DEPARTMENT OF THE ARMY
US ARMY TRADOC ANALYSIS CENTER
WHITE SANDS MISSILE RANGE, NEW MEXICO 88002-5502

REPLY TO
ATTENTION OF

ATRC-W

30 May 2007

MFR 30May07

MEMORANDUM THRU Director, TRADOC Analysis Center, 255 Sedgwick Avenue, Fort Leavenworth, KS 66027-2345

FOR Director, Capabilities Development and Assessments Directorate, Army Capabilities Integration Center, 33 Ingalls Road, Bldg 133, Fort Monroe, VA 23651-1067

SUBJECT: Mid-Range Munition (MRM) Analysis of Alternatives (AoA)

1. Reference memorandum, HQ TRADOC, Army Capabilities Integration Center, 14 Aug 06, Subject: Mid-Range Munition (MRM) Analysis of Alternatives (AoA).

2. Enclosed for your consideration and forwarding to other principal ARCIC staff as well as to appropriate Headquarters Department of the Army staff is the final report documenting the MRM AoA. The reference directed the TRADOC Analysis Center, assisted by the Unit of Action Maneuver Battle Lab (UAMBL), to prepare an MRM AoA report that leverages other past work such as Precision Munitions Mix Analysis (PMMA), the Future Combat Systems (FCS) Milestone (MS) B AoA, and the Tank Extended Range Munition (TERM) Contributions to the Battlefield Study to support a Milestone B program decision projected for 4QFY07.

3. The study plan was approved on 11 October 2006 and the final results on 13 March 2007. The study provided findings and concluded that MRM provided precision fires at the lowest tactical level enabling the FBCT commander to shape the area of interest, setting the desired conditions for the close assault. The analysis effort was focused on determining the advantages and disadvantages (in terms of force effectiveness, sustainability, and cost) of an FCS-equipped force, with and without MRM.

4. With your receipt and approval of the final report, TRAC will distribute this report as shown in enclosure 2. TRAC will consider subsequent requests for copies of the report IAW TRAC information release policy.

5. TRAC-WSMR POC is Major Gregory Lamm, ATRC-WB, 505-678-7469 (DSN 258), gregory.lamm@us.army.mil.

Pamela I Blechinger

2 Encls
1. Report, MRM AoA
2. Initial Distribution

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TRAC-W-TR-07-028
23 May 2007

Mid-Range Munition (MRM) Analysis of Alternatives (AoA)

TRADOC Analysis Center
Martin Luther King Drive
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TRAC-W-TR-07-028
23 May 2007

Mid-Range Munition (MRM) Analysis of Alternatives (AoA)

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Distribution authorized to DoD components and DoD contractors only; administrative or operational use. This determination was made on 2 April 2007. Other requests for this document will be referred to the US Army Training and Doctrine Command, Army Capabilities Integration Center (ARCIC), ATTN: ATFC-RA, Fort Monroe, VA 23651-1067.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
MRM is a developmental-stage, extended-range precision munition for the MCS platform and represents a material solution within the FCS concept. Primarily, MRM utilizes a linked UAV to engage targets for the Future Brigade Combat Team (FBCT); however, it also contains an autonomous capability when target designation is not available. This AoA consisted of five distinct but interrelated components: evaluation of previous relevant work; examination of force lethality and survivability impacts; examination of comparable precision munition; evaluation of resources; and presentation of results. The AoA leveraged eight years of previous MRM-related studies to explore and assess the force effectiveness impact of its capabilities on the FBCT. The resource analyses included logistics impact; quantity estimate analysis (generated from three quantity methodologies); and life cycle cost analysis. The analysis focused on determining the advantages and disadvantages (in terms of force effectiveness, sustainability and cost) of a FCS-equipped force, with and without MRM. The study team concluded that MRM provided BLOS fires at the lowest tactical level enabling the FBCT commander to shape the area of interest, setting the desired conditions for the close assault with precision fires via the 60 organic MCS platforms.

15. SUBJECT TERMS
precision munitions, force effectiveness, lethality, survivability, life cycle cost, logistical impact, Mounted Combat System, Future Combat Systems, beyond-line of sight, Unmanned Aerial System, Network Fires

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Mid-Range Munition (MRM) Analysis of Alternatives (AoA)

1.0 Introduction

This report presents an analysis of alternatives (AoA) of the Mid-Range Munition (MRM) program proposed for the Future Combat Systems (FCS) Brigade Combat Team (BCT) (FBCT). The AoA has been prepared in support of a Milestone B (MS B) program decision affecting the MRM program, projected for 4th quarter, fiscal year (FY) 2007. The Training and Doctrine Command (TRADOC) Analysis Center-White Sands Missile Range (TRAC-WSMR), NM, was tasked in August 2006 by the TRADOC Army Capabilities Integration Center (ARCIC) to conduct the AoA, with support from the Unit of Action Maneuver Battle Lab (UAMBL), and to complete it not later than May 2007.

The study was begun in August 2006, the study plan was presented and approved in October 2006, and a final results briefing was presented on 13 March 2007.

This final report documents the analytical approach to the study, including a historical record of relevant previous work, describes the analysis performed, and presents findings and conclusions outlining the advantages and disadvantages (in terms of force effectiveness, sustainability, and cost) of an FCS-equipped force, with and without MRM.

1.1 Study Issues

- Determine the impact of MRM on the lethality of the FBCT.
- Determine the impact of MRM on the survivability of the FBCT.
- Determine the effectiveness of MRM compared to other precision munitions.
- Determine the impact of MRM on the sustainability of the FBCT.
- Determine the life cycle cost (LCC) of each alternative.

1.2 Background

MRM is a developmental-stage, extended range precision munition for the Mounted Combat System (MCS) platform and represents a material solution within the FCS concept. Its program schedule supports the overall MCS fielding schedule in FY15 and its requirements are outlined in the corresponding Capabilities Development Document (CDD). The MRM will provide the FBCT with a beyond line of sight (BLOS) range capability of 2 to 16 kilometers, from a stationary platform, and 2 to 8 kilometers from a moving platform. It will include BLOS autonomous and designate capabilities, and will be assigned to the FBCT and fielded post MS C (FY13). Additionally, two MRM variants are in development:

- The chemical energy (CE) round, developed by Raytheon, includes a chemical warhead with a canard actuator guidance package.

- The kinetic energy (KE) round, developed by Alliant, includes a penetrator with rocket guidance package.

Autonomous and designated MRM rounds were successfully tested in relevant environments and, therefore, both variants are currently at technology readiness level (TRL) 6. The dual mode seeker, autonomous and designated components working together, is still undergoing tests.

1.3 Key References

This analysis leveraged previous MRM-related studies to explore and assess the force effectiveness impacts of MRM capabilities on the FBCT. Principal references used in support of the analysis include:

- Memorandum, TRADOC ARCIC, ATFC-RA, 14 August 2006, subject: Mid-Range Munition (MRM) Analysis of Alternatives (AoA).
- Report, TRAC-WSMR, Tank Extended Range Munition (TERM), April 1998.
- Scripted Brief, TRADOC Analysis Center (TRAC), Precision Munitions Review (Joint Capabilities Integration and Development System (JCIDS) Analysis), Study Advisory Group Presentation, 18 December 2003.
- TRAC-TR-03-018, TRAC, Future Combat Systems (FCS) Milestone B (MS B) Analysis of Alternative, 18 May 2003.
- Scripted Brief, TRAC-WSMR, Future Combat Systems Networked Lethality and Survivability KPP Analysis, 19 May 2004.
- Scripted Brief, TRAC-WSMR, Future Combat Systems (FCS) Milestone B (MS B) Update, June 2005.
- TRAC-WSMR-TR-06-018, TRAC-WSMR, Precision Munition Mix Analysis (PMMA), Volumes I and II, 30 December 2006.

A complete list of additional reference material is included in appendix A.

1.4 Constraints, Limitations, and Assumptions (CLA)

Results taken from this analysis must be considered within the appropriate context, including the following CLA governing this study:

1.4.1 Constraint

- The final results of this AoA were due to ARCIC by the end of February 2007. This precluded model updates and new simulation runs.

1.4.2 Limitations

- Only one scenario (Northeast Asia (NEA) 50.2 in PMMA) was used to compare a force with and without MRM.

- The MRM AoA cost analysis utilized the cost model developed by the program manager in 2006 (no updated version was available), and was based on the Joint Common Missile (JCM) cost estimates.

1.4.3 Assumptions

- The six available studies used as data sources for the analysis present a sufficiently wide range of battlefield conditions to examine MRM's contribution to FBCT effectiveness.
- The NEA 50.2 scenario contains complex terrain, fleeting targets, and restrictive rules of engagement (ROE) conditions and allows for the examination of an FCS-equipped force, with and without MRM.
- FBCT has organic command and control (C2) and target acquisition capabilities available via the network, allowing MRM-MCS fire control.
- MRM will have a *designate capability*, utilizing a semiactive laser (SAL), and/or an *autonomous capability*, utilizing imaging infrared (IIR) and millimeter wave (MMW) technologies, when fielded to an FBCT.
- Munitions quantity estimates, based on PMMA Quantity Methodology and Department of Defense Instruction (DODI) 3000.4, are sufficient for the MRM cost analysis.
- The objective reliability of the MRM round is 90 percent (threshold 80 percent) and will impact the FBCT MRM basic load estimates if not achieved.

2.0 Study

The work was conducted in five parts: Summary of Relevant Past Work presented in section 2.1 and appendices A and B of this document, Force Lethality and Survivability, sections 3.1 and 3.2; Munition Comparative Analysis, section 3.3; section 3.4, Resource Analysis section; overarching results findings, and conclusions are presented in section 4.0, Findings and Conclusions, which also includes a summary of the contributions of the MRM capabilities to the FBCT.

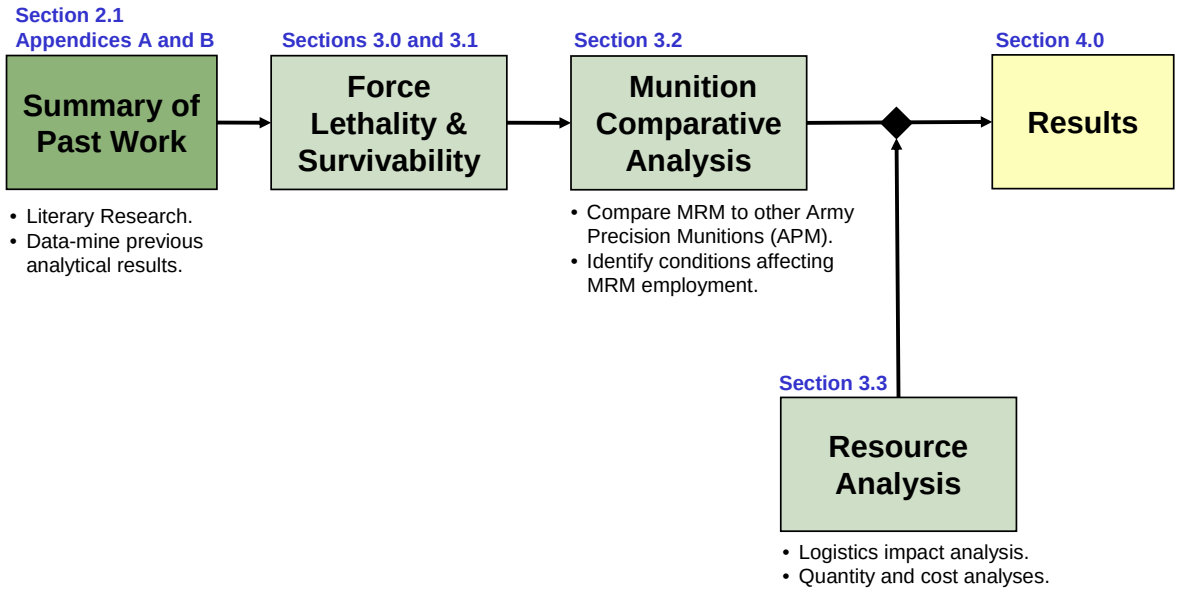


Figure 1. Analysis Framework

The analysis leveraged previous MRM-related studies to explore and assess the force effectiveness (FE) impacts of MRM capabilities on the FBCT. These studies became the analytical foundation of this work and provided valuable information regarding the contribution of MRM to force lethality and survivability. Notably, the PMMA became the core analytical study due to its broad range of conditions and scenarios (including FBCT MRM and No-MRM alternatives) and the availability and currency of its data. The remainder of the studies provided supporting information and data.

