



**U.S. Army Research Institute  
for the Behavioral and Social Sciences**

**Research Report 1804**

**Using the Laser Marksmanship Training System  
to Predict Rifle Marksmanship Qualification**

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**May 2003**

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**U.S. Army Research Institute  
for the Behavioral and Social Sciences**

**A Directorate of the U.S. Total Army Personnel Command**

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## FOREWORD

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The United States Army Reserve (USAR) is looking for more effective and efficient ways to train and evaluate rifle marksmanship through the use of simulation devices. To this end, and at the request of the U.S. Army Reserve Command (USARC), the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) has been working with the USAR's 84th Institutional Training Division (DIVIT) and Small Arms Readiness Group (SARG) to develop and evaluate a simulation-based (i.e., the Beamhit™ Laser Marksmanship Training System [LMTS]) training and evaluation program for use at home station (i.e., reserve centers). The common goal of this cooperative effort is to field a program that will produce marksmanship proficiency levels that meet or exceed unit readiness requirements while minimizing the resources needed to do so.

To date, a Program of Instruction (POI) has been developed to cover the use of LMTS in training rifle marksmanship fundamentals (e.g., steady position, aiming, breath control, and trigger squeeze). A necessary step in the implementation of this POI is to determine the relation between LMTS- and live-fire-based marksmanship performance and, if found to be of sufficient magnitude, develop tools for trainers to use in predicting the latter from the former. This report describes research conducted to assess this relation and then develop separate tools for predicting Army standard pop-up target qualification course scores from LMTS dry vs. Blazer-based modes of fire.

This research was conducted by the ARI-Reserve Component Training Research Unit, whose mission is to improve the effectiveness and efficiency of Reserve Component (RC) training through use of the latest in training technology. This research is supported under Work Package 219, "Strategies and Tools for Maximizing AC/RC Unit Performance," of ARI's Science and Technology Program for Fiscal Year 2002.

This research was sponsored by USARC under a continuing Memorandum of Understanding initially signed 12 June 1985. Findings have been presented to the Weapons Program Administrator, USARC; and Deputy Chief of Staff for Operations, 84th DIVIT, USAR.

  
KATHLEEN A. QUINKERT  
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# USING THE LASER MARKSMANSHIP TRAINING SYSTEM TO PREDICT RIFLE MARKSMANSHIP QUALIFICATION

## EXECUTIVE SUMMARY

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### Research Requirement:

To develop Laser Marksmanship Training System (LMTS) dry-fire- and Blazer-Based (i.e., sound/recoil replicator) tools for predicting first-run rifle marksmanship performance on the Army's standard, pop-up target qualification course.

### Procedure:

A total of 186 Idaho and Oregon Reserve Component (RC) soldiers fired for qualification on a scaled LMTS version and live-fire version of the Army's standard pop-up target qualification course. LMTS was fired under either a dry-fire mode, where shooters had to manually cock their rifles after firing each laser round, or a Blazer mode, where nonpolluting blanks provided the recoil and noise associated with live rounds. Separate regression analyses were performed to identify the relation between live-fire scores and those obtained under the two LMTS firing modes. The identified relations were then used to develop separate LMTS-based tools for predicting the probability of soldier live-fire qualification.

### Findings:

Statistically significant positive linear relations were found (and then validated) between first-run live-fire scores and both LMTS dry-fire- ( $r = .50$ ) and Blazer-based ( $r = .55$ ) scores. These relations were of sufficient strength to permit development of easy-to-use tools for predicting first-run, live-fire qualification with up to 90% confidence using the former and with up to 80% confidence using the latter.

### Use of Findings:

With these tools, RC marksmanship trainers can implement a competency-based training program where soldiers most in need of remedial training (i.e., poor shooters) can be quickly identified, and the point at which sufficient training has been provided (i.e., when first-run live-fire qualification is likely) easily determined. These tools also provide RC unit commanders with empirically derived live-fire performance standards needed to support use of LMTS in place of live-fire for rifle marksmanship proficiency validation purposes when standard pop-up target course range facilities are not readily available. Although both tools will serve these purposes, that based on LMTS dry-fire is recommended because of the added expense of firing with Blazer without an accompanying statistically significant increased predictive benefit.

# USING THE LASER MARKSMANSHIP TRAINING SYSTEM TO PREDICT RIFLE MARKSMANSHIP QUALIFICATION

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# Using the Laser Marksmanship Training System to Predict Rifle Marksmanship Qualification

## Introduction

Tightening budgets, escalating ammunition costs, dwindling numbers of certified live-fire ranges, and ever-present training time constraints have prompted the U.S. Army Reserve (USAR) to search for alternative ways to train and evaluate rifle marksmanship through the use of simulation. To this end, the U.S. Army Research Institute (ARI) has been working in partnership with the U.S. Army Reserve Command's marksmanship executive agent, the 84<sup>th</sup> Division (Institutional Training), to develop and evaluate a simulation-based rifle marksmanship sustainment training program designed for use at home station. The goal of this effort is to produce shooter proficiency levels that meet, or beat, unit readiness requirements while minimizing the time and ammunition needed to do so (Plewes, 1997, November 24).

