers do not fix the problem. With its thirty-nine-caliber gun tube, the Paladin is physically limited to an unassisted range of just over eighteen kilometers, well short of many other artillery systems in the world. While the Paladin has been tested with a fifty-two-caliber cannon that does extend its range, the system also needs an auto-loader to increase its rate of fire and boost its lethality to a level comparable to other self-propelled howitzers. The problem is there is no room for an auto-loader in the forty-year-old chassis of the Paladin. Moreover, increasing the Paladin's slow rate of fire would necessitate the addition of a thermal-cooling device to the cannon to keep it from overheating. Again, this requires a complete rework of the gun tube system. Additionally, its mobility problem, according to accounts taken in DESERT STORM, is not one limited solely by the suspension. The Paladin also lacks the horsepower to keep up with the Army's current fleet of armored combat vehicles.[5]

To overcome these shortfalls in our current family of self-propelled howitzers, the Army is developing the Crusader as the Paladin's replacement. The Crusader is a technologically advanced 155mm self propelled howitzer system consisting of two-vehicles, a Crusader Self-Propelled Howitzer (SPH) and a Resupply Vehicle (RSV). Together, the Crusader and its accompanying RSV promise to make up for all of the Paladin's shortfalls. Key Performance Parameters (KPP) for the Crusader include: a forty kilometer unassisted range with a fifty kilometer rocket assisted range; a maximum rate of fire, due largely to a liquid cooled gun tube, of ten to twelve rounds per minute for three to five minutes; and the ability, via the RSV, to transload sixty complete rounds and refuel in twelve minutes. Additionally, the Crusader, with a cross-country speed of thirty-nine to forty-eight kilometers per hour and a highway speed of sixty-seven to seventy-eight kilometers per hour, would be as mobile as the M1 Abrams Tank and M2 Bradley Fighting Vehicle.[6]

In addition to the advances in terms of being a purely fire support system, the Crusader also would be the first "new start" ground combat system for the future Army. As such, the Crusader would serve as a technology carrier to allow weapon system developers to try out new technologies prior to incorporating them in other future combat vehicles. In this light, the Crusader design calls for a laser ignition system, completely automated large caliber auto-loading, and advances in composite armor development.[7]

While the weight of the Crusader system places it near the top of artillery systems[8] currently under development around the world, the problem is that its weight of 110 tons combat-loaded (fifty-five tons each for the howitzer and the RSV) simply does not fit nicely with the current vision of agile, quickly deployable battle units operating on the future battlefield as described in Joint Vision 2010 and in the Army After Next.[9] In a period of increasing competition for scarce Defense Budget dollars, critics have highlighted the system's reduced transportability due to its weight as marginalizing its value to the Army. In a recent interview the Chief of Staff of the Army, General Reimer, defended the Army position in developing the Crusader noting that such "criticism ignored the increased tactical capability of the gun."[10]

This monograph attempts to do exactly what General Reimer has posed, namely to balance the Crusader's weight against its tactical capabilities. The purpose of this paper is to answer the research question: Does the Crusader Self-Propelled Howitzer's increased tactical capability offset its massive weight? The significance of this question becomes self-evident when considering the implications of adopting a fire support system that is incompatible with how an army intends to fight on the future battlefield.

Before explaining the methodology for answering this question and in order to more completely deal with the subject matter, this monograph is limited in a number of significant ways. First, the question of whether the Crusader is the best fire support system for the U.S. Army on the future battlefield is intentionally not addressed. While this topic is extremely important and very relevant it is beyond the scope of this paper. Similarly, as this monograph analyzes the tactical capabilities and deployability of the Crusader system I focus on a conventional mid-to-high intensity conflict environment. While it is likely that American forces will most frequently be involved in stability and support operations in the near future, the most relevant scenario for the utilization of a heavy self-propelled howitzer system is in mid-to high-intensity conflicts. Finally, in addition to these limitations, the monograph makes several assumptions in conducting the research and in analyzing the results. As is true of any research involving a piece of equipment which has not been completely developed, this monograph assumes that the Crusader weapon system that finally rolls off American assembly lines will have the capabilities and characteristics outlined in Section II of this paper. The risk is that for a number of reasons, the final Crusader system may not look or perform exactly as expected. Already, for example, the liquid propellant initiative originally included in the Crusader system has been curtailed due to technological problems.[11]

The basis of this monograph is to analyze what tactical capabilities Crusader can be expected to bring to the future battlefield versus any reductions in transportability it may encounter due to its weight. To do this, material from a number of different sources is brought together and laid as a foundation. First, in order to establish a common level of understanding of the system, my paper focuses on the Crusader 's physical characteristics. Second, it concentrates on identifying what the future battlefield is expected to look like and how the United States Army anticipates threat fire support systems to evolve. The monograph then analyzes this information to identify the first half of the information needed to answer my research question; namely what are the Crusader's potential tactical capabilities. Next, attention is turned to analyzing the Crusader's transportability, which is defined as the inherent capability of the system to be efficiently moved by required transportation assets using the highway, rail, marine, or air modes of transport[12]. With this information, the monograph analyzes and evaluates the system's tactical capabilities versus its deployability to arrive at the answer to my research question.

The evaluation criteria used in the monograph to arrive at the conclusion center on the fact that, as with all weapon systems, the Crusader is designed to give the Army the physical capability to take action against an opponent on the battlefield. As outlined in the latest revised draft of Field Manual 100-5, Operations:

> A force's physical capability comes from its ability to *sense* the enemy, itself, and the environment; *strike* an opponent decisively; *move* freely in the area of operations; *control* actors, actions, and events; *shield* itself from the attacks of an opponent; and *sustain* itself.[13]

Consequently, for the Crusader system's tactical capabilities to outweigh its reduced transportability it must do so within the framework of these core functions of the physical domain of conflict identified above. For this reason, my paper uses these core functions of the physical domain of conflict as evaluation criteria to answer the research question.

II. Crusader's Characteristics

From the beginning the Crusader system was intended to be a 21st Century weapon system. The current fielding plan calls for the first unit to be equipped in fiscal year 2005 with full production beginning the following year.[14] While we cannot possibly know what characteristics and features will survive the final development process, we do know the key performance indicators that weapon system developers are aiming for the Crusader to hit. Identifying these characteristics serves as a logical starting point in identifying what tactical capabilities one can expect the Crusader system to bring to the future battlefield.

Lethality

Recognizing that the specter of entering the next conflict with an inadequate fire support system loomed over the U.S. Army, weapon designers developed from the outset a weapon system that would represent a quantum leap in lethality over the current Paladin self-propelled howitzer. In terms of its range, rate of fire, accuracy, ability to conduct multiple round simultaneous impact (MRSI) missions and to conduct its own technical and tactical fire direction, the Crusader system truly does represent a revolution in firepower lethality.

The Crusader self-propelled howitzer will give the U.S. Army a fire support system that has a range that matches or exceeds that of most self-propelled cannon systems in the world. Using the advanced XM297E2 cannon, the Crusader will have an unassisted range of between thirty and forty kilometers and an assisted range extending out to between forty and fifty kilometers. This represents a twenty-five to forty percent improvement over the Paladin which has an eighteen-kilometer unassisted range and a thirty-kilometer range with rocket assisted projectiles. The XM297E2 cannon is a fifty-four-caliber gun tube, which is considerably longer than the Paladin's thirty-nine caliber cannon. In order to extend tube life the Crusader is expected to have a chromed chamber and bore. Often as the cannon tube is lengthened, barrel travel or movement reduces the accuracy of the weapon. Crusader's developers have taken this into account and have fitted the gun with modular recoil and recuperator cylinders to limit this problem[15].

While the range of a fire support system is important, it is the rate of fire which determines how many rounds can be placed on a target and therefore is the determining factor in a system's lethality. The Crusader's maximum rate of fire of ten to twelve rounds per minute more than doubles that of the Paladin. In order to accomplish this high rate of fire the Crusader relies on a number of technological firsts.[16] The most important of these are the Crusader's completely automated ammunition loading system and its actively cooled cannon and recoil system. Using a closed loop conveyor system and central shuttle the Crusader has the ability to automatically select the correct projectile from either of its thirty round magazines, set the fuze to the appropriate function, find and load the correct combination of propelling charges from any of its four charge magazines, and then fire the round using a laser ignition system[17]. To sustain its high rate of fire without overheating, the Crusader relies on an Integral Midwall Cooled (IMC) barrel which consists of a full-length cooling sleeve built around the cannon wall which circulates a mixture of ethyl glycol and water.[18]

In order to automate the Crusader's ammunition handling and loading functions, both the propelling charge and projectile fuze required special consideration. So that the propelling charges could be handled mechanically, weapon developers have had to do away with the traditional "bagged" propelling charges and have adopted the 155mm Modular Artillery Charge System (MACS). The modular charge is contained within a rigid combustible cylindrical case that is approximately fifteen centimeters long. While the rigid cylinder makes the charge easy for an automatic loader to handle, it is consumed as the propelling charge burns, eliminating any waste or residue. These modular charges are intended to be bi-directional[19], making it impossible for them to be loaded backwards and would come in two varieties, the XM231 and the XM232.[20] The concept is that a projectile could be fired at any of the Crusader's operational ranges using a combination of these charges. Similarly, the Crusader would use a family of fuzes that could be set electronically by an automatic loader. The main Crusader fuze will be the XM782 Multiple Option Fuze Artillery (MOFA). The XM782 supports the Crusader's automatic loading concept and the pre-fusing of projectiles. The XM782 is designed for bursting type projectiles and can be set in proximity, time, point detonating or delay mode.[21]

Several additional features also help boost the Crusader's lethality. One of the more interesting of these is the ability to conduct a four to eight round Multiple Round Simultaneous Impact (MRSI) mission within the range band from eight to thirty-six kilometers.[22] In an MRSI mission a single gun fires a series of rounds at different elevations so that each round impacts on the same target at the same time. The value of this type of mission centers on the fact that a person under indirect fire takes approximately three seconds to get down, which greatly reduces his vulnerability to horizontal fragmentation from incoming artillery.[23] Being able to place up to eight rounds onto a target simultaneously, the Crusader can do greater damage as people may be potentially caught in the open and have no time to react. Another feature that increases the Crusader's lethality is its ability to conduct tactical and technical fire control. This, coupled with the system's self location and automatic gun laying capability, means the Crusader can be moving, receive a fire mission, stop, compute its own firing data and send rounds down range in fifteen to thirty seconds.[24]

