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FORCES STUDY VOLUME 1(U) MARINE CORPS DEVELOPMENT AND
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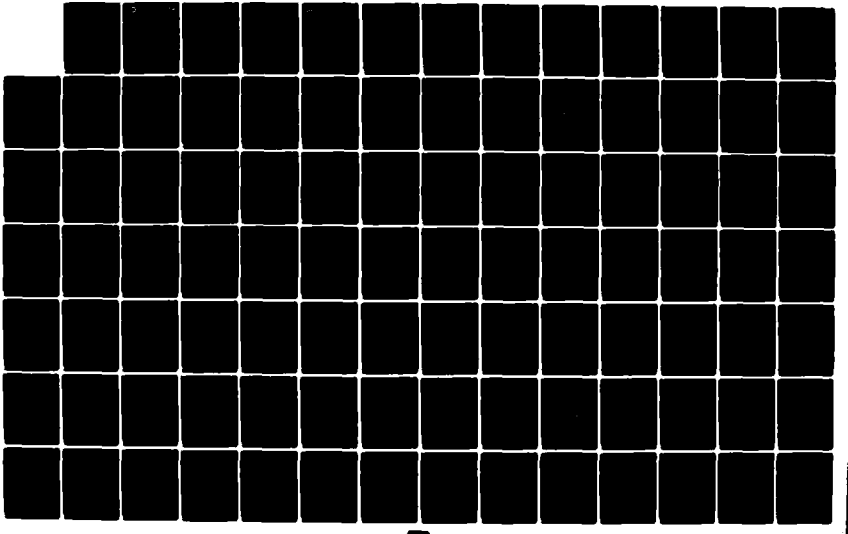

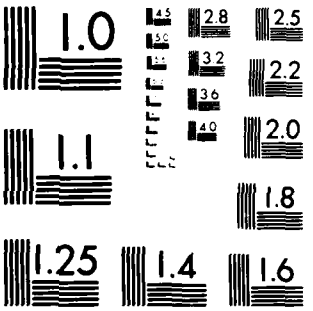

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SCN: 30-82-02

DETERMINATION OF AMMUNITION TRAINING RATES FOR MARINE FORCES STUDY - VOL I

LIEUTENANT COLONEL R. J. YEOMAN
DEPUTY CHIEF OF STAFF FOR DEVELOPMENTAL COORDINATION
DEVELOPMENT CENTER
MARINE CORPS DEVELOPMENT AND EDUCATION COMMAND
QUANTICO, VIRGINIA 22134

17 SEPTEMBER 1983

FINAL REPORT

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COMMANDANT OF THE MARINE CORPS
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WASHINGTON, D. C. 20380

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REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER SCN 30-82-02	2. GOVT ACCESSION NO. AD-A144429
	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* DETERMINATION OF AMMUNITION TRAINING RATES FOR MARINE FORCES STUDY, DECISION MEMORANDUM	5. TYPE OF REPORT & PERIOD COVERED FINAL REPORT
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) LtCol R. J. YEOMAN	8. CONTRACT OR GRANT NUMBER(s) M00027-81-G-0060
9. PERFORMING ORGANIZATION NAME AND ADDRESS Deputy Chief of Staff for Developmental Coordination Development Center, MCDEC Quantico, Virginia 22134	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Commandant of the Marine Corps (Code RD) Headquarters Marine Corps Washington, D. C. 20380	12. REPORT DATE 17 SEPTEMBER 1983
	13. NUMBER OF PAGES 248
14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)*	15. SECURITY CLASS. *(of this report)* UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution is unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

AMMUNITION, TRAINING RATES, TRAINING STANDARDS, SUBCALIBER AND SIMULATOR TRAINING, TRAINING ALLOWANCES

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This study determined the ammunition expenditures necessary to attain and ma t'n required levels of proficiency for individuals and units. Previously, very .ttle consideration was given to levels of desired proficiency in determining allowances. The study focused on the determination of training allowances based on the attainment of individual training standards in formal schools as well as in operational units; the maintenance of individual training standards; and the attainment and maintenance of

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unit training standards. Additionally, subcaliber and simulator training were assigned a quantitative value relative to the value of live-fire training. Lastly, the study addressed the methodology whereby training allowances would be responsive to changes in weapons, tactics, doctrine and budget constraints. The methodologies developed by the study provide a sound basis for determining training allowances and identified a logical alternative allowance system based on the organization vice the per weapon allowance system currently in use.