The envisioned program of marksmanship instruction (POI) calls for use of the Laser Marksmanship Training System (LMTS) (BeamHit, 1999; Dunlin, 1999, January-February) to support (a) the training of marksmanship fundamentals (i.e., steady position, aiming, breath control, and trigger squeeze), shot grouping/weapon zeroing practice, and simulated record fire evaluation, (b) competency-based exercise delivery where LMTS-based pretesting is used to predict which soldiers need training (i.e., unlikely live-fire qualifiers) and posttesting is used to signal when enough such training has been provided (i.e., once live-fire qualification becomes likely), and (c) use of LMTS-based testing to validate live-fire qualification status when range facilities are not readily available.

The POI exercises devoted to training marksmanship fundamentals have been completed and published in Appendix C of the coordinating draft of Field Manual (FM) 3.22.9 (23-9) "Rifle Marksmanship M16A1, M16A2/3, M16A4, and M4 Carbine" (Headquarters, Department of the Army, 2001, August). In addition, an LMTS-based, live-fire prediction tool has been developed to provide unit commanders with the needed yardstick upon which to base pre- and posttesting, as well as validate live-fire qualification status. Current predictions only apply, however, to scores fired on the Army's 25m Alternate Qualification Course (ALT C) where shooters fire at stationary paper targets containing E- and F-Type silhouettes scaled to represent known down-range distances of from 50-300m (e.g., Headquarters, Department of the Army, 1989; Smith & Hagman, 2000).

Although most USAR soldiers typically fire for qualification on ALT C because of its limited space and instrumentation requirements, firing on the Army's standard pop-up target qualification course, often accomplished using a Remote Electronic Target System (RETS), is preferred whenever possible because of its demand for a greater array of combat-related marksmanship skills (e.g., target acquisition). To produce a corresponding demand for these skills during simulation-based qualification firing, BeamHit (2002) has developed an LMTS-based, pop-up target qualification course called "mini-RETS." Research, similar to that completed with ALT-C, is therefore needed to determine what the relation is between simulated and live-fire pop-up target course performance and whether predictions of the latter from the

former are accurate enough to support LMTS-based pretesting, posttesting, and a record fire qualification/validation alternative to live fire.

Current live-fire predictions are also based on an LMTS dry-fire mode of target engagement where shooters manually cock their weapons before firing each simulated (i.e., laser) round. To add realism to this firing experience, and potentially boost predictive accuracy above that associated with dry fire, a recoil and sound replicator enhancement to LMTS, called the Blazer, has been developed by the device's manufacturer. The Blazer provides a dry-fire alternative that captures fully simulated live-fire functionality, using nonpolluting blanks in place of live ammunition, with nearly 100% of the associated recoil and 50% of the noise.

The question is whether this added capability results in better live-fire predictive accuracy than that achieved under dry fire. Research is needed, therefore, to identify the relation between Blazer- and live-fire-based performance, develop and validate a Blazer-based tool for predicting the latter from the former for the Army's standard pop-up target qualification course, and compare the relative accuracy of Blazer- vs. dry-fire-based predictions. The present research provides this information.

### Experiment 1

This experiment examined the relation between LMTS-based, dry-fire scores fired on mini-RETS and live-fire scores fired on an Army-certified, pop-up target qualification course. Experiment 2 examined the relation between Blazer-based and live-fire scores.

### *Method*

#### *Participants*

One-hundred and ten soldiers from an Idaho Army National Guard armored cavalry brigade support battalion voluntarily participated in the research as part of yearly rifle qualification firing at Orchard Range near Boise, Idaho. None of the participants had prior experience firing LMTS.

#### *Equipment*

LMTS is a laser-emitting device, designed primarily for indoor use, which enables soldiers to engage targets without the use of live ammunition. Its major components include a laser transmitter, a mandrel to which the transmitter is attached/aligned, a variety of laser-sensitive targets, and a dedicated computer with optional printer (Figure 1). One end of the mandrel holds the laser transmitter while the other end slips into the barrel of the weapon. Vibrations from the weapon's mechanical firing mechanism activate the laser when the trigger is pulled and the location of the emitted beam is "picked up" by the laser-sensitive target(s) and recorded/stored on the computer for future analysis and printout. Soldiers can shoot with LMTS under a dry-fire mode using their own weapons, or they can replace the upper receiver assembly with the Blazer (Figure 2) to enable weapon bolt and ejector mechanisms to function with nontoxic blank ammunition. In this first experiment, soldiers dry fired their own M16A2 weapons on the scaled 15m LMTS mini-RETS pop-up target qualification course shown in Figure 3.

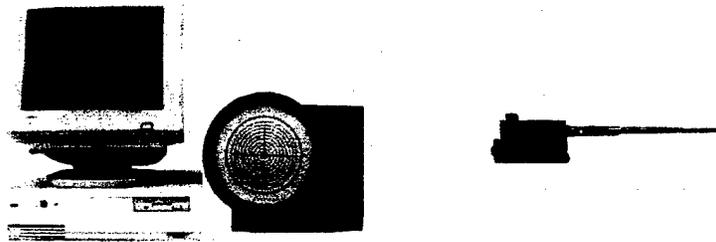


Figure 1. LMTS computer/monitor, sample electronic target, and laser transmitter with attached mandrel.