Survivability

In addition to representing a monumental improvement in lethality, the Crusader also promises to improve fire support survivability on the 21st century battlefield. While very little is being said about the Crusader's protection characteristics, one can assume that its survivability will be founded in a combination of weapon design features and employment techniques. In addition to being designed with the latest "stealth" technology, the Crusader will take advantage of recent advances in composite armor development. This lighter armor will not only provide all around protection from fragmentation, it will also protect the crew and vehicle from top-attack shaped charge munitions such as dual-purpose improved conventional munitions (DPICM). Smart countermeasures that sense an incoming round in time to deploy some type of defeat mechanism might also form part of Crusader's survivability package.[25]

To compliment these weapon design features the Crusader will also depend on its speed and agility to increase its survivability. In this light, the Crusader will be capable of "dash" or survivability moves of up to 750 meters in ninety seconds. As a matter of comparison, the

Paladin is able to "dash" 560 meters in ninety seconds. The fact that the Crusader will also be fitted with an automated situational awareness package called the Battle-Management System (BMS) will help filter tactical information, allowing the Crusader to take care of routine monitoring and reporting functions so that the crew can concentrate on tactical decision-making, further enhancing their survivability.[26]

A separate crew compartment will also help increase the Crusader's survivability. Weapon designers have separated the crew compartment from the weapons compartment. All three crewmembers of each vehicle will sit together in front of a crew station console in an isolated compartment that has been protected with additional armor and a seventy-two hour nuclear, biological, and chemical collective protection system. Because the Crusader will use drive-by-wire technology (meaning electrical signals from a computer, not mechanical linkages, will be used to steer, accelerate, brake, and shift gears in the vehicle) each crewmember will have the ability to operate the vehicle from his station, further enhancing Crusader's survivability.[27]

Mobility

Unlike the Paladin, the Crusader will have the mobility to keep up with the maneuver element it is designed to support. Weapon developers, in an effort to ensure the Crusader is endowed with plenty of horsepower, have selected the Perkins Condor CV12-1500 diesel engine matched to a Lockheed Martin HMPT 1250-EC transmission as the major components of its powerpack. This combination gives the Crusader a cross-country speed of thirty-nine to forty-eight kilometers per hour and a highway speed of sixty-seven to seventy-eight kilometers per hour. This is comparable to the cross-country and highway speeds of the M1 Abrams Tank and the M2 Infantry Bradley Fighting Vehicle. The Caterpillar-built Perkins Condor CV12-1500 promises plenty of muscle to move the fifty-five ton combat-loaded Crusader and RSV. It is a fuel injected, air cooled power plant with excellent growth potential to 2000 HP and low fuel consumption. To compliment this work horse, the Lockheed Martin HMPT 1250-EC transmission has steering agility for precise docking, high power density, and the lowest weight and volume in its class. Together, this will give the Crusader the highest fuel efficiency and the lowest smoke emissions/noise levels for a ground combat system of similar character.[28]

Several other features will help boost Crusader's mobility. The current concept for Crusader's suspension is based on General Dynamics Land Systems' externally mounted hydro-pneumatic suspension unit. The Crusader is also expected to take advantage of a wider, lighter and more advanced version of the same track that is used on the M1 Abrams tank. This track, the T158LL, is under development by Goodyear. To aid movement planning the Crusader will be endowed with position and navigational aids to include movement planning decision aids.[29]

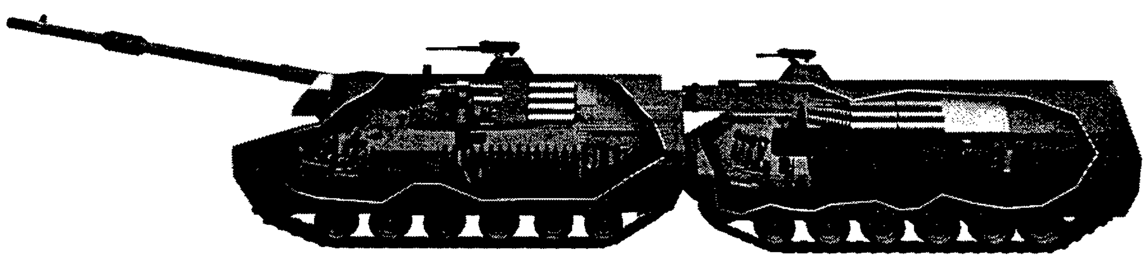
Sustainment

The Crusader system is more than just a self-propelled howitzer. The Resupply Vehicle (RSV) is an equally important component of the total system. The fielding plan calls for the RSV to be issued on a one for one basis with the self-propelled howitzer. This idea is consistent with the Paladin and its associated resupply vehicle, the M992 Forward Area Ammunition Supply Vehicle or FAASV. However, unlike the FAASV, the RSV will not only resupply its howitzer with ammunition and propelling charges, it will also refuel the gun, thereby eliminating the need to remove the howitzer from the battle to conduct separate refueling operations.[30] Also, unlike the Paladin/FAASV combination, the RSV and Crusader gun system will share many of the same components. This means the RSV will have the same size crew, automation, mobility, and survivability of the self-propelled howitzer. Additionally, both will have an embedded array of prognostic and diagnostic system monitors to alert the crew to the vehicle's mechanical status and to provide potential solutions when problems are encountered.[31]

In addition to improving ammunition survivability, the RSV will also reduce crew fatigue during resupply operations due to its automated ammunition-handling feature. The RSV will have a capacity of 130 projectiles and 480 propellant charges. This means the RSV could resupply two different gun systems without returning to reload. With the help of an adjustable angle boom and under the armored protection of both vehicles, the RSV can refuel and rearm the Crusader howitzer with sixty complete rounds in under twelve minutes. During this short time each projectile will automatically be weighed, its identification checked, and its location stored in the memory of the howitzer's on-board computer.[32]

Besides the on-board prognostic and diagnostic maintenance support computer software, the Crusader system (both vehicles) has been designed be modular allowing eighty-five percent of the necessary maintenance to be completed at crew or unit level. The engine offers a good example of this concept. The Crusader system's power plant has been packaged as a single unit in the rear of each vehicle that is easily accessed through the rear ramp. With the help of quick disconnect mechanisms for the final drive, coolant and fuel systems, electrical harness, air intake, and exhaust line, the engine can be removed in approximately one hour.[33]

As outlined in this section the Crusader system has been designed with the latest, and in some cases, not yet completely developed technologically advanced features. Through its lethality, survivability, mobility and sustainability, the Crusader system is a generation ahead of any contemporary system.



SPH Characteristics

* *RANGE: 40-50 Km*
* *Max Rate of Fire: 10-12 Rounds/Minute*
• Sustained Rate of Fire: 3-6 Rounds/Minute
• 4-8 Round Simultaneous Impact
* *Mobility Equal to Maneuver Systems*
• 55 Tons
• Crew: 3-Man

RSV Characteristics

• Payload: 130-200 Rounds
* *Automated Rearm of SPH in 12 Minutes*
• Upload Within 65 Minutes
* *Mobility Equal to Maneuver Systems*
• Position Navigation
• 55 Tons
• Crew: 3-Man

[34] * *Key Performance Parameters (KPPs)*

III. The Future Battlefield

In addition to understanding the Crusader's characteristics and features, one must also consider the environment in which it will operate in order to deduce what tactical capabilities the system will bring to the U.S. Army. Perhaps the great Prussian military theorist, Carl von Clausewitz, best captured the essence of this environment in his military classic, *On War*, when he stated that "countless duels go to make up war, but a picture of it as a whole can be formed by imagining a pair of wrestlers. Each tries through physical force to compel the other to do his will."[35] In this light, any consideration of Crusader's role in the future Army must not only address how we envision that battlefield to look, but also how we expect potential threats to evolve.

The purpose of this section is to address the first portion of Crusader's environment; namely what the U.S. Army expects the future battlefield to look like. Since the Crusader will not be fielded until 2005 and is expected to be in the inventory for forty years, the future that concerns us includes not only Force XXI, the vision of the Army in the early 21st Century, but also the Army After Next (AAN), the Army that will follow Force XXI.[36]

Force XXI

To meet the challenges of adapting the current Army for the period from the present to about the year 2010, General Gordon R. Sullivan, while serving as the Army Chief of Staff, took the initiative to begin development of Force XXI. Since 1994 Force XXI, through a series of field-tests, doctrine development initiatives, and acquisition programs, has been further defined and better developed. While it is true that the international security environment can be expected to remain unpredictable, one element that will not change is the U.S. Army's resolve to be prepared to meet "our Nation's 21st Century challenges."[37]

The U.S. Army's Training and Doctrine Command *(TRADOC) Pamphlet 525-5, Force XXI Operations*, identifies five defining characteristics of Force XXI: doctrinal flexibility; strategic mobility; tailorability and modularity; joint and multinational connectivity; and versatility to function in War and Operations Other than War.[38] By considering each of these characteristics in turn, one can identify certain fundamental expectations about the environment in which Crusader will need to operate.

The first characteristic, doctrinal flexibility, embodies the idea of being able to adapt the "way" we fight to the specific scenario at hand. More recently, the latest revised Draft of U.S. Army Field Manual 100-5, *Operations*, identifies two "timeless truths of doctrine." First, an Army must not assume a willing opponent and therefore adopt a doctrine that is too narrow or prescriptive. Second, in war, the side that is best prepared mentally to adapt will reap a significant advantage."[39] The overriding idea in this characteristic seems to be that the future battlefield will require soldiers with the mental agility to assess the situation quickly and adapt their actions to control the environment quickly.