The MRM and No-MRM alternatives (NEA 50.2) contained in the PMMA were used to investigate the effectiveness of MRM and to support the resource analysis, including its logistics and cost elements. Results from the logistics analysis, along with the quantity estimates derived from Unit Basic Load (UBL) Assessment, the PMMA quantity methodology, and the DODI 3000.4, supported the cost analysis.

2.1 Summary of Relevant Past Work

Figure 2 lists the relevant studies that provided insights and informed this study in the required areas of lethality, survivability, effectiveness, sustainment, and cost.

✓ Addressed in this study. ▭ Partially addressed in this study. ⊙ Not addressed in this study.	Lethality	Survivability	Effectiveness	Sustainment	Cost
TERM Contributions to the Battlefield Study (1998)	✓	✓	⊙	⊙	⊙
Precision Munitions Review (2003)	✓	✓	✓	⊙	⊙
FCS MS B AoA (2003)	✓	✓	⊙	⊙	⊙
FCS Networked Lethality and Survivability KPP Analysis (2004)	✓	✓	⊙	⊙	⊙
FCS MS B OSD Update (2005)	✓	✓	✓	⊙	⊙
Precision Munition Mix Analysis (2006)	✓	✓	✓	▭	✓

KPP – key performance parameters **OSD – Office of Secretary of Defense**

Figure 2. Summary of Past Work

Summary results contained in these studies and the corresponding evidence used in support of this analysis are presented in the paragraphs that follow. Detailed descriptions and complete overviews of the studies are included in appendix B.

Tank Extended Range Munition (TERM) Contributions to the Battlefield Study (1998). This study was conducted by the Army Research Laboratory (ARL) and TRAC-WSMR in two phases. The intent of the study was to analyze (1) TERM's increased range over base case munitions, (2) TERM's line-of-sight (LOS) and BLOS engagement capability, and (3) whether shoot-on-the-move capability increases FE. Results from this study provided insights on force lethality and survivability when a BLOS capability was employed from a tank platform.

Precision Munitions Review Study (2003). During the execution of this study, TRAC-WSMR evaluated three major precision munition programs: JCM, Excalibur (U), and Precision Guided Mortar Munition (PGMM). Although MRM information was gathered, capability gap results were not reported. Results of the study provided insights into MRM's

lethality and survivability due to its capability to defeat high-value targets at BLOS ranges with autonomous or laser seeker guidance.

FCS Milestone B AoA (2003). The purpose of this study was to evaluate the FBCT and higher echelons in several theaters of operation. Analysis focused on the conditions in which forces conducted offensive operations (e.g., urban, day, night, bad weather) to assess force lethality and survivability. Study results, based on the utilization of five models and eight scenarios, provided insights into MRM's precision fires capabilities and impacts on force lethality.

FCS Networked Lethality and Survivability Key Performance Parameters (KPP) Analysis (2004). This analysis underpinned the FCS Networked Lethality and Survivability KPP. Analysis examined the effects of employing networked LOS, BLOS, and non-line of sight (NLOS) fires within the FCS network. Though the MRM-related results gleaned from this analysis were minimal, it was concluded that the MCS was the primary killer of Threat systems utilizing BLOS fires, and that the MCS was one of the most survivable mounted systems, due to its BLOS capability.

FCS Milestone B Update (2005). This study examined the benefits to force effectiveness of an FBCT with increased Class II and Class III unmanned aerial systems (UAS) and armed robotic vehicles (ARV). It also compared the force effectiveness of the FBCT with increased reconnaissance and targeting capabilities utilizing the additional UAS and ARV systems to the Heavy Brigade Combat Team (HBCT). The study provided insights regarding conditions that affect the use of MRM, including UAS reduction impacts on MRM BLOS fires.

Precision Munition Mix Analysis (2006). The PMMA identified the combinations of Army precision munitions that best support the current and future combat force in FY14 in mid- to high-intensity combat situations. The study identified four tiers of munitions ranked by contribution to lethality, versatility against Threat, and other criteria. MRM was identified as one of the Tier 1 munitions (those central to any mix) capable of engaging multiple likely mission profiles.

3.0 Analysis Results

This section includes descriptions of the impacts of MRM on the lethality, survivability, effectiveness and sustainability of the FBCT, presents some overarching observations gleaned from the past studies, and details the resource analyses, including logistics, quantity and cost.

3.1 Impact of MRM on the Lethality of the FBCT

The PMMA MRM and No-MRM alternatives provided the baseline for the evaluation of the impact of MRM capabilities on the FCS-equipped force. MRM enabled the FBCT commander to shape the battlefield, setting the desired conditions for the close assault with precision fires via the 60 organic MCS platforms and a linked UAS. Its capabilities allowed the force to engage a wide range of target types (e.g., light, medium, heavy, etc.) from BLOS

with immediate, persistent, and precision fires when ROE was limited at the lowest tactical level. With MRM, the FBCT:

- Achieved a 10 percent increase in lethality at ranges beyond the MCS main gun (4 kilometers).
- Killed 10 percent more high-payoff targets (HPT) beyond direct fire range, increasing force survivability; and 17 percent more personnel in buildings, resulting in a more successful urban assault operation.
- Enhanced shaping operations at the lowest tactical echelon.
- Engaged Threat across the FBCT area of operations (AO) with reduced collateral damage and fratricide.

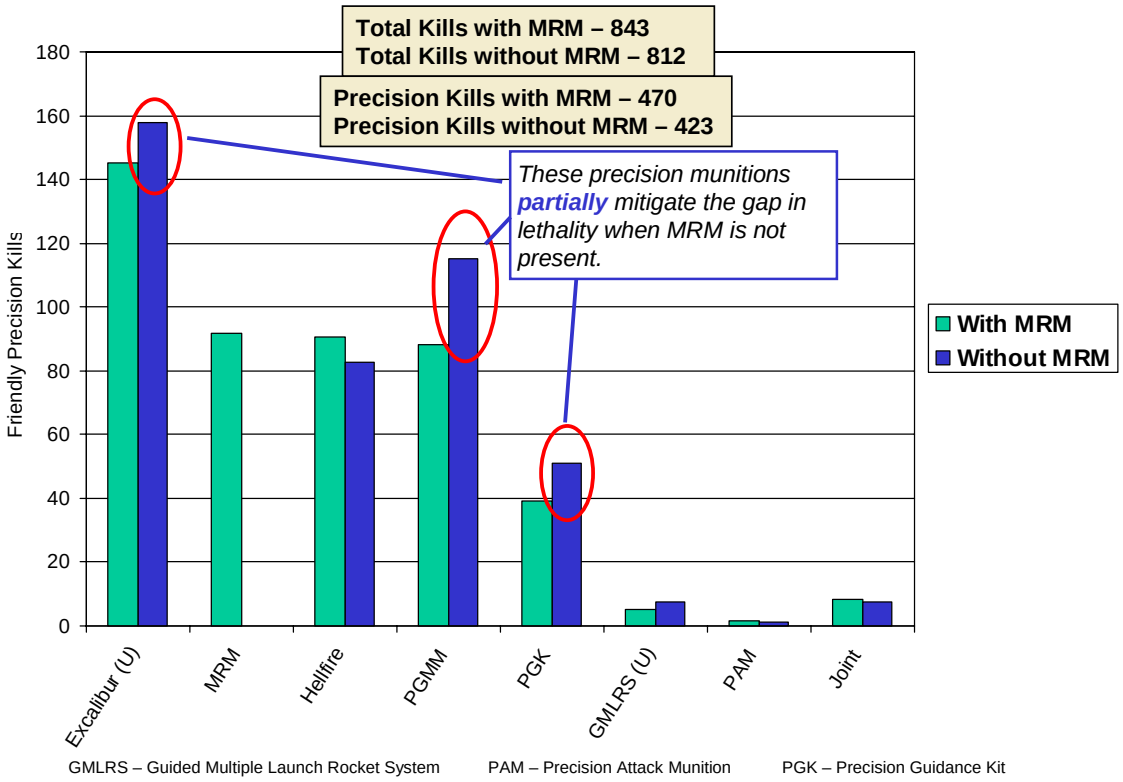


Figure 3. Precision Lethality by Munition Type
(NEA 50.2 FCS Battalion (+) Attack – PMMA 2006)

The MRM-capable MCS with designate and autonomous capability was the primary killer in the 4- to 13-kilometer range and provided the FBCT commander a tool to shape the AO using organic company-level precision fires with smaller risks of fratricide. Further, it provided the ability to kill a wide range of target types (light, medium, heavy) utilizing a linked UAS and limiting Threat's maneuver and fires capabilities throughout the battlefield.

Without the MRM-equipped MCS, other precision munitions were relied upon to maintain force lethality at ranges greater than 4 kilometers. MRM provided the commander

the ability to integrate BLOS fires with maneuver to kill Threat quickly and with greater precision and accuracy.

When BLOS fires, especially MRM, were not employed by the FCS-equipped force, 86 percent fewer targets (figure 4) were engaged between 5 and 13 kilometers resulting in an increased requirement for NLOS fires from brigade (13 percent more engagements, specifically Excalibur (U) beyond 14 kilometers) to engage targets originally engaged by MRM. This also reduced the company commander's ability to engage time-sensitive and HPT targets beyond 8 kilometers (the only precision assets available were PGMM and Hellfire), thus reducing his effect on the entire area of interest.