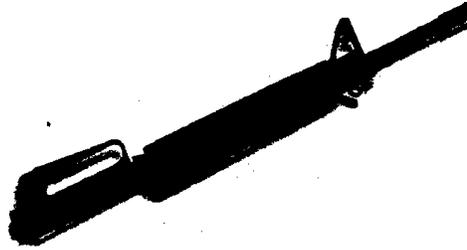


Figure 2. LMTS Blazer.



Figure 3. Soldier firing on the 15m LMTS mini-RETS range.

### *Procedure*

To control for possible sequence affects, approximately half the soldiers fired for live-fire qualification first and LMTS-based qualification second. The other half fired this sequence in reverse, with no more than 24 hr occurring between the two firings under either sequence.

*Live-Fire qualification.* Dedicated cadre from the Idaho Army National Guard conducted all range-based qualification firing in accordance with procedures stipulated in FM 23-9 (Headquarters, Department of the Army, 1989) with shot grouping and weapon zeroing accomplished immediately beforehand. All pop-up targets were automatically presented and scored. Hit numbers associated with specific shooting classifications were as follows: 0-22, Unqualified; 23-29, Marksman; 30-35, Sharpshooter; 36-40 Expert. All statistical analyses were

based on first-run hit scores (i.e., the number of targets hit, out of a possible 40, on the soldiers' first qualification attempt).

*LMTS-Based qualification.* Simulated qualification firing with LMTS was conducted indoors by dedicated cadre from the USAR's 84<sup>th</sup> Division and Small Arms Readiness Group who followed the same procedures as those associated with live fire (Headquarters, Department of the Army, 1989). LMTS was fired in a dry-fire mode that required soldiers to use their firing hand to manually cock their weapons after each round by recycling the charging handle located at the rear of the upper receiver assembly. All LMTS targets were presented and scored automatically.

### *Analytic Approach*

To determine the relation between LMTS- and live-fire-based qualification scores, a split-group, cross-validation design was used (Tatsuoka, 1969). The initial sample of 110 soldiers was randomly divided into two groups. Group 1 was used to develop a prediction equation between device and live-fire scores. This equation was then applied to Group 2 soldiers to see if their live-fire scores could be predicted successfully from the equation derived from Group 1 data.

### *Results*

#### *Group 1 Data (n = 55)*

For Group 1, LMTS hit scores ranged from 7 to 39 ( $M = 27.8$ ,  $SD = 7.7$ ). Live-Fire hit scores ranged from 10 to 37 ( $M = 27.5$ ,  $SD = 5.8$ ). A paired-samples *t*-test revealed that the mean hit scores for the two firing methods did not differ significantly. The rejection region for this and all other statistical analyses was .05.

A least-squares regression prediction equation of the form  $Y' = B_0 + B_1(X_1)$  was developed in which  $Y'$  was the predicted live-fire criterion score,  $B_0$  was the intercept (or theoretical live-fire score when the LMTS score equals zero),  $B_1$  was the empirically derived regression coefficient linking changes in the live-fire criterion variable with changes in the LMTS predictor variable, and  $X_1$  was the obtained LMTS first-run qualification score. A significant linear relation,  $Y' = 16.485 + .395(X_1)$ ,  $SE = 2.55$  was found between LMTS and live-fire performance,  $F(1, 53) = 19.96$ . In addition, the correlation between predicted and actual live-fire scores was significant ( $r = .52$ ). Thus, Group 1 LMTS scores were both linearly related to, and reasonably good predictors of, live-fire scores.

#### *Group 2 Data (n = 55)*

For Group 2, LMTS scores ranged from 3 to 39 ( $M = 28.4$ ,  $SD = 7.5$ ). Live-fire scores ranged from 8 to 39 ( $M = 26.9$ ,  $SD = 5.9$ ). As with Group 1, Group 2 mean LMTS and live-fire scores did not differ significantly.

Following cross-validation procedures described by Tatsuoka (1969), the Group 1 regression equation was used to predict Group 2 live-fire scores, and then the relative amount of variance

accounted for in each group was compared. A significant linear relation,  $Y' = .145 + .966(X_1$  [predicted]),  $SE = 6.56$ , was found between actual live-fire scores and live-fire scores predicted from the equation based on Group 1 data,  $F(1, 53) = 16.33$ . The resulting correlation ( $r = .49$ ) was significant, and the associated Group 2  $R^2$  of .236 did not differ significantly ( $z = .267$ ) from the  $R^2$  of .274 found for Group 1, indicating that the Group 1 prediction equation accounted for a comparable amount of live-fire score variance in the two groups. Thus, the predictive model was found to be valid and, therefore, likely to maintain similar efficiency when used to predict live-fire scores of other soldier samples.