Recognizing the uncertainty of the strategic environment and the constraints, both economic and political, that deny a nation the ability to station forces around the world, the Army will remain a power projection force. The second characteristic of the Force XXI battlefield, strategic mobility, "is about being in the right place at the right time with the right capabilities."[40] History has shown that the early phases of a crisis are the most crucial. "If U.S. forces arrive in a theater promptly and are prepared to operate immediately, a crisis may be averted or may be stabilized enough to allow an orderly build-up of forces."[41]

The third characteristic, tailorability and modularity, acknowledges that through advances in information technologies that "organizations will tend to grow flatter and less rigidly hierarchical." Additionally, limitations in strategic lift, the need to respond rapidly, and the unavailability of sufficient air or sea ports in the area of operations, all seem to suggest that to maintain flexibility our future forces be as "modular as logic allows to facilitate tailoring to meet each contingency." [42]

No service or governmental agency has the singular ability to achieve success in the next war. Similarly, while the U.S. has the ability to act unilaterally to protect its national interests, often our interests are consistent with other nations. Seldom, therefore, do we pursue our interests alone. Joint, Multinational, and Interagency connectivity is another important characteristic of the future battlefield. A military force that cannot communicate or operate with other members of the joint and combined team is destined for failure.[43]

The final characteristic represents a fundamental fiscal truth in the next century; nobody can afford to man, train, or equip a separate army tailored for each specific operational environment. Each nation, instead, will strive to build a force that has the versatility to win its nation's wars, as well as protect its national interests in operations other than war. As outlined in Army Vision 2010, the Army's blueprint for the future, our versatility will be due to "modern technologies that will exploit situational understanding phenomena to enable tailored, still undefined combat organizations to task organize quickly and fight dispersed with extraordinary ferocity and synchronization."[44]

The Army After Next

As stated earlier, only considering the Force XXI time period in defining the Crusader's potential operational environment paints an incomplete picture. With expectations of being in the Army's inventory for forty years, the Crusader system will undoubtedly be around in the time frame of the Army After Next (AAN), a program designed to conceptualize the geostrategic environment thirty years into the future.

In the mid-1990s Army Chief of Staff General Dennis J. Reimer commissioned Headquarters, Training and Doctrine Command (TRADOC) to begin "an exploratory program to investigate the possible shape and behavior of the Army in the 2025 time frame."[45] The need for this "Army After Next" program was threefold. First, many of the pieces of equipment purchased in the 1980s were scheduled to reach the end of their life cycle around 2010. Second, the pace of technological change had become so quick that that the only way to ward off obsolescence was with an unconstrained and long-term view to the future. Finally, the uncertainty of the geopolitical world also warranted a long-term approach to address potential security challenges.[46] Under General Reimer's directive the Army After Next process offered an unconstrained, futuristic think tank to consider issues in four areas: the geostrategic setting; the evolution of military art; human and organizational issues; and technology issues.[47] Each year in June the Army After Next team presents a study to the Army Chief of Staff detailing their findings with respect to these four broad research areas.

"Army After Next study and research efforts over the last year and a half clearly identified knowledge and speed as the central themes for the Army of 2025."[48] In this context, the AAN team has come to several conceptual conclusions that help one visualize, at least from a technological standpoint, what the outline of the Army may look like in 2025. Three of these conclusions are especially insightful.

The first conclusion is that "the Army after Force XXI will have to be strategically mobile, dramatically improving on the Army's ability to deploy forces today or even in the Force XXI period."[49] Future demands are expected to necessitate a form of "global maneuver" which is very different than how we deploy today. In this light, Large Medium-Speed Roll-On Roll-Off (LMSR) ships would give way to ultra-fast sealift (UFS) which could avoid space-based surveillance and precision interdiction by traveling at speeds at up to one hundred knots. At the operational level, the Army would pursue ways to accelerate the pace of movement to rapidly counter, check, and paralyze its opponent.[50] One concept for a force that has this ability is the "battle force." This battle force would be an "air mechanized force" which could rapidly maneuver on the battlefield, via rotorcraft, conducting ambush like strikes to hit and close with the enemy before he had the opportunity to react. Interestingly, a common misconception is that the entire Army After Next force structure would consist of these highly mobile, air mechanized battle forces.[51] In reality, they would most likely only form the rapid reaction capability of the future Army. Current technologies related to self-deploying tactical forces, fast sealift and large-capacity airlift support the AAN team's conclusion.[52]

While no one can predict what our force structure will look like in 2025, one can assume with relative certainty that the force will consist of very expensive pieces of equipment being operated by highly skilled and well-trained soldiers. The AAN team's second conclusion, that the future Army must avoid attrition warfare, follows from this revelation. "Some combination of precision fires and dominant maneuver should permit U.S. land forces to hit where they choose, and deny an enemy the opportunity to entrap U.S. forces in wearing and inconclusive combat."[53] In this environment a robotic companion may accompany manned weapon systems and remotely controlled platforms may be airdropped into position early in a conflict and detonated at a later time. Maximum use would be made of very long range or "non-line-of-sight fires" to preclude human casualties. As alternate propellants are developed, even longer-range fires might reduce the actual number of systems needed on the battlefield, since effects could be massed without physically massing weapon systems.[54]

The final conclusion to highlight is that the Army After Next must be as self-sustainable for as long as possible. "Shrinking the logistic tail to the theater of operations and on the battlefield itself is a fundamental goal in fielding AAN-era fighting forces."[55] In the Army After Next "it's possible that the bulk of logistics and administrative support may be based outside the active theater of operations, beyond the reach of most threats, which would free up combat units to concentrate on active operations instead of security."[56]

Now that we have taken a more detailed look at the environment in which the Crusader system will most likely operate, what can we expect it to look like? First, the environment can best be described as fast. "Faster deployment, faster processing of information for faster decision making, faster firepower focused faster on fleeting targets, faster maneuver, faster finishing and decision."[57] We can expect high tempo operations, in which time becomes compressed and what we traditionally think of in terms of deep, close, and rear, meld together in a confluence of long-range accurate fires followed by rapid moves to close with the enemy before he reacts. Widely dispersed and non-contiguous forces will conduct non-linear and distributed operations, massing effects and not forces to avoid casualties. This seems to be the environment in which the Crusader will exist.

IV. Evolution of Potential Threat Fire Support Systems

No plan survives contact with the enemy.

Field Marshal Helmuth von Moltke[58]

In a recent Land Warfare Paper, Douglas A. MacGregor, a U.S. Army officer and noted military author, postulated that "because technology is developing so rapidly, it is hazardous to assume too much about the details of possible future threats."[59] While we must be cautious of predicting the details of tomorrow's threats, it would be equally hazardous to ignore the evolution of these threats entirely. Based on the availability of pertinent knowledge and the ability to manufacture necessary components, economic historian Robert L. Heilbronner in his 1967 essay, "Do Machines Make History?", argues convincingly that there is a certain element of predictability to technology's path.[60] That said, it is worthwhile to take a brief look at how potential threat fire support systems may evolve. After all, these threat systems are what the Crusader must contend with on the next battlefield; and, as we all know, the enemy gets a vote in that encounter.

A complete fire support system consists of not only the actual delivery system, but also the ammunition (projectile, propelling charge, fuze), the ability to resupply and refuel, the target acquisition systems, the technical and tactical fire control system, and the key command and control elements.[61] The purpose of this section is to identify those trends in the evolution only of threat delivery systems, ammunition, and target acquisition capabilities. A note is in order at this point. When analyzing potential threats, this monograph includes all non-US systems since any of these weapons could find there way into the international arms market and from there into the hands of a potential aggressor.

Artillery Delivery Systems

As noted earlier, one of the driving reasons behind the need for a new self-propelled howitzer to replace the Paladin is that it simply is outmatched by other systems on the battlefield. Although very little can be said with relative certainty about the future, one aspect that will almost certainly be true is that future artillery delivery systems will be able to range further and faster, as well as being more mobile and harder to destroy.

Almost without exception the trend in future guns is to build longer shooting models with most nation's experimenting with guns that fall in the 155mm, fifty-two-caliber size range. *Armada International* calls the German Pzh 200O, which weighs in at fifty-five tons, "the most powerful self-propelled artillery system under development in Europe."[62] With a 155mm/fifty-two-caliber cannon and an automatic loader the Pzh 2000 has a burst rate of fire of three rounds in ten seconds or eight rounds a minute[63]. With a high level of protection from top-attack submunitions and a capacity of sixty shells on the gun, several nations have shown an interest in the Pzh 2000[64]. Bofors of Sweden and Giat of France are reportedly working jointly on a new artillery delivery platform based on the earlier Bofors ASP 2000. This gun also would use a 155mm/fifty-two-caliber cannon to achieve an anticipated assisted range of fifty-five kilometers. Besides the automatic loader and use of modular propelling charges, two points concerning this gun are particularly noteworthy. First, Bofors and Giat are only considering wheeled platforms for the gun, reportedly to improve its mobility. Second, Bofors has already revealed an advanced gun control system that will allow one of these howitzers to fire thirty rounds "in such a manner that all projectiles impact on the target area within one second."[65] Whether the South African G6 155mm/forty-five-caliber, the British AS90 155mm fifty-two-caliber, the Slovak Republic Zuzana 155mm/forty-five caliber, the French Caesar 155mm/fifty-two-caliber, the Israeli Slammer 155mm/fifty-two-caliber, or the Russian 2S19 152mm, the current trend is toward longer and faster shooting artillery platforms.[66]

While a trend also exists to build more mobile guns that would be better suited for the fluid operations envisioned on tomorrow's battlefield, disagreement appears to exist on how to do that. On one hand some nations are seizing on the advantages of lower life-cycle costs, lower noise levels, and greater strategic mobility to develop wheeled self-propelled artillery systems[67]. Other nations, to include the U.S., Britain, and Germany, are opting for the tracked version. A division also seems to exist on the type of power plant to use, gasoline or diesel. Diesels are generally preferred in armored vehicles, primarily because of their lower fuel consumption and lower costs. Two notable exceptions to this rule are our M1 Abrams tank and the Russian T-80, both of which use gas turbines.[68] One should not be confused though, for whatever the combination finally chosen, the object is simple, namely increase mobility.