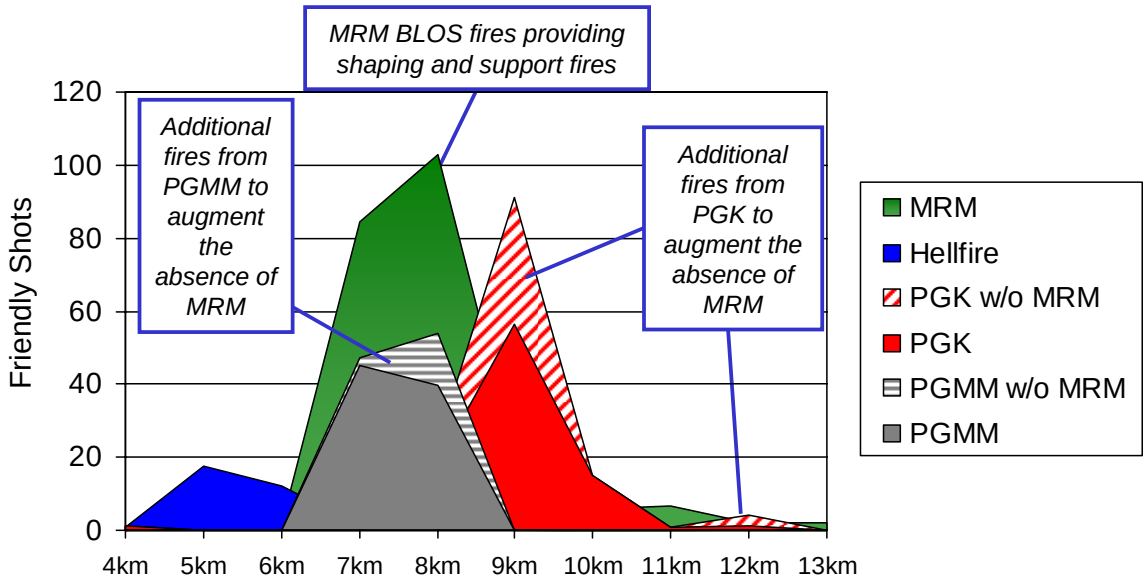


Figure 4. Company and Battalion Precision Shaping Operations (PMMA 2006)

3.2 Impact of MRM on the Survivability of the FBCT

There was no difference in survivability between the MRM and the No-MRM cases. In the MRM alternative, however, the force:

- Maneuvered out of contact with the MCS to positions of advantage and beyond Threat's indirect fire range.
- Exploited terrain for cover, concealment, and mobility for BLOS fires by utilizing a UAS link.
- Minimized risks to fratricide due to reduced target location errors, delivery errors, and lethal area effects, compared to other precision munitions.

3.3 Precision Munitions Complementary to MRM (Effectiveness)

The FBCT has numerous precision munitions that would support a variety of missions. MRM was identified as a Tier 1 munition in the PMMA study because it provides precision

capability across a variety of conditions and scenarios. Figure 5 depicts the contributions to lethality of the various munition mixes against different target categories, including:

- Personnel (e.g., Antitank Guided Missile, C2 Node, Forward Observer, Infantry Squad, Mortar Section, Sniper, Terrorist).
- Light (e.g., Towed Howitzer, Aircraft on Ground, Civilian Vehicle, Radar, Vehicle Borne Improvised Explosive Device).
- Medium (e.g., Self-Propelled Howitzer, Infantry Fighting Vehicle, Theater Ballistic Missile, Surface-to-Surface Missile).
- Heavy (e.g., Tank, Tank Platoon).
- Air Defense Artillery (ADA) (e.g., ADA Missile, Antiaircraft Artillery).

In the NEA 50.2 FBCT Battalion (BN) (+) Attack scenario, the FBCT was successful in completing its mission with and without MRM due to the ability of other precision munitions to engage MRM-type targets. However, the other precision munitions, specifically PGMM, Excalibur (U), and Precision Guidance Kit (PGK), were not able to fully offset the MRM capabilities and no one munition was able to engage all target types. In the FBCT force without MRM, other precision munitions killed 13 percent fewer targets in urban areas due to ROE limitations and 10 percent fewer Threat overall. The FBCT did not maneuver with NLOS cannons and NLOS mortars (MCS is able to fire on the move) to execute fires.

The FCS-equipped force without MRM relied on the munitions listed above to provide shaping and supporting fires, but was concurrently exposed to increased risks. This was due to (1) the increased collateral damage and fratricide by munitions with larger lethal area effects and minimum safe distances, which precluded engagements within urban environments; (2) the reduced company-level BLOS fires to shape and provide immediate supporting fires at the lowest tactical level within the 5- to 13-kilometer range, exposing the force to more Threat in the close fight; and (3) the reduced ability to affect the entire FBCT area of interest by the use of precision fires via the 60 organic MCS platforms.

MRM enhanced the current suite of Army precision munitions by extending the commander's area of interest beyond ranges of PGMM and Hellfire. MRM's BLOS capabilities supported the commander's operations by augmenting NLOS fires (beyond 14 kilometers) with Excalibur (U) and PGK. Without MRM, the FBCT relied on NLOS fires resulting in additional munitions expended. MRM leveraged the direct relationship between the MCS and a linked UAS. Target acquisition was obtained from other aerial and ground assets through the FCS network when linked UAS was absent.

When the number of UAS was reduced to examine potential impacts to the FBCT, MRM kills dropped by about 6 percent due to the force's ability to engage targets without laser designation and to utilize ground acquisition assets. The FBCT was less affected by the reduction of aerial sensors due to its overall ability to utilize other sensor assets and scouts, allowing BLOS fires to continue throughout the operation.

Inclement weather, countermeasure, and reduced sensor availability affect MRM's employment capability and the ability of the FBCT to engage Threat with precision fires. A set of versatile Army precision and Joint munitions enabled the force to successfully engage Threat under those conditions. In a Caspian Sea scenario, inclement weather (including wind, rain, and/or fog) and Threat countermeasures (including smoke and global positioning system (GPS) jamming) degraded sensor performance and lasing capability of all munitions, resulting in a 30 percent decrease in force lethality. The same conditions required the FCS-equipped force to utilize a combination of Army precision and Joint munitions to achieve mission success.

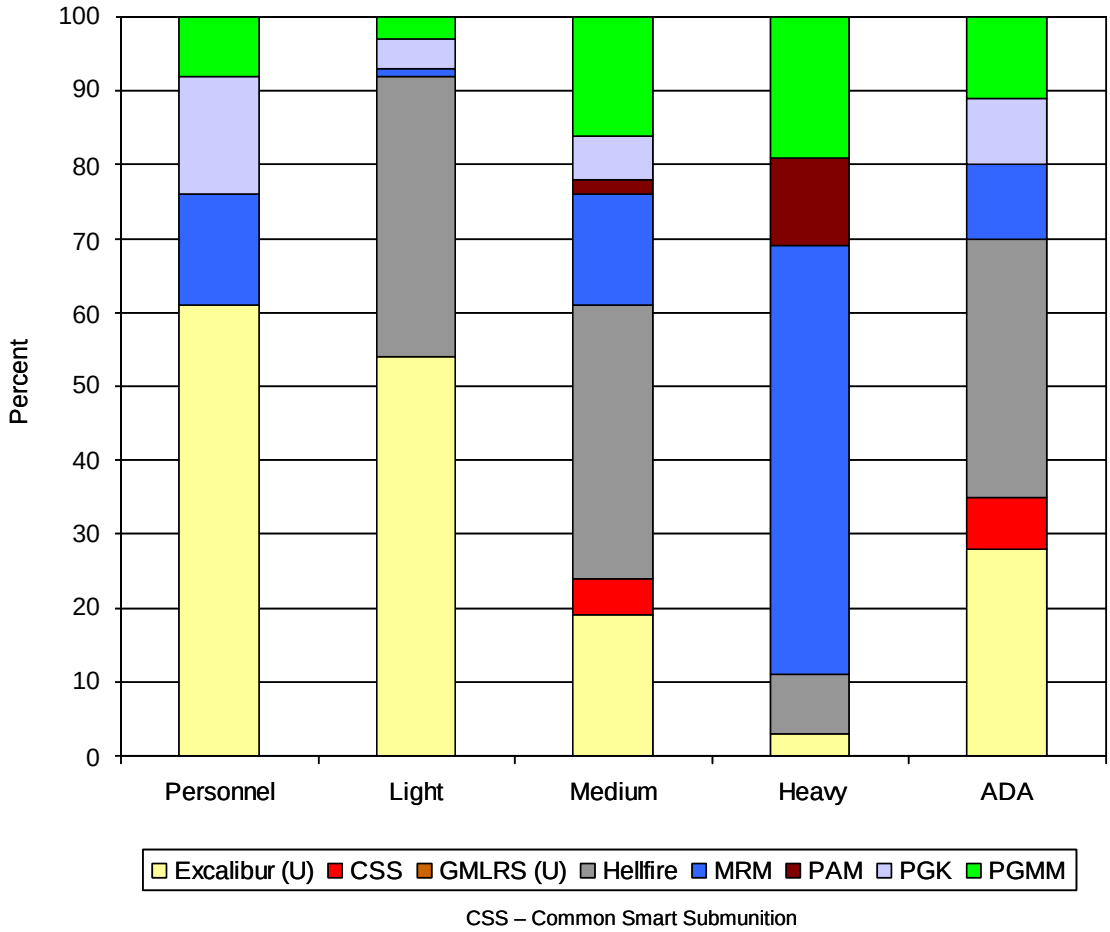


Figure 5. Percentage Contribution to Lethality by Munition Type (Battalion Level Scenarios – PMMA 2006)

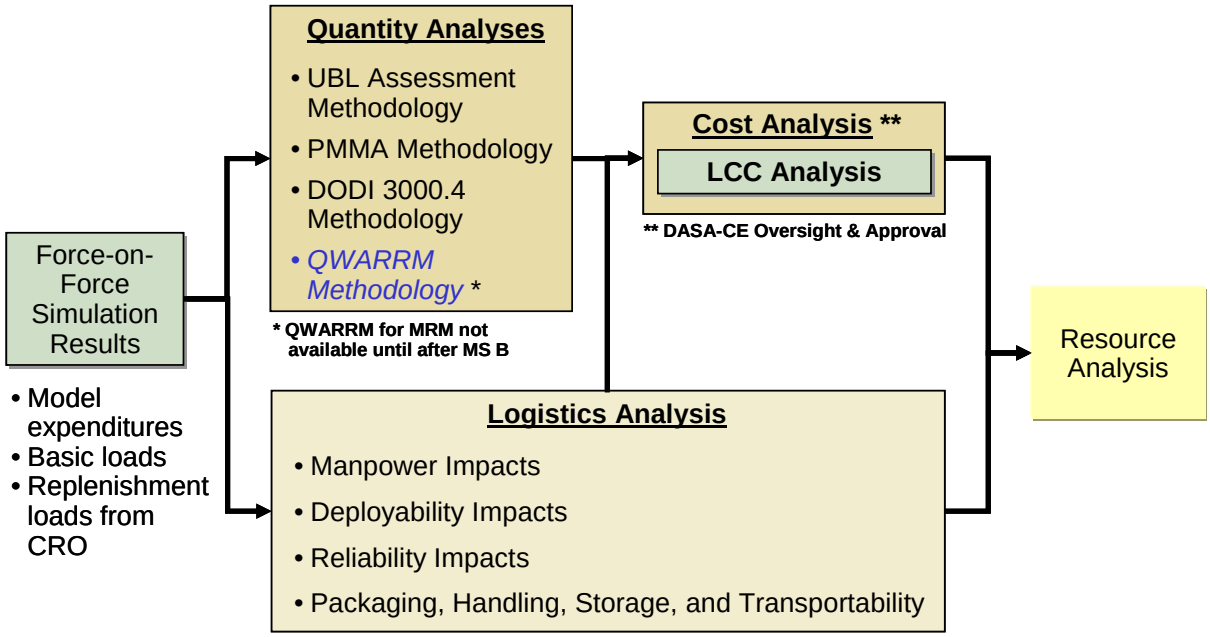
Other observations gleaned from the PMMA study include:

- PGMM, fired from NLOS mortars, engaged Threat personnel in the urban environment, but was limited to within the 8-kilometer range compared to MRM's 16-kilometer range.