#### *Pooled Data (N = 110)*

The significant linear relation found among Group 1 soldiers was successfully cross-validated on Group 2. Given the similar outcomes from these two analyses, and the generalizability of the preliminary model based on only half the sample, data from the two groups were pooled in order to develop the best possible live-fire predictions.

*Order effects.* Approximately half the soldiers fired LMTS first and then live fired. For the other soldiers, this sequence was reversed. Both LMTS and live-fire scores were examined to determine if they had been affected by firing order. In neither case was there a significant effect. Therefore, no further mention of firing order will be made.

*Descriptives and mean differences.* LMTS scores ranged from 3 to 39 ( $M = 28.1$ ,  $SD = 7.5$ ). The minimum qualification score of 23 was achieved on LMTS by 80.9% of soldiers on their first qualification attempt (Q1). Live-fire scores ranged from 8 to 39 ( $M = 27.2$ ,  $SD = 5.8$ ) with ninety-five of the soldiers (86.4%) achieving live-fire Q1. A paired-samples  $t$ -test revealed that live-fire and LMTS mean scores did not differ significantly.

*Prediction model.* A least-squares regression analysis revealed a significant linear relation,  $F(1, 108) = 36.29$ , between the predictor variable (LMTS score) and the criterion variable (live-fire score). The correlation ( $r = .50$ ) between LMTS and live-fire fire scores was significant, with the former accounting for about a fourth of the variance in the latter ( $R^2 = .25$ ; adjusted  $R^2 = .24$ ). The prediction equation took the form  $Y' = 16.323 + .387(X_1)$ ,  $SE = 1.87$ , where  $Y' =$  predicted live-fire score,  $X_1 =$  LMTS score, and  $SE =$  standard error of the prediction.

For this obtained relation to be of practical value, it should allow marksmanship trainers to predict live-fire qualification scores/probabilities based on LMTS dry-fire performance. Specifically, trainers need to know what levels of LMTS performance are associated with live-fire cut scores of 23 (Marksman), 30 (Sharpshooter) and 36 (Expert). To determine the LMTS score associated with these scores, we took the pooled data prediction equation,

$$Y' = 16.323 + .387(X_1)$$

substituted the desired live-fire cut score for  $Y'$ , and solved for the required score on LMTS. Thus, to determine the LMTS score associated with a live-fire score of 23, we found:

$$23 = 16.323 + .387(X_1)$$

$$6.68 = .387(X_1)$$

$$(X_1) = 17.25$$

Soldiers with an LMTS score of 17 will, on average, obtain a live-fire score of 23, the minimum score required for qualification at the Marksman level. Not all soldiers with an LMTS score of 17 will obtain a live-fire score of exactly 23, of course. Some will score lower than 23 and some will score higher, but their average score will be 23. Similarly, it can be determined that, on average, an LMTS score of 35 will be associated with a live-fire score of 30, the minimum score needed for Sharpshooter qualification.

$$30 = 16.323 + .387(X_1)$$

$$13.677 = .387(X_1)$$

$$(X_1) = 35.34$$

Unfortunately, insufficient data in the extreme regions of the two scales were available to permit the accurate prediction of Expert qualification. The required LMTS score lies outside the range of possible scores (i.e., 0 to 40) and indicates that soldiers wishing to Q1 as experts had best fire the highest score possible on LMTS.

$$36 = 16.323 + .387(X_1)$$

$$19.677 = .387(X_1)$$

$$(X_1) = 50.84$$

Assuming that the actual probability of firing these predicted live-fire scores will follow a normal distribution with approximately equal variability (Hays, 1963, p. 523.) and  $M = 23, 30,$  and  $36,$  the probability of an individual soldier shooting each of these live-fire scores or higher was calculated using the ARI Live-Fire Prediction Tool (Hagman, 1998). Table 1 shows the results. A soldier with an LMTS score of 24 (Column 1), for instance, would be predicted to fire 26 on the live-fire range (Column 2) and have a 70% chance of successful record fire qualification at the Marksman level (Column 3), a 20% chance of qualification at the Sharpshooter level (Column 4), and less than a 10% chance of qualification at the Expert level (Column 5). A soldier with an LMTS score of 28 would be predicted to fire 27 on the range and have an 80% chance of qualifying Marksman, a 20-30% chance of qualifying Sharpshooter, and less than a 10% chance of qualifying as an Expert, and so forth.

Another way of using Table 1 is to read down one of the last three columns to the desired level of live-fire qualification probability, and then across to the first column to determine the LMTS score associated with that probability. For example, if a marksmanship trainer wants a soldier to have at least a 50% chance of record fire qualification, then an LMTS score of 17 is required. The chance of record fire qualification rises to 70% if the soldier's LMTS score is 24, and it climbs to 90% with an LMTS score of 34.

In summary, the observed predictive correlation ( $r = .50$ ) between LMTS- and live-fire-based scores was both reliable and generalizable, as indicated by the successful cross-validation procedure using randomly constituted subgroups of the total sample. The relation was also of sufficient strength to be of practical value in predicting live-fire qualification performance.