Artillery delivery system survivability is another area that is receiving a great deal of attention, with active defense measures leading the way. Work in this area tends to be categorized based on whether it defends the vehicle via soft or hard kill. Laser and other threat warning systems that trigger a smoke or chaff grenade to defeat the incoming munition are considered "soft kill" technology. This type of active defense technology is already fitted on some of the latest tanks, such as the Israeli Merkava, the Japanese Type 90, the Italian Ariete, the Polish PT-91, and the latest Russian tanks. Infrared jammers represent another class of "soft kill" active defense measures being developed for possible employment on tomorrow's battlefield.[69] "Hard kill" active defense measures incorporate radar or electro-optical sensors to detect incoming munitions. They then trigger one of three types of kill mechanisms depending on the distance from the munition to the vehicle. Shaped charges are preferred for short-range engagements, fragmentation for medium-range, and mini-missiles are being developed for long-range engagements. The Russian DROZD system, which uses millimeter wave radar and small rockets with fragmentation warheads, is an example of this technology. The US SLID (Small Low-Cost Interceptor Device) program is another example of this trend in active defense. While this active defense technology is still very new, one can expect it to greatly improve the survivability of artillery delivery systems on tomorrow's battlefield.[70]

Ammunition

Technology has also led to great improvements in the accuracy and lethality of the ammunition available to fire support systems. These developments include not only improvements in the projectile itself, but also in the propelling charges and fuzes available to threat artillery systems.

With respect to the actual projectile, considerable time and money has been spent on developing anti-armor munitions and in improving cargo rounds designed to carry submunitions. Besides the U.S. developed Sense-And-Destroy-Armor (SADARM) munition, the French with their BONUS 155 munition and the Germans with their SMART munition are developing sensor-fuzed weapons.[71] The working principle is similar for each of these. The submunition is first ejected from the projectile at about 1000 meters above the target. The submunition then uses some type of drag device to slow its decent while its sensors (usually an infrared detector and/or millimeter wave radar) scan an area about one and a half football fields in diameter for hard targets. Once one is detected the submunition fires an "explosively formed penetrator" at the target.[72] These types of munitions will give the future artillery platform a reliable and accurate ability to "kill" armor targets out to forty kilometers.

In addition to these sensor fuzed anti-armor weapons, cargo rounds are also being improved with new, more lethal shape charge submunitions. In this area the path to the future appears divided with two trends emerging. On one hand some countries prefer fewer but larger submunitions (forty-two to sixty-three shape charges per projectile), while others, like the U.S., are developing more but smaller submunitions (132 shape charges per projectile).[73] Work is also underway in several nations to develop cargo rounds with some interesting non-lethal payloads such as radio jammers and unattended sensors.[74]

An additional trend in artillery ammunition is worthy of mention. First, while most agree that liquid propellant will be present on the future battlefield, few nations can afford to actively pursue its development right now.[75] Because of its economy, efficiency, and handling ease modular charges appear to be the near-term solution, with the U.S., Britain, and South Africa all actively involved in its development and production.[76]

Target Acquisition

While this monograph has concentrated on the delivery platform and the ammunition up to this point, one must remember that artillery fire can only be effective through the use of suitable target acquisition. During OPERATION DESERT STORM, even though the Iraqi army was supported by longer shooting artillery than that of the U.S. Army, without accurate targeting data superior range meant little.[77] Reasonably then one can expect the technology of target acquisition to continue to evolve at a dramatic pace. Already many countries " have developed artillery observation vehicles fitted with day/night sighting systems, laser rangefinders, computers, and in some cases battlefield surveillance radars."[78] Similarly, artillery locating radars continue to be developed that can see further, faster, and more accurately than current systems. "The European COBRA artillery locating system is expected to be able to find forty batteries within two minutes, suggesting the ability to locate over one hundred guns, rockets, launchers, and mortars per minute."[79] In a similar attempt to extend the ability to acquire targets, the U.S. and Britain recently announced they were conducting research into "imaging shells."[80]

While each of these trends will enhance target acquisition capabilities in the future, most experts agree remotely piloted vehicles (RPVs) "are almost certainly destined to become the primary means of locating deep targets."[81] Consequently, in addition to artillery locating radars, the Crusader must also concern itself with eluding RPVs. Modern RPVs employ real-time data links to transmit images and the Global Positioning System (GPS) to locate targets. With the advantages of being under continuous operator control and being able to vary its flight path, RPVs offer an element of flexibility to the future threat's real-time targeting effort.[82]

In summary, while we cannot predict the detailed evolution of threat fire support systems, we can identify certain trends which help paint the vision of the environment in which Crusader will have to operate. First, the generic threat artillery platform will be a survivable, long shooting weapon system that will be able to sustain high rates of accurate fire. Second, in terms of mobility we must expect the gun to be extremely agile both on and off road and to be able to set-up, shoot, and move very quickly. The rounds that the threat will employ will most likely be smart sensor fuzed munitions, capable of finding targets within a limited geographical area. Finally, we must assume that the threat learned through the Iraqi experience in DESERT STORM that target acquisition is as important as the delivery system. Consequently, the Crusader system must accept that it will be an actively pursued, high-value target for any opponent.[83]

V. Crusader's Tactical Capabilities

With the Crusader's characteristics and the future battlefield environment defined, this monograph will now turn to identifying what specific tactical capabilities the Crusader system can be expected to bring to the fight. The Crusader's ability to engage the enemy at longer ranges and for longer time periods, coupled with its responsiveness and sustainability, gives it several important tactical capabilities. The most important of these are its flexibility, survivability, ability to increase force effectiveness, and the ability to support a wider range of fire support tasks.

The Crusader offers the maneuver commander a very flexible fire support system that potentially facilitates a more effective application of combat power on tomorrow's battlefield. It does this in a number of ways. First, the Crusader would appear to be very capable of shifting effects quickly. With its increased range and ability to operate at and sustain high tempo operations, the Crusader is well suited to provide fires for a number of maneuver units near simultaneously. Additionally, the automated gun laying and ammunition handling systems give the Crusader the ability to rapidly transition from fire mission to fire mission, or from a tactical move to a fire mission, while the multiple round simultaneous impact (MRSI) feature would allow the force to still mass decisive combat power.

The Crusader's mobility also presents the force with an added element of flexibility. This flexibility is derived not only from the fact that the system can now keep up with the maneuver elements it is intended to support, but just as importantly it can do it with a smaller "logistical tail" which could potentially restrict its freedom of action. A number of features make the Crusader less dependent on constant resupply. For example, fuel is saved because the "the highly advanced electronic controller in the transmission allows precise automatic scheduling of engine speed and transmission ratio for optimal fuel economy."[84] By eliminating the need for mechanical primers the laser ignition system also shrinks the Crusader's appetite.[85] Conceivably, the embedded diagnostic and prognostic maintenance support features will alert crewmembers to potential problems early enough for preventive maintenance to be performed. And as noted earlier, when it is required, eighty-five percent of the work is designed to be done at crew and unit level. The ability for one Resupply Vehicle (RSV) to replenish two guns also bodes well for the prospect of being able to keep the system fed.[86] One RSV can attend to the guns, while the other returns to a logistical resupply point (LRP) to "top-off" with ammunition and fuel.

The final point is that the Crusader potentially offers the maneuver commander greater flexibility by giving him a wider range of options in selection of firing locations. Being very survivable and having the ability to deliver large volumes of fire from position areas much smaller than traditionally considered appropriate for artillery platforms, the Crusader can help the force regain its freedom of action when required.[87]

Enhancing fire support survivability is another potential tactical capability of Crusader. As noted when reviewing the evolution of threat fire support systems, U.S. Army artillery platforms must accept that they will always be one of the enemy's top high-value targets. This point is especially disturbing in light of the ongoing proliferation of sensor-fuzed weapons and the dramatic evolution of target acquisition technology. It is reassuring to know that the Crusader system offers excellent all-around protection. Only requiring a crew of three, the Crusader significantly reduces potential casualties before it even arrives on the battlefield. Once deployed, crewmembers are separated from the actual weapons compartment, as explained in Chapter II of this paper, and protected with additional armor. Automation support and decision aids eliminate the requirement for the crew to perform most of the physical acts of loading, firing, and re-supplying the projectiles. This should allow the crewmembers to be more aware of their tactical surroundings and quicken their reaction time to avoid danger.[88] A secondary effect of this digital crew compartment is that it may actually reduce the psychological stress of operating autonomously on tomorrow's battlefield. "Tests in other countries have already shown that the situational awareness provided through digitization reduces the sense of isolation that can occur within sub-units when unable to operate in close company."[89]

Not only the crew, but also the entire Crusader system will enjoy a high level of survivability. With reactive armor protecting the vehicles from top attack munitions, the ability to move 750 meters in ninety seconds, and a suite of active defense measures, the Crusader ought to be able to adequately defend itself without degrading the fire support provided to the maneuver force. Interestingly, this capability was apparent in simulations, such as the simulation conducted during the determination of the Crusader's mission profile, which used TRADOC's Southwest Asia (SWA) 4.2 scenario. In the SWA 4.2 scenario, individual Crusaders averaged thirty survivability moves per day over an average distance of 1340 meters[90]. The ability to operate more dispersed on the future battlefield, while retaining the ability to mass effects, will also improve Crusader's survivability. A secondary effect of the RSV's advanced armor protection is that the resupply ammunition and fuel will be more survivable also.

In addition to flexibility and survivability, the Crusader will also increase the force's overall effectiveness. The Crusader offers the maneuver commander the rare potential to reduce the number of his unit's direct fire, force-on-force engagements or at least to shape the conditions of each engagement to create more favorable terms. With its long range, high rate of fire, and improved accuracy, the Crusader can extend and thicken the indirect fire umbrella over the supported force to ensure its freedom of action. In the Southwest Asia 4.2-scenario simulation conducted to determine the Crusader's Operational Mode Summary and Mission Profile (OMS/MP), forty-three percent of all its fires were shot at ranges at or above twenty-four kilometers.[91]

The final tactical capability offered by the Crusader system is an ability to support a broader range of specialized fire support missions. In addition to the support of maneuver forces in the close fight and the interdiction of enemy units out to the limits of its range and mobility, because each individual system represents such an intelligent, durable, and potent firepower capability, the Crusader is well suited for "stealthy" applications of short duration, high volume fires.