- Excalibur (U) and PGK fired from NLOS cannons filled the gap against Threat personnel, but their effectiveness was limited due to the risks of fratricide and collateral damage.
- Without MRM, PGK engagements increased against medium-type targets in non-urban areas, but kills of those targets decreased because of the lack of laser designation.
- Aviation and ARV platforms with Hellfire and Precision Attack Munition (PAM) in non-urban areas filled the gap against heavy targets. Although other munitions offset some of MRM target engagements, Hellfire range limitations and PAM prevented the application of effects against all MRM targets.

3.4 Resource Analysis

The Resource Analysis consisted of three distinct analytical parts (Logistics, Quantity, and Cost), that generated two distinct but interrelated products: the MRM Logistics Impact Analysis and the LCC Analysis (figure 6). Both products were developed based on the results obtained from the force-on-force simulations contained in the MRM and No-MRM alternatives (NEA 50.2). Within the Quantity Analysis, the NEA scenario represented the major contingency operation (MCO) and Southwest Asia (SWA) represented the lesser contingency operations (LCO).



CRO – combat replenishment operations
DASA-CE – Deputy Assistant Secretary of the Army for Cost and Economics
QWARRM – Quantitative War Reserve Requirements – Munitions

Figure 6. Resource Analysis Methodology

3.4.1 Logistics Analysis

The Logistics Analysis included an assessment of the impacts of reliability, manpower, transportability packaging and handling, and storage of the MRM round.

MRM is being developed as a "closed" precision munition that requires no maintenance, resulting in an objective reliability of 90 percent (threshold of 80 percent) which, if not achieved, will impact the FBCT MRM basic load estimates.

No additional manpower was required to field and utilize MRM and no additional special requirements for packaging, handling, storing, or transporting MRM rounds were identified. The MRM round has comparable dimensions but a slight decrease in weight compared to current 120 millimeter (mm) tank munitions. It utilizes the 120mm logistics support and distribution system.

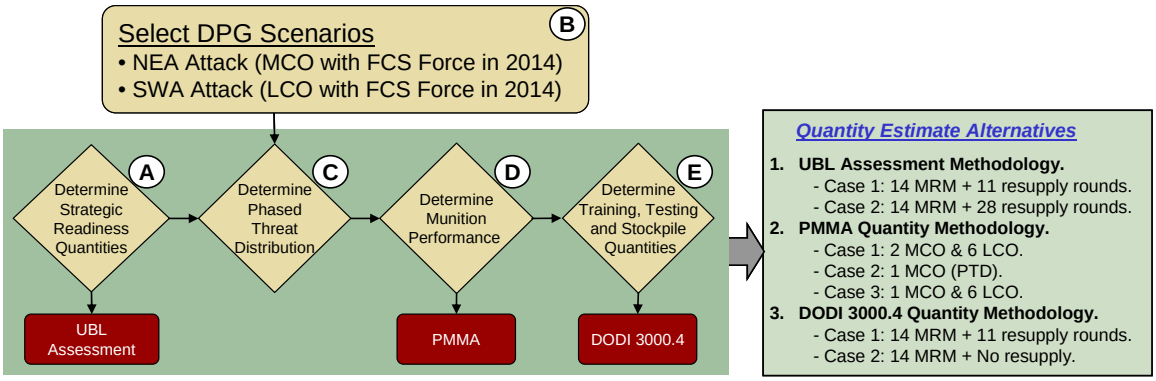
The overall logistics analysis showed that MRM reduced the total number of precision munitions used by the force during combat operations by killing Threat efficiently at extended ranges. When MRM was absent from the FBCT, Class V expenditures increased by 10 short tons for indirect and direct fire rounds without MRM. The increased consumption of precision NLOS munitions was a major contributor to the increase in the overall FBCT logistics burden.

Additional MRM rounds beyond the MCS MRM basic load are stored on the Multifunction Utility/Logistics Equipment-Transport (MULE-T) or at the brigade support battalion (BSB) in the form of stockpile rounds. The combined arms battalion (CAB) commander retains 12 MULE-T assets that can be directed from the support platoon to the MCS companies based on mission, enemy, tactics, terrain – time and civilians (METT-TC) to carry additional MRM rounds. Each MULE-T has a total capacity of 1,926 pounds, or approximately one short ton, and is designed to carry a combination of logistical classes of service (water, fuel, etc.).

3.4.2 Life Cycle Costs

Quantity Analysis

A set of quantity estimate methodologies was used to generate LCC and identify potential risks associated with the Army planning strategy. The overall quantity estimate framework depicted in figure 7 illustrates the processes used to generate the quantity estimates used to support the LCC. The three quantity methodologies produced a set of seven cases and are described in detail in appendix C.



DPG – defense planning guidance PTD – phased threat distribution

Figure 7. Quantity Estimate Methodologies

PMMA and DODI 3000.4 methodologies used simulation output and projected theater Threat distributions to generate munition quantity estimates. The PMMA quantity methodology and the DODI 3000.4 are well established. The UBL assessment methodology was added as a third quantity estimate technique to support the PMMA and DODI 3000.4 results. The Quantitative War Reserve Requirements – Munitions (QWARRM) method was not used, as it was not available for this analysis.

Cost Analysis

The LCC represents the 20-year costs[1] of the procurement of the MRM round consisting of an autonomous and designate capability. The LCC utilized MRM program parameters derived in the Program Manager - Maneuver Ammunition Systems - Large Caliber (PM MAS-LC) Automated Cost Estimating Integrated Tools (ACEIT) model and relevant findings from the logistics analysis. The following paragraphs summarize the findings from the cost analysis. More detailed definitions and descriptions are found in appendix C.

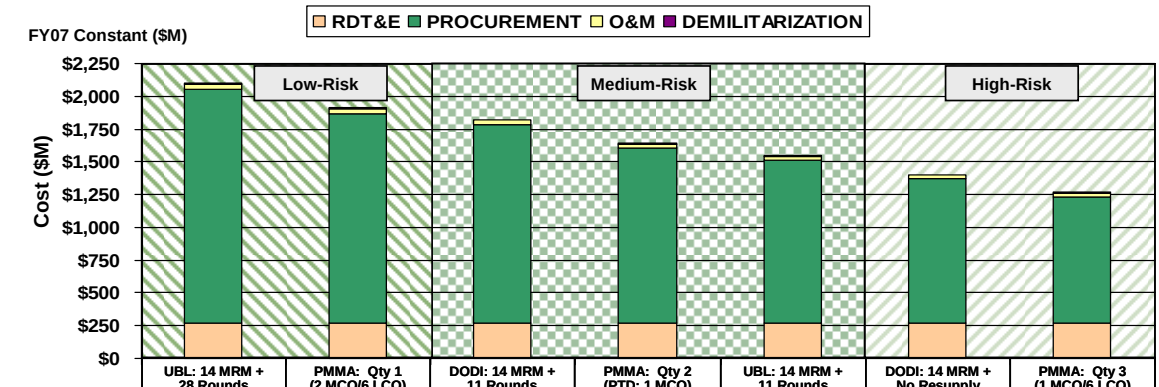
Deputy Assistant Secretary of the Army for Cost and Economics (DASA-CE) concurred with the cost analysis. DASA-CE examined the cost assumptions and the PM MAS-LC ACEIT cost model for MRM and concluded that the assumptions and cost methodology were reasonable for estimating LCCs.

Moreover, Headquarters, Department of the Army (HQDA) G-8, Force Development Analysis (FDA), also assessed and concurred with the cost analysis methodology. The G-8 FDA found that the MRM LCC was accurate based on the study assumptions and the MRM program parameters incorporated in the MRM ACEIT cost model, provided by PM MAS-LC.

The G-8 and DASA-CE used the procurement quantity of 22,680 MRM rounds for their assessment. The similarity of LCC calculations implies accuracy in the estimates across all alternatives.

[1] Research, development, testing, and evaluation (RDTE) costs, operations and maintenance (O&M) costs, and demilitarization costs

Figure 8 (arranged by order of magnitude) illustrates the LCC expressed in FY07 constant dollars for the seven different quantity estimate cases. The respective LCC in current dollars (inflation and escalation factors included) are presented in appendix C, along with assumptions and the cost methodology used with the ACEIT model to generate them. Average unit production cost (AUPC) was determined by dividing the cost of procurement by the respective procurement quantity. The LCC were categorized by operational risk in terms of the 2006-2023 Army Strategic Planning Guidance (ASPG).



	UBL: 14 MRM + 28 Rounds	PMMA: Qty 1 (2 MCO/6 LCO)	DODI: 14 MRM + 11 Rounds	PMMA: Qty 2 (PTD: 1 MCO)	UBL: 14 MRM + 11 Rounds	DODI: 14 MRM + No Resupply	PMMA: Qty 3 (1 MCO/6 LCO)
Quantity Estimates	37,800	32,633	29,484	24,903	22,680	19,404	16,375
AUPC ($K) *	$47.1	$48.9	$51.2	$53.4	$54.5	$56.4	$58.6

O&M – operations and maintenance Qty – quantity RDT&E – research, development, test, and evaluation

Figure 8. MRM LCC Comparisons (FY07 Constant ($M))

The Low-Risk category provides for the conduct of two MCOs and six LCOs and represents the ability to execute two near simultaneous major conflicts and a limited number of lesser contingency operations as stated in the ASPG.

The Medium-Risk category provides MRM rounds to execute one MCO but fewer than the requirement to execute the operations defined in the ASPG. Because quantities in this category are equal to or larger than the proposed MCS and resupply basic loads for the FBCT, the commander is able to engage additional targets with MRM (41 percent residual capability beyond one MCO and six LCOs) if such targets represent a heavy to medium Threat force. In those cases, MRM is the first choice munition.

The High-Risk category provides for the conduct of one MCO and at least one LCO with a maximum of six. This category reflects quantities below the current MCS UBL, with no additional resupply capability, and is not resourced to execute the operations defined in the ASPG.

4.0 Findings and Conclusions

The FBCT successfully completed all assigned missions, satisfied the commander's measures of performance, and was capable of executing follow-on missions.

The FCS-equipped force with MRM:

- Reduced close fight engagements by engaging HPTs beyond direct fire range.
- Enhanced shaping operations within ROE.
- Engaged a wide range of Threat targets (e.g., light, medium, heavy, etc.) across the FBCT AO from the MCS with a linked UAS.
- Provided the commander laser-designated company-level precision fires to 16-kilometers but proved capable as well of engaging Threat without laser designation.
- Reduced the FBCT logistical burden for both indirect and direct fire systems by killing Threat efficiently with its lethal effects.