Table 1.

*LMTS-Based Predicted Chances of First-Run Qualification at Marksman ( $\geq 23$  hits), Sharpshooter ( $\geq 30$  hits), and Expert ( $\geq 36$  hits) Levels on a Standard Pop-Up Target Qualification Course*

LMTS Score	Predicted Mean Record Fire Score	Chances of a Live-Fire Score of ...		
		$\geq 23$ Marksman	$\geq 30$ Sharpshooter	$\geq 36$ Expert
	16	10	--	--
6	19	20	--	--
10	20	30	--	--
14	22	40	--	--
17	23	50	--	--
19	23	--	10	--
21	24	60	--	--
24	26	70	20	--
28	27	80	--	--
29	27	--	30	--
32	29	--	40	--
34	29	90	--	10
35	30	--	50	--
39	31	--	60	--
40	32	--	--	20

### Experiment 2

This experiment examined the relation between LMTS Blazer-Based mini-RETS scores and live-fire scores collected on a standard Army pop-up qualification course employing RETS technology.

#### Method

##### Participants

Seventy-six soldiers from an Oregon Army National Guard infantry battalion voluntarily participated in the research as part of yearly rifle qualification firing at Camp Rilea, Oregon. None of the participants had previous experience firing LMTS.

##### Procedure

To control for possible order effects, approximately half the soldiers fired for live-fire qualification first and LMTS-based qualification second. The other half fired this sequence in reverse, with no more than 24 hr occurring between the two firings under either sequence.

*Live-Fire qualification.* Live-Fire qualification was fired with the M4 Carbine (using backup iron sights) and conducted by dedicated range cadre from the Oregon Army National Guard in accordance with procedures stipulated in FM 23-9 (Headquarters, Department of the Army,

1989) with shot grouping and weapon zeroing accomplished immediately beforehand. Target presentation and scoring were automated. Hit numbers associated with specific shooting classifications were as follows: 0-22, Unqualified; 23-29, Marksman; 30-35, Sharpshooter; 36-40, Expert. All statistical analyses were based on first-run hit scores.

*LMTS-Based qualification.* Simulated qualification firing with the LMTS M4 Carbine Blazer (Figure 4) was conducted on a scaled, indoor, 15m mini-RETS range by dedicated cadre from the USAR's 84<sup>th</sup> and 98<sup>th</sup> Institutional Training Divisions. Blazer firing followed the same procedures as those used for live fire and employed automated target presentation and scoring.

### *Analytic Approach*

A split-group, cross-validation design was used to examine the relation between LMTS Blazer- and live-fire performance. The initial sample of 76 soldiers was randomly divided into two groups. Group 1 was used to develop a prediction equation between Blazer- and live-fire scores. This equation was then applied to Group 2 soldiers to see if their live-fire scores could be predicted successfully from an equation based on Group 1 data.



Figure 4. Soldiers firing with the M4 Carbine Blazer.

### *Results*

#### *Group 1 Data (n = 38)*

For Group 1, Blazer hit scores ranged from 8 to 39 ( $M = 28.8$ ,  $SD = 8.4$ ). Live-fire scores ranged from 2 to 36 ( $M = 24.1$ ,  $SD = 7.0$ ). A paired-samples  $t$ -test revealed that the mean number of Blazer hits was significantly greater than that achieved with live-fire,  $t(37) = 4.00$ .

A least-squares regression prediction equation of the form  $Y' = B_0 + B_1(X_1)$  was developed in which  $Y'$  was the predicted live-fire criterion score,  $B_0$  was the intercept,  $B_1$  was the empirically derived regression coefficient linking changes in the live-fire criterion variable with changes in the Blazer predictor variable, and  $X_1$  was the obtained Blazer hit score. A significant linear relation,  $Y' = 10.675 + .466(X_1)$ ,  $SE = 3.42$  was found between Blazer and live-fire performance,  $F(1, 36) = 16.74$ . In addition, the correlation ( $r = .56$ ) between predicted and actual live-fire scores was significant. Thus, Group 1 Blazer scores were both linearly related to, and

reasonably good predictors of, live-fire performance despite the finding that soldiers fired better with Blazer than with live ammunition.

#### *Group 2 Data (n = 38)*

For Group 2, Blazer hit scores ranged from 13 to 40 ( $M = 31.1$ ,  $SD = 6.3$ ). Live-fire scores ranged from 9 to 35 ( $M = 24.4$ ,  $SD = 5.6$ ). As found for Group 1, the mean Blazer score was significantly greater than the mean live-fire score,  $t(37) = 7.04$ . Thus, Blazer scores were significantly higher than live-fire scores in both groups.