One such mission, a deceptive-fires mission, takes advantage of the Crusader's multiple round simultaneous impact (MRSI) capability. It is conceivable, since a single Crusader can fire up to eight rounds and have them impact simultaneously on the same target, it would appear like a "traditional artillery" battery to an enemy. Logically, several individual Crusaders could portray a battalion or several battalions of artillery to the enemy. This technique, in addition to being used to confuse the enemy as to how much artillery we have, could be used to lure the enemy into firing his guns, making them vulnerable to our counterfire. Admittedly, the Crusader's MRSI capability will be known by a future enemy, so this mission would be most effective on a battlefield which contained a mix of systems. The enemy could not be sure then if it was a single Crusader that just fired or a battery of another cannon system that fired.

Often suppression of enemy air defense (SEAD) missions are problematic due to a combination of their long range and the reluctance to use MLRS rockets on what are often only templated targets. The Crusader's "stealthy" nature, coupled with its mobility and quick fire mission transition time, make it well suited for a type of "mobile SEAD." mission. Two Crusaders, and possibly one RSV, could move forward and position offset from the flight route. At the appropriate time, the Crusader's could begin to fire on the SEAD targets, "leap-frogging" forward to extend their indirect fire umbrella.

The final mission that appears well suited for Crusader is that of the raid. In a traditional raid heavy artillery is rolled forward or light artillery is carried forward by helicopters to strike key targets and catch the enemy off guard. The limitation of using heavy artillery is that it has a notable signature and lacks mobility for a quick get away. Light artillery, on the other hand, does not have the punch and requires the escort of attack helicopters for protection. Crusader offers an interesting alternative. With the firepower and organic protection of heavy artillery and the small signature and mobility of light artillery, Crusader fits the profile to execute near surgical strikes against enemy extremely high payoff targets.

Even though the Crusader does offer these tactical capabilities to tomorrow's Army, there is one concern that may diminish its effectiveness. The Crusader does not have manual back up capability on some key systems. The autoloader ranks at the top of this list. "The Crusader howitzer only has one autoloader, and the current howitzer design will not allow the crew to hand load the cannon if the autoloader fails. Therefore, the Crusader howitzer cannot fire if the autoloader fails." Similarly, the engine and the transmission each only have one microprocessor that links it to the main processor. Because the vehicles are "drive by wire" a failure of this single microprocessor would prevent the crew from driving the vehicle.[92]

VI. Crusader's Transportability

> Mobility, both strategic and tactical, is the partner of flexible organization. We must be able to shift combat strength rapidly to any threatened point in the world. Strategic airlift of troops by the Air Force is the answer to the requirement of speed.... While airlift adds to our strategic mobility, it does not supplant Navy transport for maintaining the lines of heavy supply and reinforcements to overseas theaters. The Navy has provided this support for the Army throughout our history; w cannot foresee the day when it will not be needed.[93]
>
> General Barksdale Hamlett
> Vice Chief of Staff of the Army, 1963

It was critics' concern over a perceived decrease in the Crusader's transportability, because it weighs almost twice as much as the system it is intended to replace, that provided the impetus for my research into the question of whether the Crusader's tactical capabilities will offset its massive weight. Having identified the capabilities we can expect the Crusader to bring to the future battlefield, it is time to analyze its transportability. The aim of this section is to determine just how significantly the Crusader's weight will affect the Army's ability move it by required transportation assets using the highway, rail, marine, or air modes of transport.

In conducting this analysis this monograph made several assumptions. First, while transportation restrictions may be relaxed when deemed essential for national defense, this is not guaranteed[94]. I therefore held the Crusader accountable for the more stringent peacetime transportation restrictions throughout this analysis. Second, since the Crusader may logically be called on to deploy directly into a combat situation, this monograph analyzes its transportability based on its heavier combat loaded weight of fifty-five tons per vehicle[95]. Finally, for the purpose of determining the Crusader's transportability in relation to the system it will replace, the Paladin, I used the following dimensions and weights for each system[96]:

System	Height (inches)	Width (inches)	Length (inches)	Weight (Combat Loaded)
Paladin(I)	142.5 (128 inches with machine gun removed)	154 (124 inches with stowage basket folded to rear)	464.2 (240.2 inches for chassis)	34.1 tons
FAASV(I)	132	124	270	31.8 tons
Crusader	132 (122 inches with panoramic sight retracted)	132.7	477 (295 inches for chassis)	55 tons
RSV	113.5	132.7	299	55 tons

Land Mode of Transport

Since every Army installation is not conveniently situated adjacent to a viable Port of Embarkation (POE), and not all conflict environments can be expected to occur next to a Port of Debarkation (POD), land transportation is an important consideration in the Crusader's overall transportability. Two modes of travel exist to transport the Crusader via land. The first option is by road movement, and while being the most flexible, it is also very restrictive.[97] The second mode of transport for the Crusader on land is via rail. Rail movement is essential for the transport of oversize and overweight equipment and is often less expensive than road movements when a significant number of vehicles must be transported.[98]

"The United States usually prohibits movement of track-mounted units of equipment as self-propelled vehicles."[99] This necessitates analyzing the Crusader's transportability on a road network in combination with a prime mover. The Army has two Heavy Equipment Transports (HETs) capable of carrying the Crusader. The first is the M911 tractor with an M747 semi-trailer with a payload capacity of sixty tons. This combination has a curb weight of thirty-five and one half tons; however, the HET "does not have sufficient axles to obtain permits for highway movement in most States."[100] The second HET is the M1070 tractor with the M1000 semi-trailer having the payload capacity of up to 70 tons. This combination has a curb weight of 44.72 tons and exceeds the gross vehicle weight (GVW) limit in most States without any cargo. The requirement to use HETs on United State's roads means some of the road restrictions the Crusader encounters are a result of the HET and not the actual Crusader system.

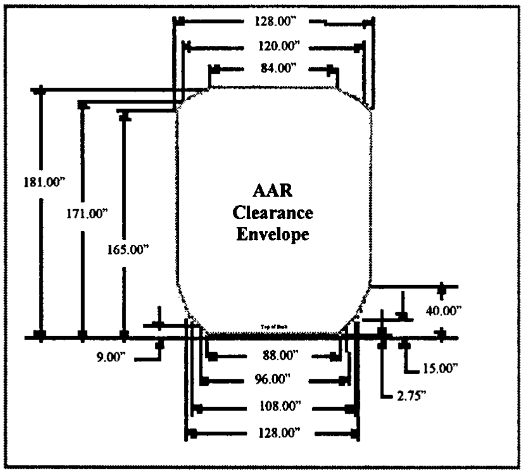
Each State owns and controls all the roads within its boundaries, including local, national, and interstate routes. Consequently, States impose size and weight limitations on each route for safety reasons and to protect bridges, tunnels, and overpasses.[101] These limits are published in the American Trucking Association's (ATA) *Summary of Size and Weight Limits.*[102] When a vehicle exceeds a route's legal limit, a permit is required. The limit at which State officials will no longer issue permits to allow passage of a vehicle is called the roadway permit limit. A State might still allow a vehicle that exceeds the roadway permit limit to transit the route if the load is certified as "essential for national defense."[103] This certification requires at least thirty working days to process, often requires a detailed engineering analysis of the requested route done at DOD expense, and if the roadways are damaged then DOD must reimburse the State.[104]

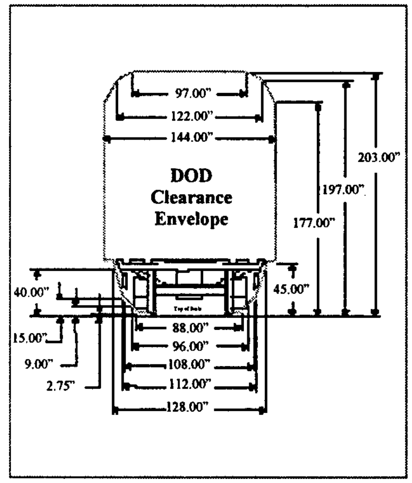
Section 127 of United States Code, Title 23 defines the Bridge Gross Weight Formula (BGWF) which establishes the maximum axle loads and Gross Vehicle Weights based on axle spacing.[105] Although each State determines its own maximum GVW, as a general guide, the GVW limit for the United States is 80,000 pounds or forty tons.[106] The combination of the Crusader with either HET (90.5 tons and 99.72 tons) or the Paladin with either HET (69.6 tons and 78.82 tons) both easily exceed the forty ton GVW legal limit; therefore necessitating a permit. Permits, "in almost all instances, require that the vehicles make movements along certain appointed routes, restricted to daylight hours, prohibited on weekends and holidays, and completed at extremely reduced speeds.[107] Additionally, the axle loads for the HETs carrying the Crusader or the RSV exceed the maximum limits allowed with permits for many States.[108] This may require certification that the movement is essential for national defense.

The International Road Federation (IRF) publishes legal limits for highway transport in foreign countries. As dimensional and weight restrictions in foreign countries are more stringent than those in the United States, road movement for either the Crusader or the Paladin will be hampered by severe restrictions. Similarly, as in the United States it will be more difficult to obtain permits for vehicles overweight and overheight than for width or length.[109]

In short, to move the Crusader, as with the Paladin, requires additional time and money to gain permits and conduct required route analysis. While the Crusader/HET combination may need additional paperwork because it exceeds many of the States' maximum allowed limits for permits, and the Paladin/HET combination does not, the fact is that road movement of these vehicles is not an effective means of transport.

Unlike restrictions on road movements, weight is not the limiting factor in assessing the ability of a piece of equipment to be moved by rail. With an abundance of low tunnels and narrow bridges, height and width clearance requirements are more critical in determining rail transportability. The maximum height and width allowed on a certain rail line is determined by that line's clearance diagram.