The FCS-equipped force without MRM:

- Expended more rounds and killed fewer HPTs beyond direct fire ranges.
- Engaged targets with other precision munitions (Excalibur (U), PGMM, PGK) but killed fewer Threat in the urban environment due to ROE.
- Engaged targets using Joint assets during inclement weather.

In terms of cost, the analysis provided the cost insights and results listed below. All cost amounts are expressed in FY07 constant dollars.

- A total of 22,680 MRM rounds ($1.5 billion) will provide a BLOS capability to the full FCS-equipped force. This amount represents the total requirement to field 60 MCS in 15 BCT at the proposed MCS UBL and resupply capacities. At this level, the force can conduct one MCO and six LCOs, which represents less than the requirement to execute operations within the current ASPG (two MCOs and six LCOs).
- At 32,633 MRM rounds ($1.9 billion), the force can conduct two MCOs and six LCOs and execute the operations within the ASPG.
- The MMW seeker, if integrated into the MRM round, makes up 34 percent of total LCC across alternatives. The MMW is used for extreme battlefield conditions (i.e., Threat countermeasures) or as an alternative to IIR technology in order to provide an autonomous capability.
- No cost-related logistics impacts exist.

Finally, MRM provided BLOS fires at the lowest tactical level and enabled the FBCT commander to shape the area of interest, setting the desired conditions for the close assault with precision fires via the 60 organic MCS platforms.

Appendix A. Key References

A.1 Technical Reports

1. TRAC-TR-03-018, TRAC, Future Combat Systems (FCS) Milestone B Analysis of Alternatives, 14 May 2003.

2. Report, LSI/USAIC/UAMBL, Future Combat Systems (FCS) MOUT Study, April 2005.

3. TRAC-WSMR-TR-06-018, TRAC-WSMR, DRAFT, Precision Munition Mix Analysis (PMMA), Volume 1 and 2, 30 March 2006.

4. TRAC-WSMR-TR-06-020, TRAC-WSMR, Integrated Analysis of Future Combat Systems (FCS) Brigade Combat Team (BCT) Effectiveness Study, Executive Summary, 2 May 2006.

A.2 Scripted Briefings

5. Scripted Briefing, TRAC-WSMR, Tank Extended Range Munition Analysis, April 1998.

6. Scripted Briefing Objective Force/Future Combat Systems Analysis of Alternatives, Tactical Level Force Effectiveness Analysis, Volumes 1, 2, and 3, September 2003.

7. Scripted Briefing, TRAC, Precision Munitions Review (JCIDS Analysis), Study Advisory Group Presentation, 18 December 2003.

8. Scripted Briefing, TRAC-WSMR, Future Combat Systems, Networked Lethality & Survivability KPP Analysis, 19 May 2004.

9. Scripted Briefing, TRAC-WSMR, Future Combat Systems (FCS) Analysis of Alternatives Update, Tactical Analysis (U) Final Report, 2 November 2004 (Secret).

10. Scripted Briefing, TRAC-WSMR FCS Milestone B Update, June 2005.

11. Scripted Briefing, TRAC-WSMR, FCS Milestone B Update for OSD Spring Review May 2006 (CASTFOREM Force Effectiveness), May 2006.

A.3 Briefings

12. Briefing, TRAC-WSMR, Janus Emerging Force Effectiveness Results Caspian Brigade, Gaming (Legacy, SBCT PIP'D, Increment I and FCS Block I), 8 May 2003.

13. Briefing, UAMBL, Force Effectiveness Study, No MRM, 2004.

14. Briefing, TRAC-WSMR, Precision Munition Mix Analysis (PMMA) Study Overview, 16 August 2004.

15. Briefing, Integrated Concept Team, Omni Fusion 2005 (OF 05) – Build 1, Emerging Insights Brief, 24 February 2005.

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17. D786-11678-1, FCS SSEI, FBCT Design Concept Baseline Description (FBCT-001-01-060328), Rev C, 18 May 2006.

18. Briefing, FBCT Increment I, Threshold URS (Resourced) 25 September 2006.

19. Briefing, PM-MAS, Mid Range Munition/MCS Integration Schedule, 5 October 2006.

20. Briefing, PM-MAS, Mid-Range Munition (MRM) 6 November 2006.

21. Briefing, UAMBL, Beyond Line of Sight Fires, BLOS in the UA.

22. Briefing, PM-MAS, Review of TRAC Precision Munitions Review (PMR) Study.

A.4 Other References

23. UAMBL, TRADOC Pamphlet 525-3-90, United States Army Future Combat Systems Operational and Organizational Plan for the Future Combat Systems Brigade Combat Team, Change 3, 16 December 2005.

24. UAMBL, Capabilities Development Document (CDD) for Mid-Range Munition (MRM), ACAT II, Version 1.1, 1 March 2006.

25. UAMBL, Operational Requirements Document for Future Combat Systems, (Change 2), April 2006.

26. UAMBL, Future Combat Systems Brigade Combat Team (FBCT) Integrated Process (IP) Description IP 14 Conduct Cooperative Engagements, Version 3.0, April 2006.

27. UAMBL, Future Combat Systems Brigade Combat Team (FBCT) Integrated Process (IP) Description IP 03 Conduct Network Fires, Version 3.0, April 2006.

Appendix B. Overview of Relevant Previous Studies

The following summaries reflect the general overview of the studies and their results. They were identified as core studies applicable to this analysis.

B.1 TERM Contributions to the Battlefield Study, 1998 - 2005

This study was conducted by the ARL and TRAC-WSMR. It analyzed the effects of direct fire only versus direct and indirect fire MRM rounds deployed from an Abrams and M1A2 system enhancement program (SEP) tank, and was conducted in two phases. During Phase I, ARL modeled a single company tank-on-tank battle in the Modular Semiautomated Forces (ModSAF) model to distinguish the capabilities of the TERM round (now known as MRM). Main focus of the study was to examine TERM in direct fire-only mode versus BLOS mode with conventional tank ammunition. In Phase II, TRAC-WSMR ran several high resolution scenarios (HRS) in the CASTFOREM model and compared two TERM concepts (TERM-KE and TERM-CE) with other precision munitions and conventional tank ammunition. Scenarios included:

- HRS 52 SWA Night Attack.
- HRS 31 NEA Heavy Attack.
- HRS 58 SWA Hasty Defense with Counterattack.
- HRS 37 Europe Attack.

Alternatives were designed to capture the effects of (1) TERM's increased range over base case munitions, (2) TERM's LOS and BLOS engagement capability, and (3) whether shoot-on-the-move capability increases effectiveness. In addition, TERM results were compared to the effectiveness of other antiarmor weapons such as the PGMM, FOTT, and EFOGM.

Study results provided insights to this analysis on force lethality and survivability when compared to other munitions (i.e., PGMM). Specific study results highlighted the following:

- TERM candidates had an operational payoff in increased lethality at extended ranges.
- TERM increased force survivability, reducing tank losses by 50 percent.
- TERM LOS/BLOS combined capability improved lethality and survivability of the force compared to LOS only.
- FOTT, EFOGM, and PGMM antiarmor weapons showed a considerable contribution to Threat kills; however, the force equipped with TERM killed more due to TERM's increased rate of fire, lethal effects, and range compared to the antiarmor weapons.
- In HRS 37, the tank in the TERM-No Move alternative performed better than the TERM alternative (shoot-on-the-move) due to terrain constraints, allowing tanks to kill more and engage less.

- KE LOS/BLOS TERM proved to be best overall performer.

B.2 Precision Munitions Review Study, 2003

During the 2003 Precision Munitions Review study, TRAC-WSMR evaluated and reported on three major precision munitions programs: JCM, Excalibur (U), and PGMM. Although MRM information was gathered, MRM capability gap results were not reported. PM-MAS reviewed the study results in March 2004 and compared the capabilities of MRM to the other precision munitions. The capability assessments were based on the TERM and FCS Operational Requirement Document (ORD) requirements and MRM draft performance specification.

The Precision Munitions Review Study and MRM AoA assessment by PM-MAS (agreed to by TRAC-Fort Leavenworth), showed that MRM provided several capability gaps that do not exist with presently fielded conventional munitions or with future precision munitions. MRM was the primary FBCT ground-based killer of enemy Threat armor vehicles in the Caspian Sea and SWA scenarios. Specifically MRM:

- Provided responsive kills of stationary and moving targets in difficult adverse weather and countermeasure scenarios.
- Engaged high-value targets at BLOS ranges with an autonomous or a designate capability.

B.3 FCS Milestone B AoA, TRAC, 2003

TRAC utilized several models, including Janus, CASTFOREM, VIC, JVB, and JCATS to evaluate the FBCT and the division in several theaters of operation. This included five Caspian Sea, one SWA, and two Balkan scenarios. Janus, JCATS, and CASTFOREM provided examination of the tactical force effectiveness of brigade- and battalion-level forces, while VIC provided examination of the corps-level forces. JVB modeled individual FBCT and division force slices in a distributed interactive simulation/high-level architecture compliant environment. JCATS was also used to distinguish the FBCT capabilities in urban terrain. The future force was compared to a product improvement program Stryker Brigade Combat Team (SBCT) and current force.

Results from the FCS Milestone B AoA, provided the following insights into force lethality and survivability:

- FBCT force killed 1.5 to 4 times as many Threat targets as the interim brigade and current forces in Caspian Sea and Balkans scenarios.
- BLOS (MRM) and NLOS precision munitions engaged targets more efficiently compared to area effect munitions due to better communication and networking assets within the FBCT.
- BLOS fires provided lethal and responsive fires down to platoon level, resulting in maneuver elements killing more at extended ranges.

B.4 FCS Networked Lethality and Survivability KPP Analysis, 2004

This analysis underpinned the FCS Networked Lethality and Survivability KPPs. This part of the KPP analysis was focused on determining if the threshold values of the metrics established for networked lethality and survivability enable the FCS-equipped brigade to be effective during the conduct of combat operations as described in the FBCT O&O.

In each of the Caspian Sea cases, the FBCT achieved mission success. The Friendly force mission was to secure route to facilitate the passage of a follow-on division. The Threat mission was to delay the Friendly force and fight from urban areas, while preserving their military capability.

In this scenario, the MCS with MRM was a primary killer of Threat systems and was one of the most survivable systems due to its BLOS capability.

B.5 FCS Milestone B Update, 2005

This update assessed the force effectiveness of the FCS-equipped 24T DCB compared to the FCS-equipped Increment I baseline. The 24T DCB force is described in the FBCT Increment 1 Threshold Unit Reference Sheet (URS), dated 6 December 2004. The Caspian Sea scenario was used to compare the effectiveness of the forces.

This study highlighted that when the number of sensors and sensor time-on-station were reduced:

- MRM effectively engaged targets without designation using autonomous or direct fire modes.
- MCS employed MRM using target designation from ground acquisition assets (manned ground vehicle (MGV) and unmanned ground vehicle (UGV)) reducing MRM kills by only 6 percent.