Following the same cross-validation procedures used earlier, the Group 1 regression equation was used to predict Group 2 live-fire scores, and then the relative amount of variance accounted for in each group was compared. A significant linear relation,  $Y' = -1.021 + 1.0(X_1 \text{ [predicted]})$ ,  $SE = 6.56$ , was found between actual live-fire scores and live-fire scores predicted ( $X_1$ ) from the equation based upon Group 1 data,  $F(1, 36) = 13.85$ . The resulting correlation ( $r = .53$ ) was significant, and the associated Group 2  $R^2$  of .278 did not differ significantly ( $z < 1$ ) from the  $R^2$  of .317 found for Group 1, indicating that the Group 1 prediction equation accounted for a comparable amount of live-fire score variance in the two groups. Thus, the predictive model was found to be valid, in spite of mean differences between Blazer and live-fire scores and, therefore, likely to maintain similar efficiency when used to predict live-fire scores of other soldier samples.

#### *Pooled Data (N = 76)*

The significant linear relation found among Group 1 soldiers was successfully cross-validated on Group 2. Given the similar outcomes from these two analyses, and the apparent generalizability of the preliminary model based on only half the sample, data from the two groups were pooled in order to develop the best possible live-fire predictions.

*Order effects.* Approximately half the soldiers fired Blazer first and then live fired. For the other soldiers, this sequence was reversed. Both Blazer and live-fire scores were examined to determine if they had been influenced by firing order. In neither case was there a significant effect. Therefore, no further mention of firing order will be made.

*Descriptives and mean differences.* Blazer scores ranged from 8 to 40 ( $M = 29.9$ ,  $SD = 7.5$ ). The minimum Q1 qualification score of 23 was achieved with Blazer by 85.5% of the soldiers in the pooled sample. Live-fire scores ranged from 2 to 36 ( $M = 24.2$ ,  $SD = 6.3$ ). Fifty-two soldiers (68.4%) achieved live-fire Q1. A paired-samples  $t$ -test revealed that the mean hit scores found for Blazer were reliably higher than those found for live-fire,  $t(75) = 7.50$ .

*Prediction model.* A least-squares regression analysis revealed a significant linear relation,  $F(1, 74) = 31.46$ , between the predictor variable (Blazer hit score) and the criterion variable (live-fire hit score). The correlation ( $r = .55$ ) between Blazer and live-fire scores was significant, with the former accounting for more than a fourth of the variance in the latter ( $R^2 = .30$ ; adjusted  $R^2 = .29$ ). The prediction equation took the form  $Y' = 10.470 + .460(X_1)$ ,  $SE = 2.53$ , where  $Y'$  = predicted live-fire score,  $X_1$  = Blazer score, and  $SE$  = standard error of the prediction.

For this relation to be of practical value, it should allow marksmanship trainers to predict live-fire qualification scores/probabilities based on Blazer performance. Specifically, trainers need to know what levels of Blazer performance are associated with live-fire qualification cut scores of 23 (Marksman), 30 (Sharpshooter), and 36 (Expert). To determine the Blazer score associated with these live-fire scores, we took the pooled data prediction equation,

$$Y' = 10.470 + .460(X_1)$$

substituted the desired live-fire cut score for  $Y'$ , and solved for the required Blazer score. Thus, to determine the Blazer score associated with a live-fire score of 23, we found:

$$\begin{aligned} 23 &= 10.470 + .460(X_1) \\ 12.53 &= .460(X_1) \\ (X_1) &= 27.24 \end{aligned}$$

Soldiers with a Blazer score of 27 will, on average, obtain a live-fire score of 23, the minimum required for qualification at the Marksman level. Of course, not all soldiers with a Blazer score of 27 will obtain a live-fire score of exactly 23. Some will score lower than 23 and others will score higher, but their average score will be 23.

Unfortunately, further examination revealed that the model cannot successfully predict live-fire performance levels above Marksman. For example, when we plugged in a live-fire score of 30, the minimum live-fire score needed for Sharpshooter qualification, we obtained a Blazer score of 42, which lies outside the range of possibility.

$$\begin{aligned} 30 &= 10.470 + .460(X_1) \\ 19.53 &= .460(X_1) \\ (X_1) &= 42.46 \end{aligned}$$

An even more extreme outcome occurred when we calculated the Blazer score necessary to predict live-fire scores of 36, the minimum necessary score for Expert qualification.

$$\begin{aligned} 36 &= 10.470 + .460(X_1) \\ 25.53 &= .460(X_1) \\ (X_1) &= 55.50 \end{aligned}$$

The resulting score of 55 was well outside the possible range of Blazer scores. Thus, soldiers interested in live-fire qualifying as either Sharpshooter or Expert would be advised to train to the highest possible LMTS Blazer score.

ARI Prediction Tool results (Table 2) for LMTS Blazer data reveal that a soldiers with an LMTS Blazer score of 33 (Column 1), for instance, would be predicted to fire 26 on the live-fire range (Column 2) and have a 70% chance of successful qualification at the Marksman level (Column 3), a 20% to 30% chance of qualification at the Sharpshooter level (Column 4), and less than a 10% chance of qualification at the Expert level (Column 5). From the last two columns in

Table 2, it can also be seen that the model cannot support Sharpshooter or Expert live-fire predictions with a high degree of probability.