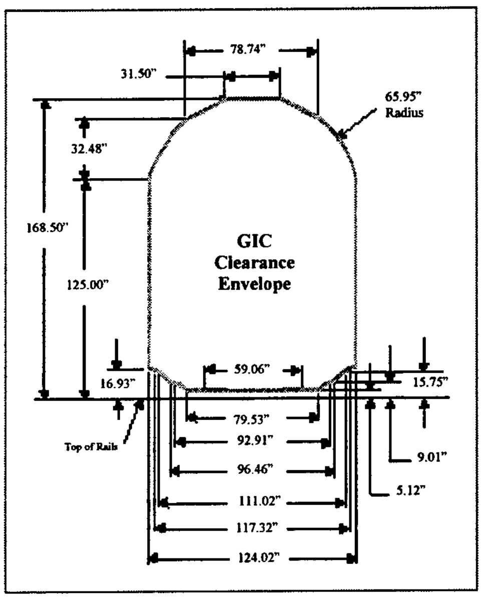


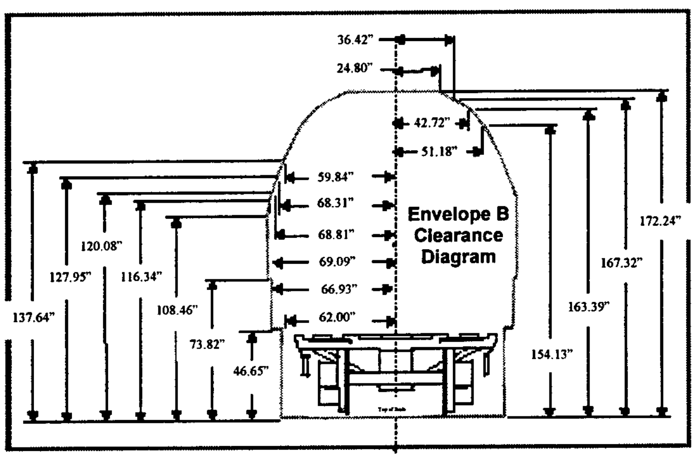


The two rail clearance diagrams of concern to military movement planners in the United States are the Association of American Railroads (AAR) Outline Diagram for Single Loads, without End Overhang on Open Top Cars, and the Department of Defense (DOD) Clearance Profile for the Strategic Rail Corridor Network (STRACNET).

In accordance with Military Traffic Management Command Transportation Engineering Agency (MTMCTEA) Reference Guide 98-70-1, *Transportability and Deployability for Better Strategic Mobility* dated April 1997, "equipment that is mounted on fifty inch high rail cars and falls within the limitations of the AAR diagram will be capable of unrestricted movement on almost all rail lines."[110] The maximum height of the AAR outline is 181.00 inches above the top of the rails.[111] This means that a vehicle that is below this limit when sitting on a fifty-inch tall rail car (maximum vehicle height of 131.00 inches) meets the height requirement. Both the Crusader (122.00 inches tall with the panoramic sight retracted) and the Paladin (128.00 inches tall with the machine gun removed) meet this limit. The allowable width of the AAR diagram is 128.00 inches.[112] The Paladin with the stowage basket folded to the rear can meet this limit at 124.00 inches. The Crusader at a width of 132.7 inches does not meet the AAR profile and therefore will not enjoy unrestricted rail access in the United States that the Paladin can in its shipping configuration.

As mentioned earlier the DOD clearance profile for the STRACNET is the second profile that concerns military rail movement planners. The DOD outline is taller and wider than the AAR outline and was established to support the movement of outsized equipment over military significant rail routes.[113] While only about twenty-two percent of the standard gauge lines in the United States meet this limit, the DOD STRACNET connects all major Army installations, depots, and POEs.[114] The maximum allowed height and width on the DOD clearance profile are 203.00 and 144.00 inches respectively.[115] The Crusader easily makes the DOD height and width limits. The drawback to being limited to the STRACNET is that movement of the Crusader to its destination may not be by the most direct route and may be at severely restricted speeds.[116] This may result in movement delays.





The most important overseas clearance profiles are the Gibarit International de Chargement (GIC) diagram and the NATO envelope B. The GIC, similar to the AAR profile in the U.S., sets the standard for maximum height and width allowed for essentially unrestricted rail movement throughout Europe.[117] The GIC height and width limits are set at 168.50 and 124.02 inches respectively.[118] Neither the Paladin nor the Crusader, even if placed in the shipping configuration, can get inside the GIC profile. NATO STANAG 2832, *Restrictions for the Transport of Military Equipment by Rail on European Railways* regulates rail transport of military equipment in NATO countries. A vehicle that does not meet the GIC outline can still pass the envelope B outline and gain access to nearly eighty-five percent of the GIC rail lines.[119] The max height and width in the envelope B profile are 172.24 and 138.18 inches respectively.[120] The Crusader with the panoramic sight retracted sits 172.00 inches tall above the rail on a fifty-inch tall rail car and is 132.7 inches wide, therefore, making the envelope B profile. The Paladin on the other hand can meet the envelope B profile, but requires more work to do so, such as folding the stowage rack and removing the machine gun. Similar to travel on the STRACNET in the United States, rail movement on NATO's envelope B lines is subject to route selection and speed restrictions, and therefore, a unit may experience deployment delays.

Unquestionably, rail movement offers a more practical and effective means of moving heavy tracked vehicles to a port of embarkation.[121] With the ability to carry heavier and larger cargo than possible via a road network, rail is essential for moving oversize or overweight vehicles. Rail movement also offers several advantages: rail movement is less expensive than road movement in many cases; it puts less wear and tear on the vehicles, and rail movement requires less maintenance and route support during movement.[122] Consequently, the ability of a heavy tracked vehicle such as Crusader to be moved via rail is absolutely paramount to its utility to the force. In light of the difficulties of moving on road networks, rail movement is the only viable option.

In summary, because the Crusader/HET combination exceeds the maximum limit for permits for many States due to GVW and /or axle loads, it is slightly less transportable via road than the Paladin. This drawback is mitigated by the fact that road movement of any heavy tracked vehicle is both inefficient and impractical. As for rail movement, because the Paladin can meet the AAR profile in the shipping configuration, it is more transportable in the U.S. than the Crusader which is limited to the STRACNET rail system. Once overseas, the Crusader, which only requires retraction of the panoramic sight to meet the envelope B profile, is actually more rail transportable than the Paladin which requires intensive work to meet the envelope B diagram.

Fixed-Wing Air Transportability of the Crusader

According to MTMCTEA Reference Guide 98-70-1, air transport is the most important mode of transport in terms of rapid strategic mobility.[123] Not surprisingly, it is also in the greatest demand and is the most limited asset. That said, while both the C-5 Galaxy and the C-17 Globemaster III are physically capable of transporting Crusader systems at the rate of one vehicle per aircraft, it is extremely inefficient to do so.[124] So why analyze the Crusader's fixed-wing air transportability? The simple truth is that while it is unlikely that the large numbers of Crusader systems will be transported to the theater of operations via fixed-wing assets, a small number of Crusaders as part of a robust rapid reaction force may need to do so.[125]

Currently, only the C-5 and C-17 are capable of transporting heavy tracked vehicles via air. The C-5 Galaxy is the larger of the two aircraft. With a wingspan of 222 feet and a cargo compartment comparable to an eight-lane bowling alley, the C-5 can transport virtually any piece of army combat equipment, including tanks, helicopters, and the seventy-four ton mobile scissors bridge.[126] With a height of 132 inches, a width of 132.7 inches, and a length of 477 inches, the Crusader vehicle easily fits inside the C-5's maximum height of 156 inches, maximum width of 144 inches, and maximum length of 1454 inches. If dimensional limitations were the only consideration, theoretically two Crusaders should be able to be transported at once. Of course, this is not possible due to payload limitations.

Although the C-5 has a maximum payload of 291,000 pounds or 145.5 tons, its effective payload limit is 150,000 pounds or seventy-five tons, falling well short of the combat loaded weight of the two-vehicle Crusader system of 110 tons. However, this does allow the C-5 to carry two Paladins at 34.1 tons each. Interestingly, the maximum ramp payload capacity of the forward loading ramp limits the C-5's maximum tracked vehicle weight to 129,000 pounds or 64.5 tons.[127] While the actual maximum payload capacity will vary depending on the quantity of onboard fuel, air density, and other atmospheric factors, the simple truth is that a C-5 can carry two Paladins, but only one Crusader vehicle. Crusader advocates are quick to point out that this fact is mitigated by the Crusader's ability to deliver more firepower than two Paladins.

Similar to the C-5, the C-17 Globemaster III can also only carry one Crusader vehicle; however, it can also only carry one Paladin. The maximum payload of the C-17 is 169,000 pounds or 84.5 tons[128], but the maximum effective payload is 120,000 pounds or sixty tons.[129] This is less than required to carry two Crusader vehicles (110 tons combat loaded) or two Paladins (68.2 tons combat loaded). As far as transportability, the Crusader and Paladin are identical if using C-17 aircraft, while the C-5 Galaxy allows the force to carry two Paladins for every one Crusader. Of course, part of this advantage in using the C-5 aircraft might be negated by the fact that the 118 aircraft in the C-5 fleet reportedly average less than a 70 percent mission capable rate.[130]

Sea Transportability of Crusader

The final mode of transport to analyze is sealift. Being the least restrictive mode of transport, sealift, historically, carries the majority of the heavy lift burden in deployment. During the deployment for OPERATION DESERT SHIELD/STORM, over ninety percent of the equipment and vehicles destined for southwest Asia went by sea.[131] In general, almost all items of equipment can be transported by ship without major problems or restrictions.[132]

Roll-On/Roll-Off (RORO) ships will likely be the primary carrier for the Crusader system as they facilitate more efficient loading and unloading of heavy tracked vehicles with a series of external and internal ramps. While the Crusader system is just as deployable via sealift assets as the Paladin, the longer cannon of the Crusader howitzer may restrict maneuvering to negotiate RORO ship internal ramps.[133] Conceivably, this might restrict where the Crusader can be parked on the ship and therefore affect how many can be carried onboard.[134]

Another consideration with ROROs is that improved port facilities are required in order to use the ramp system to enter and exit the ship. If an improved port is not available, then the vehicles must be transloaded to amphibian or conventional landing craft, called lighterage, and these vessels deliver them to the shore. This Logistics Over The Shore (LOTS) operation is crucial to building up a credible force in an austere theater. In this respect, both the Crusader and Paladin are equally transportable on all Army lighterage.[135] This includes LARC-LX and larger vessels as they have normal cargo capacities that meet or exceed sixty tons.[136]

With respect to the Crusader's transportability several conclusions can be drawn. First, the Crusader, as with any heavy armored vehicle, will require at least two modes of transport for deployment to a theater of operations. At least one of these will be a land mode to get the equipment to and from the POE and POD. The other mode, either fixed wing air or sealift, will carry the vehicle across the ocean.