B.6 Precision Munition Mix Analysis, 2006

TRAC was tasked in July 2004 by the TRADOC ARCIC to conduct the PMMA, to identify the combinations (mixes) of Army precision munitions that best support the current and future combat force in FY14 in mid- to high-intensity combat situations. PMMA examined precision munitions initially within battalion sized force-on-force battles; operational performance was oriented on measuring the benefit of precision munitions to the overall force. Precision mixes were then further examined in additional battles, to include FBCT and corps/division, in order to verify the mix recommendations and aid in identifying potential adjustment areas. Outcomes from these battles were used to provide input for the various resource analyses (e.g., quantity, cost, affordability, and logistics).

The analysis was conducted in two phases: the Front End Analysis and the Mix Analysis. The Front End Analysis was comprised of two distinct elements: Operational Framework

and Requirements Analysis and Examination of Potential Mixes. The Operational Framework and Requirements Analysis portion identified missions, Threat targets, and ultimately identified and prioritized precision munition usage against Threat mission profiles. Precision munition subject matter experts, representing many aspects of the precision munition community, contributed to this effort. The Examination of Potential Mixes identified versatile munitions for further consideration in the Mix Analysis portion of the study. Versatile precision munitions were defined as those deemed most capable of achieving effects across the spectrum of Threat mission profiles. The precision munitions termed "most versatile" included: Army Precision Kill Weapons System (APKWS) Block I, Common Smart Submunition (CSS), Excalibur (U), MRM, PAM, PGMM, GMLRS (U), GMLRS (D), Hellfire II and Hellfire Longbow, M2005 high explosive (HE) w/PGK, M549A1 HE w/PGK, and M864 dual purpose (DP) w/PGK.

CASTFOREM was the primary force-on-force simulation used in support of this analysis effort. The VIC combat simulation was also used to assess the sustainability and scalability of the precision mixes in corps- and division-level force-on-force analysis. VIC provided unit-based corps and division-level outcomes and CASTFOREM provided entity-based battalion and brigade-level outcomes. In addition to the force-on-force simulators, the PMMA employed several stand-alone engineering and performance models as well as optimization models.

Although the PMMA examined battles in five different scenarios, only two scenarios were used for this MRM analysis. The Caspian Sea FBCT Attack was used to investigate the effects of weather on precision munitions and the NEA 50.2 FCS Battalion (+) Attack scenario was the only scenario that provided for MRM/No MRM alternatives.

As described earlier, the PMMA was the principal study used in support of this analysis because many of its results were specifically and directly applicable to the MRM AoA. Specifically, the PMMA results provided the following insights into the conditions that affect the employment of MRM and other precision munitions:

- Tier 1, comprised of Excalibur (U), Hellfire, MRM, and GMLRS (U), provides the best mix of precision capability to support the HBCT and FBCT force within the operational environment in FY 14.
- Without MRM, Friendly forces engaged more and killed less targets within an urban environment due to ROE limitations.
- MRM engaged 98 percent of its targets from BLOS at an average range beyond that of the conventional main gun (4 kilometers).
- MRM's mission profile distribution was mainly focused on personnel in the urban environment. In the small percentage (3 percent) of heavy targets that MRM services, Hellfire from the ARV filled the gap in MRM's absence.
- The force was successful without MRM in the FBCT Battalion (+) Attack scenario because other precision munitions (i.e., Excalibur (U), PGK, and PGMM) increased fires to kill some of the MRM targets.

Appendix C. Resource Analysis

This appendix contains descriptions and details of the two basic elements of the resource analysis: Quantities (C.1) and Cost (C.2).

C.1 Quantities Analysis

As noted elsewhere, three quantity estimate methodologies were used: (1) *UBL Assessment Methodology,* (2) the *PMMA Quantity Methodology,* and (3) *DODI 3000.4 Quantity Methodology*. They were executed outside the normal Center for Army Analysis (CAA) quantity estimate processes due mainly to lack of time, the absence of QWARRM, and the need to present a range of quantities for the costs of MRM. The sections below document the assumptions and calculations of each of the quantity estimate methodologies.

C.1.1 UBL Quantity Estimate Methodology

MRM quantities are estimated utilizing strategic readiness quantities (MCS basic load schemes) for two resupply cases. The methodology complements PMMA and DODI 3000.4 quantity methodologies and identifies trade-offs between placing a number of MRM rounds on the MCS platform versus on the resupply vehicles. The most likely MCS distribution is the 14 MRM rounds with 11 MRM resupply rounds proposal, providing an 80 percent additional BLOS capacity carried on additional assets (table C-1). Table C-1 highlights the distribution between the onboard MRM and LOS (Advanced Multipurpose (AMP) and Advanced Kinetic Energy (AKE)) MCS rounds as a function of MRM, all restricted to 27 rounds. The following assumptions were utilized for the methodology:

- There are 15 proposed FBCT that require MRM.
- There are 60 MCS platforms in each FBCT.
- There are 14 MRM rounds onboard each MCS (Source: FBCT Logistic Force Design Structure Alternative).
- There are currently two proposed resupply distributions for the MCS:
  - 80 percent reload capacity = 11 resupply MRM rounds (Source: UAMBL).
  - 200 percent reload capacity = 28 resupply MRM rounds (Source: UAMBL).

Table C-1. MCS Proposed MRM Munition Distribution (Source: UAMBL)

	MRM-14	MRM-7	MRM-0
MRM (BLOS/LOS)	14	7	0
AMP	11	18	22
AKE	2	2	5
Total:	**27***		

**Distribution between the onboard MRM and LOS (AMP and AKE) MCS rounds as a function of MRM, all restricted to 27 rounds.*

A trade-off exists between placing MRM rounds on the MCS or on resupply vehicles and impacts the type of fires that the commander can execute (shaping, close support, and protective fires). As an example, the MCS with 10 onboard MRM rounds and 8 resupply rounds is equal in BLOS capacity to the MCS with 6 onboard MRM rounds and 12 resupply rounds. Figure C-1 illustrates the quantity and cost trade-offs associated with reducing the amount of MRM resupply capacity from 28 to 11 rounds while keeping 14 MRM rounds in the MCS. For the proposed 14 MRM MCS rounds, a reduction from 28 to 11 resupply rounds, resulted in a savings of 1,008 rounds per FBCT (15,120 rounds for 15 FBCT) and $36.8M per FBCT in FY07 ($552M for 15 FBCT). The quantities used in this methodology represent procurement quantities only; research, development, test and evaluation (RDTE) is not quantity related. Operations and maintenance (O&M) and demilitarization costs are included but are almost negligible.

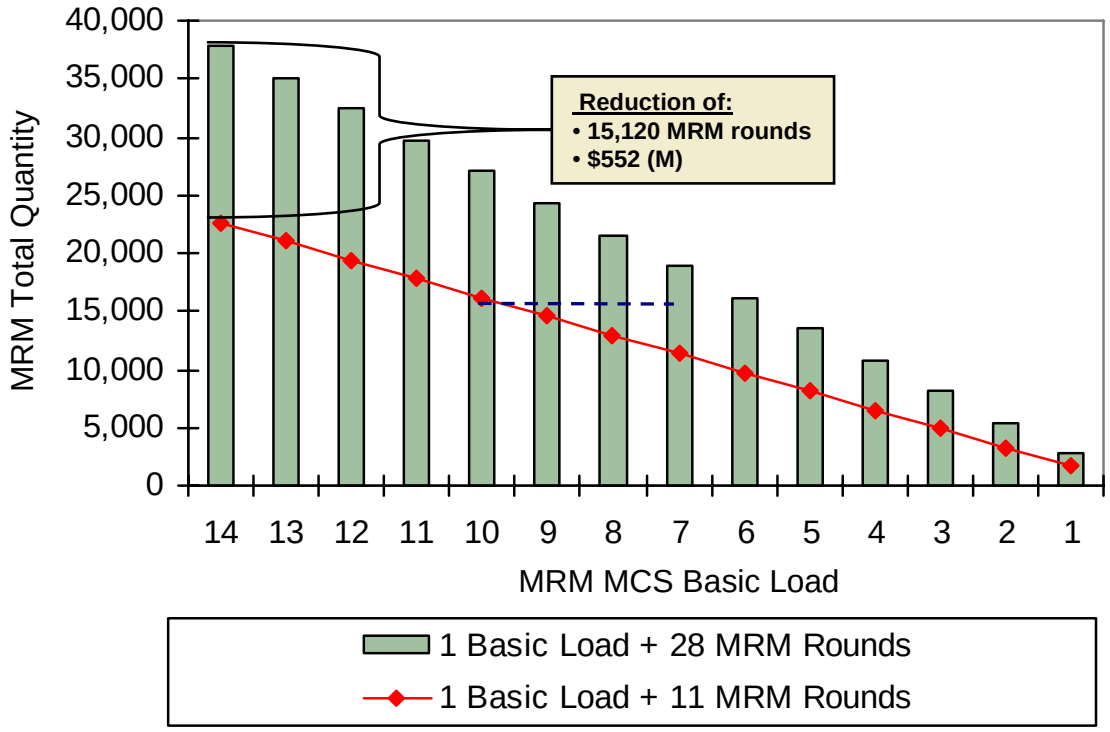

Figure C-1. MRM MCS and Resupply Quantity Estimates

C.1.2 PMMA Quantity Methodology

The PMMA quantity estimate methodology was created in order to forecast warfighting requirements.

It has the following limitations:

- Only less than brigade sized scenarios, representing individual tactical engagements, are available for MS C support.

- The MRM results contained here were produced with the full set of 12 Army precision munitions present within the brigade and below simulation results. MRM results within a smaller mix of Army precision munitions may vary.

The PMMA Quantity Methodology utilizes the following assumptions:

- Quantity estimates based upon the brigade and below scenario (BBS) results are adequate to inform MS B decision points and to estimate MRM costs.
- Zeroing, functional checks, or round registration were not addressed.
- MCS or resupply vehicle rounds lost from tactical engagements were not addressed.
- Brigade/battalion scenarios (Defense Planning Guidance (DPG)-compliant) are scalable to the MCO level and adequately represent MRM operational requirements for conducting the MCO fight.
- An MCO consists of six equivalent division fights and the same division may fight multiple fights that, for the purpose of the calculation, are assumed to be exact. Each division has four tactical FBCTs and each FBCT has three tactical battalions.
- An LCO consists of two dismounted FCS-equipped battalions as part of a Joint forcible entry operation.
- Phased Threat Distribution (PTD), at the Strike Unfavorable Out Year level, was used to represent degraded (e.g., weather, battlefield conditions, platform availability, etc.) battlefield conditions, which results in more targets being defeated by maneuver forces.
- The Army engages 25 percent of Threat personnel to achieve mission success.

Figure C-2 illustrates the three distinct cases and the various inputs using the PMMA quantity methodology. Two of these (Cases 1 and 3) utilized BBS results from the PMMA study to calculate quantities for one and two MCOs with six LCOs. Cases 1 and 3 represent straightforward calculations by scaling the battalion results from NEA 50.2 to MCO and LCO levels. The requirement for two MCOs is based on the ASPG (2006-2023), which calls for two near simultaneous major conflicts and a limited number of LCOs. Case 3 reflects the needs for one MCO and six LCOs. MRM quantities were calculated in the same manner as Case 1 with the exception of excluding one MCO. The required quantity for a single division was 2,712 MRM rounds. The required quantity for a LCO was 19 MRM rounds.