Even though the model cannot confidently support either Sharpshooter or Expert live-fire predictions, it can predict live-fire qualification vs nonqualification. For example, if a marksmanship trainer wants a soldier to have at least a 50% chance of record fire qualification, then an LMTS Blazer score of 27 is required. The chance of record fire qualification rises to 70% if the soldier's Blazer score is 33, and it climbs to 80% with a Blazer score of 37. Notice, however, that it tops out at 80%. Even an LMTS score of 40 falls short of supporting a 90% prediction of first-run qualification. Likewise, a perfect Blazer score of 40 produces no more than a 40% probability of Sharpshooter qualification, and no more than a 10% probability of Expert qualification.

Table 2.

*LMTS Blazer-Based Predicted Chances of First-Run Qualification at Marksman ( $\geq 23$  hits), Sharpshooter ( $\geq 30$  hits), and Expert ( $\geq 36$  hits) Levels on a Standard Pop-up Target Qualification Course*

LMTS Score	Predicted Mean Record Fire Score	Chances of a Live-Fire Score of ...		
		$\geq 23$ Marksman	$\geq 30$ Sharpshooter	$\geq 36$ Expert
12	16	10	--	--
17	18	20	--	--
21	20	30	--	--
24	22	40	--	--
27	23	50	10	--
30	24	60	--	--
32	25	--	20	--
33	26	70	--	--
36	27	--	30	--
37	28	80	--	--
40	29	--	40	10

### Discussion and Conclusions

Overall, these findings show that (a) positive linear relations exist between simulated rifle marksmanship performance on LMTS mini-RETS and live-fire rifle marksmanship performance on automated (e.g., RETS) standard Army pop-up target ranges, (b) these relations exist for both dry-fire- and Blazer-Based simulation, and (c) these relations are both reliable and of sufficient magnitude to support implementation of an LMTS-based tool for predicting first-run, live-fire qualification rates.

Moreover, the results were consistent with earlier findings (e.g., Smith & Hagman, 2000; 2001) that established the ability of LMTS performance to predict ALT-C live-fire qualification scores/probabilities. Thus, the scores from both ALT-C and standard pop-up target qualification courses have been successfully predicted through use of LMTS-based simulation. To date, ALT-

C predictions have only been validated for LMTS dry-fire, whereas pop-up target qualification course predictions have now been validated for both dry- and Blazer-Based fire.

In both current experiments, obtained predictive relations were of sufficient strength to be practically useful in addition to statistically significant, permitting the prediction of first-run qualification with up to 90% confidence using dry-fire-based scores (Table 1) and with up to 80% confidence using Blazer-Based scores (Table 2). Thus, with either LMTS dry- or Blazer-Based fire, it is possible for marksmanship trainers to set the minimum acceptable probability of first-run, live-fire qualification (either for individual soldiers or for the unit as a whole) and then conduct LMTS-based training/evaluation to meet or exceed that standard.

#### *Simulation Methods: Dry-Fire vs. Blazer-Based Fire*

Firing LMTS under a dry-fire mode is less expensive, less complex, and less prone to malfunction than firing LMTS under a Blazer-Based mode, primarily because the former requires less equipment. Under the dry-fire mode, soldiers use their own (intact) standard-issue weapons equipped with a laser-emitting barrel insert/attachment. Under the Blazer-Based mode, however, a weapon's upper receiver assembly must be replaced by the LMTS Blazer assembly. While the replacement process is not difficult, and while the Blazer assembly is realistic in appearance, weight, balance, and (simulated) function, firing with it involves additional cost (e.g., for the assemblies themselves and the nontoxic blanks they fire). Moreover, Blazer assemblies require additional storage space, require maintenance during operation, and were observed to be somewhat susceptible to malfunction.

Thus, although the Blazer-Based mode of fire has the potential of delivering enhanced realism, including features such as semi-automatic ammunition cycling, spent cartridge ejection, recoil, sound effects, and smoke, these added features are achieved at additional cost without additional predictive benefits. That is, live-fire predictions derived from Blazer-Based firing were no more accurate than predictions associated with dry-fire. Thus, the dry-fire method of LMTS-based simulation seems preferable at this time. The dry-fire version of LMTS mini-RETS works now and provides a viable marksmanship training and evaluation tool that is ready for immediate implementation.

#### *LMTS Implementation*

Based on the results of this and other supporting investigations (e.g., Smith & Hagman, 2000; 2001), it is clear that LMTS can be used to predict first-run, live-fire qualification scores with a reasonably high degree of success, and that this predictive capability can be applied either to the standard Army pop-up target course of fire, as demonstrated here, or to ALT-C, as demonstrated earlier (Smith & Hagman, 2000). When this predictive capability is coupled with the previously developed and validated (Hagman, 2000) LMTS-based rifle marksmanship program of instruction (POI) (Headquarters, Department of the Army, 2001, August), the result is a comprehensive package of LMTS-based technology that can be used as an effective diagnostic tool for (a) identifying soldiers most in need of remediation/sustainment training, (b) signaling when enough such training has been provided, and (c) providing simulation-based, live-fire performance standards for enabling the substitution of LMTS-based qualification firing

for live-fire qualification firing when outdoor range facilities are not readily available. In doing so, these tools can form the basis for competency-based instructional delivery within the USAR's newly developed rifle marksmanship POI.