Second, in terms of sealift, the largest carrier of military equipment in deployments, the Crusader does not represent a decrease in transportability over Paladin. The Crusader and Paladin are equally transportable on RORO vessels and Army lighterage. Third, in terms of fixed-wing air transportability only half as many Crusaders can be moved via C-5 Galaxy aircraft as can Paladins. This point is mitigated though by the Crusader's increased firepower (the force therefore would need fewer) and the limited availability mission capable C-5 aircraft.

Fourth, both the Crusader/HET and the Paladin/HET combinations require permits for exceeding legal weight and dimensional limits for road movements in most States. The Crusader, though, also exceeds many of the State's permit limits, so it is reasonable to expect more difficulty in gaining a State's approval to move the Crusader via its road network. Finally, rail transport appears to be a wash. The Paladin is more transportable in the United States, but the Crusader is more than able to get from home station to its POE via the STRACNET rail system. Surprisingly, the Crusader appears to more easily meet the NATO envelope B clearance profile for the European rail system than the Paladin does.

VII. Analysis and Evaluation

> In the physical domain of conflict, forces use physical means to take action. ...In the physical domain, we find the physical capabilities, the tangible elements of war and military operations – soldiers, their equipment, weapons, and technological applications – and their physical effects.[137]

So far this paper has focused on identifying the potential tactical benefits of the Crusader and on analyzing its transportability. Now it is time to return to General Reimer's earlier comment and answer the question of whether the Crusader's tactical capabilities offset its massive weight. Upon reflection, one will recall that the purpose of the Crusader system is to give back to the Army a fire support capability which was lost when the M109 self-propelled howitzer was potentially outmatched by other cannon delivery systems. Within the physical domain of conflict, the Crusader's ability to sense, strike, shield, control, sustain, and move combine to give the system its physical capabilities and ultimately will be the determining factors in its utility to the future Army. These six core functions of the physical domain of conflict serve as a logical set of evaluation criteria in balancing the Crusader's capabilities against its weight. I

Sense

According to the 6 April 1998 revised final draft of FM 100-5, *sense* is defined as the ability "to perceive or detect: a discerning awareness or appreciation that comes from effective application of intellect as a basis for action or response."[138] Clearly, from the perspective of the ability to sense, the Crusader's tactical capabilities do offset its weight. The Crusader not only has the ability to sense itself, in terms of monitoring its on board fuel, ammunition, and propellant status, but it also has a complete array of prognostic and diagnostic automation support features to sense its own maintenance status and recommend possible fixes. With an anticipated suite of active defense measures, one can expect the Crusader to have the ability to sense incoming munitions and employ "soft" and/or "hard" defeat measures to protect itself and its crew.

Most importantly, however, the Crusader will facilitate the crew's ability to sense their surroundings by relieving them of the responsibility to perform many of the routine and labor intensive tasks associated with providing fire support for the maneuver commander. This crew automation support goes well beyond the automated ammunition handling and gun laying features, to include a host of onboard tactical systems such as decision aids, advanced navigational aids, and automated Identify Friend or Foe (IFF) features. The Crusader represents an intelligent system that will be well suited to sense its environment.

Strike

With respect to the physical domain of conflict, *strike* is defined as the ability "to close with the enemy or, through distributed fires or information dominance, apply lethal and/or nonlethal effects to achieve objectives."[139] As a fire support system, Crusader's reason for existing is to "strike" the opponent. Its improved ability to close with the enemy to deliver a greater volume and wider range of effects on target make it well-suited to perform this "strike" function. The Crusader will give tomorrow's maneuver commander the ability to hit the opponent with cannon delivered munitions at distances well beyond what is possible today. The Crusader does this not only by increasing the range of cannon artillery by roughly fifty percent, but just as importantly, Crusader's vastly improved tactical mobility over the Paladin means the system can now close with the enemy at a pace that is envisioned for tomorrow's Army. With the ability to keep pace with the M1 Abrams tank, the Crusader facilitates synchronizing the maneuver and fire support battlefield operating systems in tomorrow's fight.

The Crusader will also have the ability to place a greater volume of fire on the enemy. In terms of an ability to strike the enemy with a greater volume of immediate fires, the Crusader's ability to place four- to eight rounds on a single target simultaneously via its Multiple Round Simultaneous Impact (MRSI) function surely fits the bill. For sustained volume of fire, the Crusader's vastly improved rate of fire will mean the maneuver force can strike the opponent at greater distances and with greater lethality than previously possible.

Shield

The shielding function entails "deny(ing) opponents the ability to threaten the force or interfere with its action and preserve one's own freedom of action and initiative."[140] Once again, the Crusader's ability to not only shield itself and its crew, but also the force at large, indicates that from this perspective its tactical capabilities again offset its weight. Crusader's self-shielding ability is comprised of a two-part system. First, its tactical mobility and dash speed mean the Crusader can deliver rounds on target and displace well beyond the effects of potential incoming counter battery fire before it arrives. Secondly, the Crusader's suite of active and passive defense measures will help shield the crew from potential harm. This will be extremely important on tomorrow's battlefield, not only because of the threat trend toward proliferation of sensor fuzed weapons, but also because this ability supports the distributed, non-contiguous operations expected on the future battlefield.

More importantly than shielding itself, the Crusader will also shield the supported force as a whole. With the ability to extend the indirect fire umbrella and to move it forward as they close with the enemy, the maneuver force can interdict the opponent at a range and rate that forces him into the reaction mode, thus helping to retain the friendly freedom of action.

Control

Looking solely at the FM 100-5 definition of *control*, which is "to create a response; pressures exerted by physical, moral, or cybernetic means to exercise directing or restraining influence over an entity - –friendly, enemy, or neutral,"[141] one may wonder what role the Crusader could possibly play in this function. However, encompassed in this definition of control are two concepts highlighted by James R. Beniger, a well-known behavioral and social scientist, in his work, *The Control Revolution: Technological and Economic Origins of the Information Society.* The first element of control entails "the influence of one agent over another." The second element is "purpose, in the sense that influence is directed toward some prior goal of the controlling agent."[142] Beniger goes on to explain that inherent in control is a "continual comparison of current states to future goals" and a "two-way interaction between controller and controlled."[143] In this way, control may be viewed as a continuous process of acting on an entity, observing the effect on the intended goal, and then acting again. If thought of in this way, efficiency in exerting control over an entity can come as a result of getting the action needed to achieve the intended goal correct the first time or in completing the necessary iterations of the "act-observe-act" cycle to achieve the desired result as quickly as possible.

Similar to the functions of sense, strike, and shield, from the perspective of control, the Crusader's tactical capabilities, once again, clearly offset its weight. The Crusader will facilitate the force's ability to travel through the "act-observe-act" cycle more quickly than previously possible. The Crusader does this by providing the maneuver commander with much greater flexibility. The system's ability to stop during a move and being prepared to fire within fifteen to-thirty seconds facilitates quick transitions between missions. Additionally, because the Crusader can operate at a faster tempo, relying largely on automated support functions, it allows the force to observe and act more quickly than possible with any previous fire support system.

Sustain

Sustain is defined as the ability "to provide and preserve resources; human, material, and other support required to maintain and prolong operations until successfully completed."[144] In terms of the sustain function, the answer to the question of whether the Crusader's tactical capabilities offset its weight, the answer is "yes," but my conclusion is that it is a "qualified yes." Undoubtedly, the system, by exposing fewer crewmembers to danger (three-man crew versus a 6-man crew) and by offering better protection to what few crewmembers it does have, does sustain human resources. Similarly, material resources are somewhat sustained by the Crusader system's capability to keep fuel and ammunition under armor protection at all times. The high level of commonality between howitzer and RSV components, as well as onboard prognostics and diagnostics, further bolsters the Crusader's sustainability. My qualification on the system's ability to perform the "sustain" function is twofold. First, "at fifty-five tons, Crusader is near the upper weight limit efficiently recoverable by the M88A1, the primary recovery vehicle projected for Crusader battalions."[145] While the RSV is capable of recovering the howitzer, it is unrealistic to think that it will always be available to do so. The second qualification stems from the lack of a backup for the automatic loader. Currently, as the Crusader crew is not able to manually load the howitzer, if the automatic loader goes down the system is not able to fire. While these concerns fall short of negating the positive aspects of the Crusader's ability to perform the sustain function, they do cause me to qualify my assessment.

Move

The final core function of the physical domain of conflict is *move*, which is defined, in the revised final draft of FM 100-5, as the ability "to position and reposition forces."[146] The Crusader should have excellent tactical mobility due largely to its powerful engine, advanced hydro-pneumatic suspension, and improved light track system. The only limiting factor might be the lack of sufficient bridges capable of carrying the Crusader's weight. That said, however, being well over ten tons lighter, anywhere the M1 Abrams tank can go, the Crusader can follow.

As highlighted in Section VI, overall the transportability of the Crusader is much better than one might expect from a self-propelled howitzer. While the fact that it exceeds the axle load permit limit when aboard its necessary HET for highway movement in the U.S., severely restricts its road transportability, the fact is that road movement is not a practical mode of transport for heavy vehicles. The Crusader is transportable on the STRACNET rail network that links every major installation with its POE. Again, although extremely inefficient, the Crusader is transportable aboard C-17 and C-5 aircraft at a ratio of one vehicle per aircraft. Sealift is historically how the majority of equipment is deployed to a theater of operations and here the Crusader is unrestricted except for a further need to evaluate the space the howitzer has to turn to maneuver loading and unloading ramps.

My conclusion with respect to the *move* function is that the tactical capabilities do seem to offset the Crusader's weight, but again the conclusion is qualified. In accordance with the Military Traffic Management Command Transportation Engineering Agency's transportability goals, "the next generation of heavy armored vehicles should be designed to weigh forty to fifty-five tons."[147] They warn, "based on previous transportability engineering analyses of military equipment ... to design as much below the maximum weight and dimensional limits as possible to ensure transportability." Their rationale is that the minor weight growth that is inherent in the design process will cause the piece of equipment that is already at its maximum allowable weight to become overweight by the end of the process.[148] Of course, the Crusader is already at its maximum allowable combat-loaded weight of fifty-five tons and Crusader developers are reportedly facing a technical challenge in keeping the vehicle to its weight limit.[149] As one looks out over the expected forty-year life of the Crusader, the growth potential of the system without exceeding the ability of our current transportation assets is another source of interest.[150] Even with these qualifications, in the final analysis the Crusader's tactical capabilities still offset its weight.