DEPARTMENT OF THE NAVY
HEADQUARTERS UNITED STATES MARINE CORPS
WASHINGTON, D.C 20380

IN REPLY REFER TO
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18 JUN 1984

From: Commandant of the Marine Corps
To: Distribution List

Subj: DETERMINATION OF AMMUNITION TRAINING RATES FOR MARINE FORCES STUDY

1. The objective of this study, as modified, was to obtain a methodology to collect the data and to compute allowances for training ammunition.

2. The objective of the study was accomplished.

3. The conclusions and recommendations of the study have been accepted with minor modifications. The first is that the collection of hard data will be held in abeyance until the Marine Corps can evaluate data that has been collected by the U.S. Army. In addition, the timing of the recommendation to institute data collection will be deferred until fiscal year 1986.

4. This study is approved for public release; distribution unlimited.

5. A copy of this letter will be affixed inside the front cover of each copy of the subject study prior to its distribution.

Ray M. FRANKLIN
BRIGADIER GENERAL, U.S. MARINE CORPS
DEPUTY CHIEF OF STAFF FOR RD&S

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CHAPTER I
EXECUTIVE SUMMARY

A. BACKGROUND

The purpose of this study is to determine the ammunition expenditure necessary to attain and maintain required levels of proficiency. Allowances for training ammunition are currently promulgated by a Marine Corps Order published by the Deputy Chief of Staff for Installations and Logistics. These allowances have been based on a combination of usage data, budget constraints, and numerous unvalidated requests from users. Little consideration has been given to levels of skill attainment, alternative means of training, or recognized standards of proficiency. The increasing costs of ammunition, sophistication of weapons systems, and training area constraints require a more effective and efficient means to allocate training ammunition. To establish that means, a measure of ammunition expenditure considering the above parameters and relative to skill attainment and proficiency must be determined.

B. STUDY OBJECTIVES AND MODIFICATIONS

1. Objectives

The major objectives of this study effort are to:

(1) Recommend Marine Corps ammunition training allowances based on:

(a) Attainment of required training standards for individuals in units (IAW appropriate Marine Corps Combat Readiness Evaluation System (MCCRES) volume).

(b) Maintenance of required training standards of individuals (IAW appropriate MCCRES volume).

(c) Attainment of required training standards of teams, batteries, etc. (IAW appropriate MCCRES volume).

(d) Maintenance of required training standards of commands (IAW appropriate MCCRES volume).

(e) This study shall not address Battalion Staff or Regimental Staff expenditure of training ammo requirements or M-16 training requirements.

(2) Recommend a method by which subcaliber and simulator training can be assigned a quantitative value relative to the value of live-fire training.

(3) Recommend a methodology through which training allowances are responsive to changes in weapons, tactics, doctrine and budget constraints.

2. Modifications

In this study major emphasis has been placed on artillery and tank training ammunition requirements; they constitute the major annual training ammunition expense. However, the study does consider the following other systems:

(1) Mortars: 81mm and 60mm,

(2) Anti-tank systems - TOW and DRAGON,

(3) Machine Gun, 7.62mm M-60 and .50 Caliber, HB flexible, ground mounted, and

(4) Air Defense Systems - Improved HAWK and STINGER/REDEYE.

This study modification was agreed to by the study sponsor and project officer.

C. FACTS BEARING ON THE PROBLEM

The USMC conducts progressive training to attain and maintain proficiency in crew-served weapon systems.

Training publications such as Technical Manuals (TMs), Field Manuals (FMs), and Marine Corps Combat Readiness Evaluation System (MCCRES) provide guidance and weapons specific instructions for crew-served weapon systems training. However, commanders are authorized flexibility in the conduct of

training to meet mission requirements, constraints of training facilities and time, budget limitations, and unit readiness proficiency.