Figure 5 shows, in flowchart format, how this competency-based delivery approach would work. For example, soldiers would first be pretested by dry firing with LMTS on simulated mini-RETS (or ALT-C). Based on their pretest scores, soldiers would receive either a "Go" or "NoGo" depending upon which LMTS-based cut-off score were set beforehand by the unit commander. Let's say, for instance, that the LMTS pretest cut-off score was set at 28, the score associated with an 80% probability of live-fire qualification at the Marksman level (Table 1). Soldiers firing at or above this cut off would receive a Go and be considered simulation qualified. Soldiers firing below the cut off would be identified as needing remediation (to be delivered via the current LMTS-based POI). Remediation is provided only for those in need of it, thereby, making the most of valuable training time while saving range time and ammunition in the process. Those completing remediation would then be posttested on LMTS. Those receiving a Go on the posttest would be considered simulation qualified, whereas those receiving a NoGo would undergo further remediation until they were able to meet the posttest cut-off score and its associated live-fire expectancy standard of 80% probability of live-fire qualification.

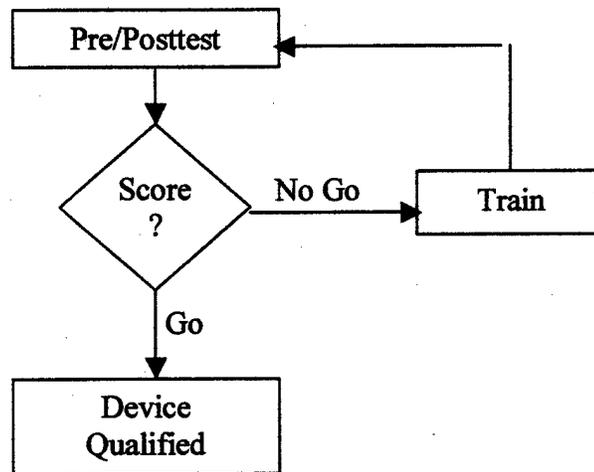


Figure 5. Flowchart of delivery strategy

The LMTS prediction tool (Table 1 for dry fire; Table 2 for Blazer) provides an empirically derived set of marksmanship performance probabilities for use in determining live-fire qualification standards. Such standards, in the form of cut-off scores, would be required to support a decision to use LMTS to validate live-fire marksmanship proficiency. Unit standards could be set at an acceptable probability level, using the values in Column 3 of either Table 1 or 2. Standards could be changed over time to reflect unit proficiency, or different standards might be applied to different unit subgroups.

This competency-based delivery strategy for LMTS-based marksmanship training, with empirically derived live-fire performance standards serving as its basis, should enable the USAR to take a substantial step forward in its ongoing commitment to meeting the Total Army

readiness challenge through more productive home-station small arms marksmanship training and evaluation. Current LMTS technology has the potential of optimizing the payoff from each soldier's live-fire range experience, while conserving ammunition and ensuring that scarce training resources are devoted to those most in need. With their marksmanship skills at the ready, Reserve Component soldiers will be better prepared to mobilize and deploy on short notice when called upon to support worldwide contingency operations.

## References

- BeamHit (1999). *Marksmanship training that works* (Brochure). Columbia, MD: Author.
- BeamHit (2002). *MINI-RETS Range* (Brochure). Columbia, MD: Author.
- Dunlin, E. G. (1999, January-February). BEAMHIT: This marksmanship training system uses lasers and can go anywhere. *Armor*, 44-46.
- Hagman, J. D. (2000). *Basic rifle marksmanship training with the Laser Marksmanship Training System* (Research Rep. 1761). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Science. (ADA380109)
- Hagman, J. D. (1998). Using the Engagement Skills Trainer to predict rifle marksmanship performance. *Military Psychology*, 10(4), 215-224
- Hayes, W. L. (1963). *Statistics*. New York: Holt, Rinehart, & Winston.
- Headquarters, Department of the Army (2001, August). *Rifle Marksmanship M16A1, M16A2/3, M16A4, and M4 Carbine* (Field Manual 3-22.9(23-9); Coordinating Draft). Washington, DC: Author.
- Headquarters, Department of the Army (1989). *M16A1 and M16A2 Rifle Marksmanship* (Field Manual 23-9). Washington, DC: Author.
- Plewes, T. J. Jr., MG. (1997, November 24). Memorandum: Subject; U.S. Army Reserve (USAR) Weapons Training Strategy for the 21st Century.
- Smith, M. D., & Hagman, J. D. (2000). *Predicting rifle and pistol marksmanship performance with the Laser Marksmanship Training System* (Tech. Rep. 1106). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Science. (ADA384045)
- Smith, M. D., & Hagman, J. D. (2001). *A review of research on the Laser Marksmanship Training System* (Research Note 2001-05). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Science. (ADA388198)
- Tatsuoka, M.M. (1969). *Selected topics in advanced statistics: Validation studies*. Champaign IL: Institute for Personality and Ability Testing.