VIII. Conclusion

Evaluation Criteria	Does Crusader's Tactical Capability offset its Weight?	Remarks
Sense	Yes	-
Strike	Yes	-
Shield	Yes	-
Control	Yes	-
Sustain	Qualified Yes	1. Near weight limit recoverable by M88A1. 2. Lack of redundancy on key systems.
Move	Qualified Yes	1. Designed at maximum allowable weight limit. 2. Without new transportation assets, growth potential is limited.

In conclusion, General Reimer's comment in the 6 April 1998 *Army Times,* that individuals who criticized the Crusader as less deployable than the Paladin were ignoring the increased tactical capability of the gun, was exactly right. In terms of all six of the core functions of the physical domain of conflict the Crusader's tactical capabilities offset its weight.

In terms of its physical capability to *sense* the enemy, itself, and the environment; to *strike* an opponent decisively; to *shield* itself from the attacks of an opponent; and to facilitate the *control* of actors, actions, and events; to *sustain* itself; and to *move* freely in the area of operations, the Crusader overwhelmingly represents a system well suited for Force XXI and the Army After Next. As articulated in this paper its flexibility, survivability, ability to increase force effectiveness, and the ability to support a wider range of fire support tasks makes the Crusader an intelligent, durable, and potent BRIDGE to the future.

ENDNOTES

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[3] Barbara Starr, "Crusader Reaches for Warfare Revolution", Jane's Defense Weekly, Vol. 26, No. 19, 6 November 1996, p. 35.
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[6] United States General Accounting Office, National Security and International Affairs Division, Report to the Secretary of Defense, *Army Armored Systems: Meeting Crusader Requirements Will Be a Technical Challenge*, (Washington, D.C.: GPO, 1997.), p. 2.
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[9] John M. Matsumura, Randall Steeb, and John Gordon IV, *Assessment of Crusader: The Army's Next Self-Propelled Howitzer and Resupply Vehicle*, (The RAND Corporation, 1998), p. xiv.
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[14] MAJ Warren N. O'Donell and LTC (Ret) William A. Ross, "TTP for the Crusader Battalion – A Beginning", *Field Artillery Journal*, HQDA PB6-97-6 (November-December 1997), p. 16.
[15] Eric H. Biass, "We Desperately Need Crusader", Ibid., p. 43.
[16] United States General Accounting Office, National Security and International Affairs Division, Report to the Secretary of Defense, *Army Armored Systems: Meeting Crusader Requirements Will Be a Technical Challenge*. Ibid., p. 5.
[17] United States Army Field Artillery School, *Operational Concept Document for Crusader*, Fort Sill, OK: May 1998, p. 1-6.
[18] MAJ John R. Holland, "Crusader Update", *Field Artillery Journal*, HQDA PB6-97-2 (March-April 1997), p. 15.
[19] The current family of 155-mm propelling charges must be loaded in a specific direction so that the red igniter pad sewn to one end of the bagged charges is closest to the igniter. The familiar saying in the artillery community, "I see red" is the crewmembers' check that the propelling charge is loaded in the correct direction. Failing to do this can not only cause damage to the gun, but also will result in an unpredictable round. The MACS eliminates this problem with the characteristic of generating equal amounts of gas and pressure regardless of which end is ignited. This means the MACS can be loaded in either direction, making it a "bi-directional" charge.
[20] Eric H. Biass, "We Desperately Need Crusader", Ibid., p. 43.
[21] United States Army Field Artillery School, *Operational Concept Document for Crusader*, Ibid., p. 1-7.

[22] United States General Accounting Office, National Security and International Affairs Division, Report to the Secretary of Defense, *Army Armored Systems: Meeting Crusader Requirements Will Be a Technical Challenge*. Ibid., p. 7.
[23] Rupert Pengelley, "Crusader Charts New Course", *International Defense Review*, Vol. 29, No. 8, 1 August 1996, p. 47.
[24] Eric H. Biass, "We Desperately Need Crusader", Ibid., p. 43.
[25] Pengelley, Ibid., pp. 48-52.
[26] Ibid., p. 48.
[27] Donald M. Babers, "Crusader Ushers New Era for Combined Arms Team", *National Defense*, Vol. 81, No. 528, May-June 1997, pp. 32-33.
[28] Both of the following works offer excellent detailed summaries of the Crusader's mobility characteristics: MAJ John R. Holland, "Crusader Update", *Field Artillery Journal*, HQDA PB6-97-3 (May-June 1997), p. 12. and Eric H. Biass, "We Desperately Need Crusader", Ibid., p. 44.
[29] MAJ John R. Holland, "Crusader Update", *Field Artillery Journal*, HQDA PB6-97-3 (May-June 1997), p. 12.
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[32] MAJ John R. Holland, "Crusader Update", *Field Artillery Journal*, HQDA PB6-97-2 (March-April 1997), p. 14.
[33] United States Army Field Artillery School, *Operational Concept Document for Crusader*, Ibid., p. 1-8.
[34] Briefing Slides, *Crusader-The ARMY XXI Firepower Revolution*, Department of the Army DCSOPS TSM-Cannon, April 1997, Pentagon, Washington, D.C., pp. 13.
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[43] Revised Final Draft Field Manual 100-5, pp. 1-15 – 1-18.
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[46] COL Robert B. Killebrew, "The Army After Next: TRADOC's Crystal Ball Eyes The Service's Shape Beyond Force XXI", *Armed Forces Journal International*, Vol. 134, No. 3, October 1996, p. 36.
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[80] Ibid., p. 28.
[81] Ibid., p. 27.
[82] Ibid., p. 27.
[83] United States Department of the Army, *Field Manual 101-5-1, Operational Terms and Graphics*. (Washington, DC: U.S. Government Printing Office, 30 September 1997), p. 1-77. A high-value target (HVT) is an "asset that the threat commander requires for the successful completion of a specific course of action." By design assets are allocated to look for and delivery effects against each high-value target.

[84] United Defense, Armament Systems Division, *Crusader Powerpack.* 1998 http://www.teamcrusader.com/info/pdfs/pwrpck.pdf/ (28 October 1998), p. 2.
[85] United Defense, Armament Systems Division, *Crusader Armament.* 1998 http://www.teamcrusader.com/info/pdfs/armamnt.pdf/ (28 October 1998), p. 2.
[86] One RSV carries 130 projectiles. Since the Crusader self-propelled howitzer can only store sixty rounds, the RSV can conceivably provide a complete resupply of ammunition for two Crusader howitzers without returning to an ammunition supply point to replenish its own stocks.
[87] United States Army Field Artillery School, *Operational Concept Document for Crusader,* Fort Sill, OK: May 1998, p. 1-4.
[88] MAJ Reginald Brown, "Crusader Update", *Field Artillery Journal*, HQDA PB6-98-3 (May-June 1998), p. 43.
[89] Pengelley, Ibid., p. 48.
[90] United States Army Field Artillery School, Directorate of Combat Development, *Annex B to the AFAS COEA: Advanced Field Artillery System (AFAS) Operational Mode Summary/Mission Profile (OMS/MP)*, Fort Sill, OK: U.S. Army Field Artillery School, 1996, p. 2.
[91] Ibid., p. 3.
[92] United States General Accounting Office, National Security and International Affairs Division, Report to the Secretary of Defense, *Army Armored Systems: Meeting Crusader Requirements Will Be a Technical Challenge*, p. 5.
[93] United States Department of the Army, *Field Manual 100-17, Mobilization, Deployment, Redeployment, Demobilization.* (Washington, DC: U.S. Government Printing Office, 28 October 1992), p. 4-2.
[94] U.S. Army Training and Doctrine Command (TRADOC) Analysis Center, *Appendix F – Transportability/Deployability Analysis to Technical Document TRAC-TD-0294, Supporting Documentation to the Advanced Field Artillery System (AFAS) and Future Armored Resupply Vehicle (FARV) Milestone I Cost and Operational Effectiveness Analysis (COEA).* (Fort Leavenworth, KS: U.S. Army Training and Doctrine Command Research and Analysis Center, 1994), p. 1.
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[96] Ibid., p. 2.
[97] Military Traffic Management Command Transportation Command Transportation Engineering Agency *(MTMCTEA) Reference Guide 98-70-1, Transportability and Deployability for Better Strategic Mobility*, p. 28.
[98] Ibid., p. 31.
[99] U.S. Army Training and Doctrine Command (TRADOC) Analysis Center, *Appendix F – Transportability/Deployability Analysis to Technical Document TRAC-TD-0294, Supporting Documentation to the Advanced Field Artillery System (AFAS) and Future Armored Resupply Vehicle (FARV) Milestone I Cost and Operational Effectiveness Analysis (COEA)*, p. 12.
[100] Ibid., p. 16.
[101] Military Traffic Management Command Transportation Command Transportation Engineering Agency *(MTMCTEA) Reference Guide 98-70-1, Transportability and Deployability for Better Strategic Mobility*, p. 29.
[102] U.S. Army Training and Doctrine Command (TRADOC) Analysis Center, *Appendix F – Transportability/Deployability Analysis to Technical Document TRAC-TD-0294, Supporting Documentation to the Advanced Field Artillery System (AFAS) and Future Armored Resupply Vehicle (FARV) Milestone I Cost and Operational Effectiveness Analysis (COEA)*, p. 12.
[103] Ibid., p. 14.
[104] Military Traffic Management Command Transportation Command Transportation Engineering Agency *(MTMCTEA) Reference Guide 98-70-1, Transportability and Deployability for Better Strategic Mobility*, p. 30.
[105] U.S. Army Training and Doctrine Command (TRADOC) Analysis Center, *Appendix F – Transportability/Deployability Analysis to Technical Document TRAC-TD-0294, Supporting Documentation to the Advanced Field Artillery System (AFAS) and Future Armored Resupply Vehicle (FARV) Milestone I Cost and Operational Effectiveness Analysis (COEA)*, p. 15.

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[109] Ibid., pp. 46-47.
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[111] Ibid., p. 32.
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