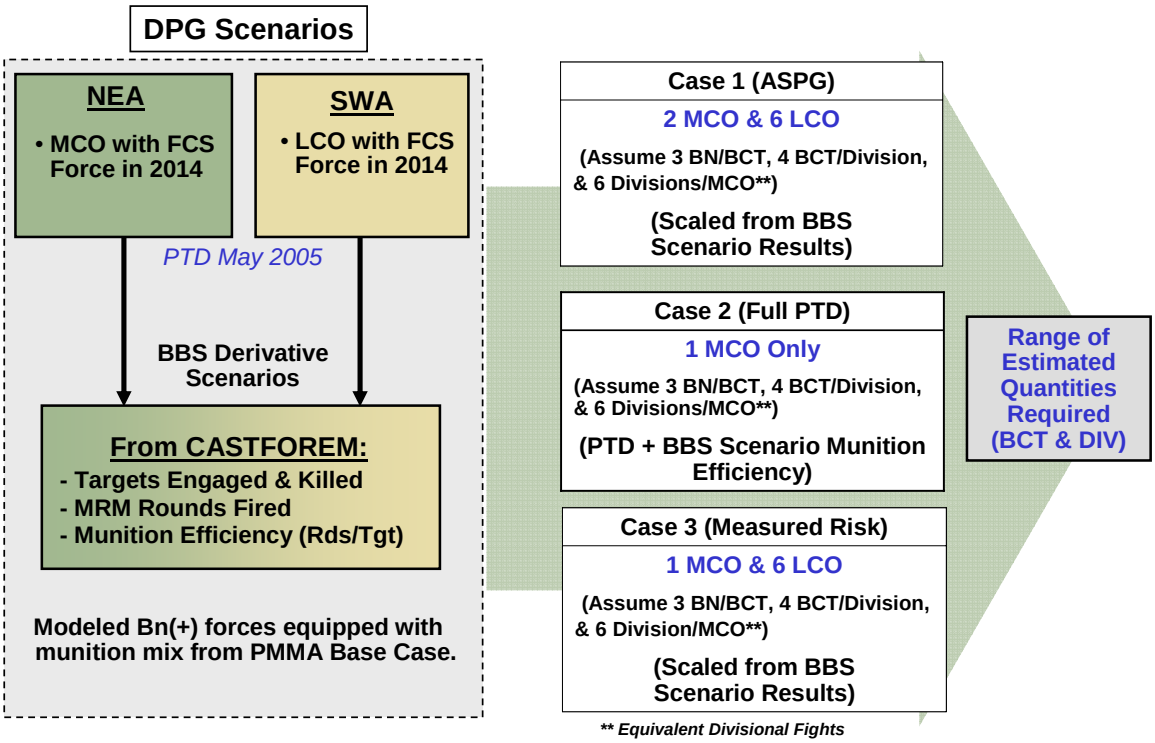

Figure C-2. PMMA Quantity Estimate Methodology

Case 2 was calculated using the PTD that is managed by J-8. The PTD incorporates operational objectives against targets and allocates those targets to each service and coalition forces for an MCO. Case 2 reflects the requirement for only one MCO and is comprised of three parts:

- Determine the Army maneuver distribution assigned by the PTD.
- Determine the potential Threat targets appropriate for MRM within the Army allocated distribution.
- Determine the efficiency of MRM (rounds per kill) from the force-on-force simulation (NEA 50.2) to estimate the number of rounds required to kill the potential targets assigned to MRM.

Table C-2. PMMA Methodology Estimated Case 2 MRM Requirements

Reference	Calculation Categories	MCO Quantities	Targets/ Division	Targets/ FBCT
A	*Total Targets* (Based on MCOX1 OY PTD)	5,863,110 (144,894 + 5,718,216)		
B	*Army Targets (1.47%)* (86,208 / 5,863,110 = 1.47%) (Based on MCOX1 OY PTD)	39,664 (24,149 + (62,059 x 25%))		
C	*MRM Total Targets (17%)* (6,670 / 39,664 = 17%) (Based on MCOX1 OY PTD)	6,670 (690 + 62,059) x 25% x 38%		
D	*Army Targets Targeted* (Extrapolated from FBCT)	33,384 (6 x 5,564)	5,564 (4 x 1,391)	1,391 (1,165+226)
E	*MRM Targets (16%)* (226/1391 = 16%) (Targeted, extrapolated from FBCT)	6,024 (6 x 1,004)	1,004 (4 x 251)	251 (uniquely targeted)
F	*MRM Rounds* (Extrapolation from targeted at FBCT, 3.48 average efficiency from FBCT)	20,964 (6,024 x 3.48) 24,903	3,494 (1,004 x 3.48)	873 (251 x 3.48)

Table C-2 provides a summary of PMMA Case 2 calculations. The reference notes are as follows:

Reference A. Total *theater* targets assigned in the 2006 MCOX1 out year (OY) PTD.

Reference B. Total *Army* targets assigned in the 2006 MCOX1 OY PTD. Army is allocated a small percentage (1.47 percent) equating to 24,149 systems and 62,059 personnel targets. The Army engages 25 percent of Threat personnel (62,059) to achieve mission success (assumption).

Reference C. Total *MRM* targets determined as appropriate Threat targets within the PTD. MRM can engage 17 percent of the Threat targets within the Army's allocation distribution equating to 690 systems and 62,059 personnel targets. MRM engages 38 percent of Threat personnel in which precision munitions were used based on BBS results.

Reference D. There were 1,391 targets engaged by the FBCT in the NEA 50.2 scenario (226 were engaged by MRM, 1,165 engaged by other precision munitions) equating to 1,391 total targets. This translates into 33,384 total Army targets (six divisional fights with 4 for BCTs per division). There remain 6,280 (39,664 - 33,384) Army targets that are not assigned to any FBCT system {Difference between Reference B and Reference D}.

Reference E. MRM engaged 16 percent of all FBCT targets equating to 6,024 using the same scaling assumption in Reference D.

Reference F. MRM efficiency in the BBS results was 3.48 rounds per kill. MRM may engage 1,005 (16 percent of 6,280 (Reference D)) additional targets resulting in 3,919 (1,005 x 3.90) additional rounds required. Therefore, the total MRM

requirement is 24,903 (20,984 + 3,919) for the PMMA quantity methodology Case 2 is 24,903.

Table C-3 identifies the MRM quantity estimates for all three cases:

Table C-3. PMMA Methodology Three Case Summary

	Case 1 (ASPG)	Case 2 (Full PTD)	Case 3 (Measured Risk)
MRM Ammunition Force Requirements	2 MCO + 6 LCO (Scaled from BBS Scenario Results)	1 MCO Only (PTD + BBS Scenario Munition Efficiency)	1 MCO + 6 LCO (Scaled from BBS Scenario Results)
FCS-equipped Force MRM Totals	32,633	24,903	16,375

C.1.3 DODI 3000.4 Quantity Estimate Methodology

This methodology provides guidance to warfighting combatant commanders to allocate targets to each military service and allied forces in order to generate munition requirements.

For this study, DODI MRM quantities were estimated utilizing BBS results with assigned targets from the PTD for MRM (exactly as in the PMMA quantity methodology) and generated to distinct cases. The methodology incorporated munition performance, enemy reconstitution data, stockpile requirements, munition losses from BBS results, and MRM basic load estimates. Additionally, the following assumptions were used:

- Brigade battalion scenarios are scalable to the MCO level and adequately represent MRM operational requirements for conducting the MCO fight.
- Army targets 25 percent of the total allocated Threat personnel quantities from the PTD and engages 10 percent of total Threat personnel quantity.
- An additional 6 percent MRM rounds required due to combat losses in the battalion fight.
- Enemy forces have a reconstitution percentage based on area of operations (32 percent for NEA and 0 percent for SWA) (Source: Fort Sill).
- There are 14 MRM rounds onboard each MCS (Source: UBL quantity methodology).
- There are 11 MRM resupply rounds per MCS (Source: UBL quantity methodology).

Case 1 was extrapolated directly from the BBS simulation results and follows the guidance contained in the DODI 3000.4, as well as the assumptions listed above. Case 1 does not include resupply quantities and the calculated quantity of MRM rounds (19,404) is slightly higher than Case 2 under the PMMA method due to added quantities based on combat losses and enemy reconstitution factors. The DODI Case 1 quantity fills the requirement to conduct one MCO and six LCOs.

Case 2 was calculated in a similar fashion, except that it included additional resupply requirement of 28 MRM rounds per MCS. This reflects the requirement to conduct at least

one MCO and six LCOs but less than the requirement to execute the ASPG. Case 2 provides a residual capacity beyond the one MCO and six LCOs of 56 percent (13,109 MRM rounds) that may be used to conduct a second MCO with measured risk.

C.1.4 Quantity Analysis Summary

Figure C-3 provides a summary of the seven quantity estimate cases generated using the three estimating methodologies, bound into low-, medium- and high-risk categories:

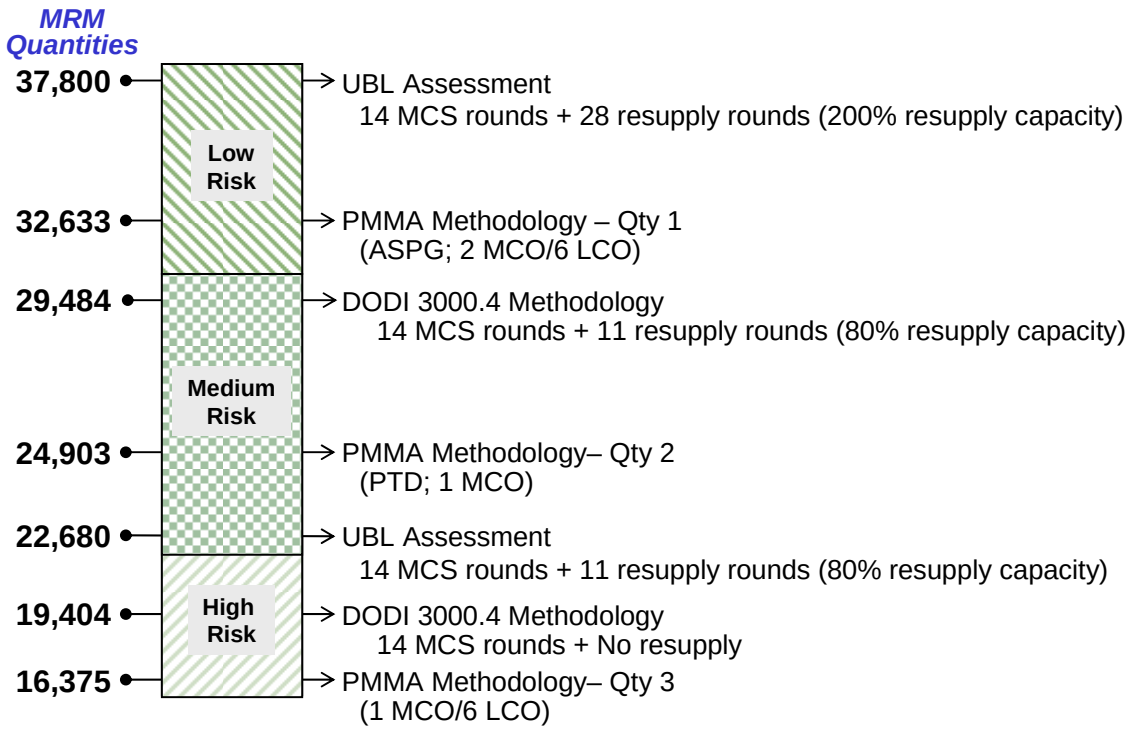

Figure C-3. Quantity Estimates Summary

- The low-risk category assumes the commitment to conduct two MCOs and six LCOs to meet the ASPG.
- The medium-risk category assumes only one MCO divisional fight, along with additional requirements to engage additional Threat to meet operational objectives; however, it falls short to meet the ASPG.
- The high-risk group allows the force to conduct one MCO and at least one LCO with a maximum of six LCOs.

C.2 Cost Analysis

The fundamental objective of the Cost Analysis was to determine the LCCs of each alternative. The following sections describe the assumptions, calculations, and coordination documentation used in the Cost Analysis effort. All cost estimates assume that the MCS fires the full capable (tri-mode seeker) MRM round (Source: Project Manager - Maneuver Acquisition Systems - Large Scale (PM MAS-LC).

C.2.1 Methodology

The Cost Analysis methodology included a literature search of previous MRM cost efforts (i.e., PMMA) and coordination with the agencies listed below. The methodology is described in four parts (coordination, cost inputs, cost model utilization, and results).

Coordination

- G-3, Office of the Deputy Chief of Staff for Operations and Plans (ODCSOPS)
  - Point of Contact: Mr. Bruce Miller (703-692-7802).
  - Responsibilities: Develops and coordinates resources and plans based on the Army missions.
- G-8, HQDA, Force Development Analysis
  - Point of Contact: Mr. Benjamin Blas (703-602-2487) or Ms. Myrna Kroh (703-602-3256).
  - Responsibilities: Provides programming, analysis, and assessment of resources for equipping the Army.
- DASA-CE
  - Point of Contact: Mr. Randy Wilson (703-601-4140).
  - Responsibilities: Provides oversight of the cost portion of the MRM AoA. DASA-CE reviews, provides guidance on the cost methodology used in the AoA, and accesses the fidelity of cost inputs.
- PM MAS-LC
  - Point of Contact: Mr. Carl Roller (973-724-2648).
  - Responsibilities: Provides program plans, MRM cost estimating relationships (CER), and the ACEIT cost model.

Inputs. The cost analysis utilized inputs from the MRM quantity analysis (seven cases) to determine procurement costs. Additional logistics cost requirements (i.e., personnel costs) were not included in the estimates since no additional requirements were identified in the logistical impact analysis. LCC estimates consist of RDTE, procurement, 20-year O&M, and demilitarization costs.

Cost Model Utilization. The cost analysis utilized the ACEIT cost model provided by PM MAS-LC for the MRM program. The model contained cost factors, CER, and complexity factors. The ACEIT model represented MRM time-phased program costs over the life cycle, from development and procurement through O&M (20 years) and demilitarization. Note that the foundation of many of the components within the ACEIT cost model are based on JCM cost estimates generated by DASA-CE (2006).

Results

- The high-risk quantity with MMW seeker technology is approximately equal to the low-risk quantity without an MMW seeker; this is due to the seeker technology comprising nearly 60 percent of the munitions' total cost.
- Costs were expressed in FY07 constant dollars (table C-4) and current dollars (table C-5) for the full capable MRM round with tri-mode seeker. Costs will be adjusted if a dual-mode or single-mode concept is considered for the MRM round. The constant dollar estimates normalize costs in FY07 base-year dollars and enables a comparison across alternatives with different production and 20-year O&M schedules.
- The current dollar estimates include the impact of inflation over time and are calculated by applying specific inflator factors for RDTE, procurement, and O&M costs. Current dollar estimated costs are appropriate for affordability assessments conducted by G-8. Tables C-4 and C-5 provide the total cost estimates for each category and the AUPC based on the generated quantity.

Table C-4. FY07 Constant Dollars ($M) for MRM Quantity Alternatives

Quantity Estimates	37,800	32,633	29,484	24,903	22,680	19,404	16,375
RDTE	$274.4	$274.4	$274.4	$274.4	$274.4	$274.4	$274.4
Procurement	$1,782.1	$1,594.3	$1,509.0	$1,329.9	$1,235.5	$1,094.9	$959.7
Military Personnel	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
O&M	$34.8	$34.6	$33.7	$33.5	$32.2	$30.9	$29.6
Demilitarization	$6.8	$6.0	$5.6	$5.0	$4.6	$4.2	$3.7
Total	**$2,098.2**	**$1,909.3**	**$1,822.8**	**$1,642.8**	**$1,546.8**	**$1,404.4**	**$1,267.4**
AUPC ($K)	$47.1	$48.9	$51.2	$53.4	$54.5	$56.4	$58.6

Table C-5. Current Dollars ($M) for MRM Quantity Alternatives

Quantity Estimates	37,800	32,633	29,484	24,903	22,680	19,404	16,375
RDTE	$299.90	$299.90	$299.90	$299.90	$299.90	$299.90	$299.90
Procurement	$2,411.50	$2,141.40	$1,960.90	$1,710.80	$1,577.90	$1,382.60	$1,199.20
Military Personnel	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
O&M	$58.70	$58.40	$55.50	$55.20	$52.50	$49.70	$47.00
Demilitarization	$15.70	$14.00	$12.70	$11.20	$10.20	$9.00	$7.90
Total	**$2,785.80**	**$2,513.70**	**$2,329.00**	**$2,077.10**	**$1,940.50**	**$1,741.20**	**$1,554.00**
AUPC ($K)	$63.8	$65.6	$66.5	$68.7	$69.6	$71.3	$73.2

Acronyms

24T	24-Ton

A	
ACEIT	Automated Cost Estimating Integrated Tools
ADA	air defense artillery
AKE	advanced kinetic energy
AMP	advanced multipurpose
AO	area of operations
AoA	analysis of alternatives
APKWS	Advanced Precision Kill Weapons System
APM	Army Precision Munitions
ARCIC	Army Capabilities Integration Center
ARL	Army Research Laboratory
ARV	armed robotic vehicle
ASPG	Army strategic planning guidance
AUPC	average unit production cost

B	
BBS	brigade and below scenario
BCT	brigade combat team
BLOS	beyond line of sight
BN	battalion
BSB	brigade support battalion

C	
C2	command and control
CAA	Center for Army Analysis
CAB	combined arms battalion
CASCOM	Combined Arms Support Command
CASTFOREM	Combined Arms and Support Task Force Evaluation Model
CDD	capabilities development document
CE	chemical energy
CER	cost estimating relationship
CLA	constraints, limitations, and assumptions
CRO	combat replenishment operations
CSS	Common Smart Submunition

D	
DASA-CE	Assistant Secretary of the Army for Cost and Economics
DCB	design concept baseline
DODI	Department of Defense Instruction
DP	dual-purpose
DPG	defense planning guidance

E	
EAB	echelon above brigade
EFOGM	enhanced fiber optic guided missile

F	
FBCT	Future Combat Systems brigade combat team
FCS	Future Combat Systems
FDA	force development analysis
FE	force effectiveness
FOTT	follow-on to TOW
FY	fiscal year

G	
GMLRS	Guided Multiple Launch Rocket System
GPS	global positioning system

H	
HBCT	heavy brigade combat team
HE	high explosive
HIMARS	High Mobility Artillery Rocket System
HPT	high-payoff target
HQDA	Headquarters, Department of the Army
HRS	high resolution scenario

I	
IIR	imaging infrared
IP	integrated process

J	
JCATS	Joint Conflict and Tactical Simulation
JCIDS	Joint Capabilities Integration and Development System
JCM	joint common missile
JSF	Joint Strike Fighter
JVB	Joint Virtual Battlespace

K	
KE	kinetic energy
KPP	key performance parameters

L	
LCC	life cycle cost
LCO	lesser contingency operation
LOS	line of sight
LSI	Lead Systems Integrator

M	
MCO	major contingency operation
MCS	mounted combat system
METT-TC	mission, enemy, tactics, terrain - time and civilians
MFR	memorandum for record
MGV	manned ground vehicle
mm	millimeter
MMW	millimeter wave
ModSAF	modular semiautomated forces
MRM	mid-range munition
MS	milestone
MULE-T	multifunction utility/logistics equipment transport

N	
NEA	Northeast Asia
NLOS	non-line of sight
NLOS-C	non-line of sight cannon

O	
O&M	operations and maintenance
O&O	operational and organizational
ODCSOPS	Office of the Deputy Chief of Staff for Operations
ORD	Operational Requirements Document
OSD	Office of the Secretary of Defense
OY	out year

P	
PAM	precision attack munition
PGK	precision guidance kit
PGMM	precision guided mortar munition
PM MAS-LC	Project Manager -Maneuver Ammunition Systems - Large Caliber
PMMA	precision munitions mix analysis
PMR	Precision Munitions Review
PTD	phased threat distribution

Q	
Qty	quantity
QWARRM	Quantitative War Reserve Requirements - Munitions

R	
RDT&E	research, development, test, and evaluation
ROE	rules of engagement

S	
SAL	semiactive laser
SBCT	Stryker brigade combat team
SEP	system enhancement program
SWA	Southwest Asia

T	
TERM	tank extended range munition
TMDE	test, measurement, and diagnostic equipment
TRAC	TRADOC Analysis Center
TRAC-WSMR	TRADOC Analysis Center-White Sands Missile Range
TRADOC	Training and Doctrine Command
TRL	technology readiness level

U	
U	unitary
UAMBL	Unit of Action Maneuver Battle Lab
UAS	unmanned aerial system
UBL	unit basic load
UGV	unmanned ground vehicle
URS	unit reference sheet
USAIC	United States Army Infantry Center

V	
VIC	Vector-in-Commander

Coordinated Initial Distribution List
SUBJECT: Mid-Range Munition Analysis of Alternatives

1. Upon study sponsor (ARCIC) receipt of the Mid-Range Munition (MRM) Analysis of Alternatives (AoA), the TRADOC Analysis Center (TRAC) will distribute the document, TRAC-W-TR-07-028, 23 May 2007, in electronic or compact disc (CD) medium to the following organizations and offices:

a. Director, Unit of Action Maneuver Battle Lab, ATTN: ATZK-UAE (LTC O'Donnell), Brandenburg Station Road, Fort Knox, KY 40121.

b. Deputy Assistant Secretary of the Army for Cost and Economics, ATTN: SAFM-CEA-W (Mr. Randy Wilson), 109 Army Pentagon, Room 3E352, Washington, DC 20310-0109.

c. Headquarters, US Army G-8, Warfighting Analysis Division, ATTN: DAPR-FDA (Mr. Benjamin Blas), 700 Army Pentagon, Washington, DC 20310-0700.

2. Refer all subsequent requests for the MRM AoA final report to TRAC HQ, Programs Division, (913) 684-5511 (DSN: 552).