Crew-served weapons training is intended to improve combat readiness of individual and weapons system teams to meet specific mission requirements and operational standards.

Current level of mission commitments including deployments and training and readiness exercises will continue for the foreseeable future.

D. MAJOR ASSUMPTIONS

(1) That the standards of proficiency in the Marine Corps Combat Readiness Evaluation System (MCCRES) are valid.

(2) That the standard of proficiency to be attained at Marine Corps schools can be provided.

(3) That the mission of the Marine Corps, as outlined in the Marine Corps Midrange Objective Plan (MMROP) will remain substantially unaltered.

E. STUDY FOCUS, LIMITATIONS, AND RATIONALE THEREFORE

This study emphasizes crew-served weapon systems training in active Fleet Marine Force (FMF) units. Reserve unit training is not considered.

Only current weapons and simulators are considered. These included the 155mm howitzer M-198, the M-60A1 tank, 60mm light weight company mortar, and the 81mm mortar.

Priority and emphasis are given to examining weapons systems with medium costs and high volume ammunition requirements (artillery, mortars, and tanks). Low priority is given to examining weapons systems with high cost and low volume ammunition requirements (TOW, DRAGON, REDEYE/STINGER, and I-HAWK).

F. METHOD OF ANALYIS

1. General

To meet the objectives of the study, an analytical plan was developed which outlined the approach, the necessary tasks to be accomplished, and their sequencing which would be required for the development of the methodologies for use in estimating ammunition training allowances. The methodologies would be based on proficiency levels and training/budgetary tradeoffs rather than the historically based parametric approach to expenditure rates, and periodic unjustified requests.

2. Overview of Tasks

To accomplish the study the tasks and their sequencing are illustrated in Figure II-1.

3. Critical Issues

In the approach, the study group felt that the following critical issues to the study problem would be answered:

(1) Have other studies been done that would contribute to the study?

(2) Is there sufficient data available to conduct the study?

(3) Can the data be quantified and organized for analysis?

(4) Is there an existing methodology for the analysis?

G. THE TRAINING ENVIRONMENT

The Marine Corps' dedication to training readiness is well known and effectively enunciated in a wide variety of official publications. Also, as a force-in-readiness, the Marine Corps sustains a high operational tempo of peacetime activities. These activities are conducted on a world-wide basis encompassing almost all climatic conditions and terrain variables. It is useful to briefly review these peacetime commitments, operational tempo, and force posture in order to ensure a contextual picture of the Fleet Marine Force (FMF) training environment.

First it is noted that the Marine Corps maintains a minimum of two forward deployed forces afloat, Marine Amphibious Units (MAUs), on a continuous basis and is expected to be capable of rapidly embarking Marine Amphibious Brigade (MAB) level forces in amphibious shipping to increase the level of forward deployed forces afloat. In addition, III MAF is forward deployed in Japan in a "6/9s" configuration including the 31st MAU. The five infantry battalions of the 3rd Marine Division (-) are forward deployed to Japan on a unit rotation basis from home bases located in the 1st and 2nd Marine Divisions.

In addition to the commitments described above, the Marine Corps:

(1) Provides forces to the RDJTF including the 7th MAB related to the Near Term Prepositioning Ship concept,

(2) Provides ready BLT level forces in an alert status related to both airlifted and amphibious contingencies, and

(3) Conducts both amphibious and other major exercises on a regular basis in support of JCS and unilateral training objectives.

The major factors fundamental to the training environment are:

(1) Force basing posture,

(2) Availability/location of appropriate training areas to include live fire ranges, and

(3) Personnel turnover or turbulence generated by the high operational tempo and unit rotation.

In regard to the basing posture related to training areas and live fire ranges, it is noted that only at 29 Palms, CA is there an effective match of basing and live fire training areas. All other basing posture-training area combinations are less than effective matches. In regard to personnel turnover, it should suffice to state that the perishable nature of unit training in an environment of significant personnel turbulence makes unit training readiness one of the most difficult problems facing today's Marine Corps.

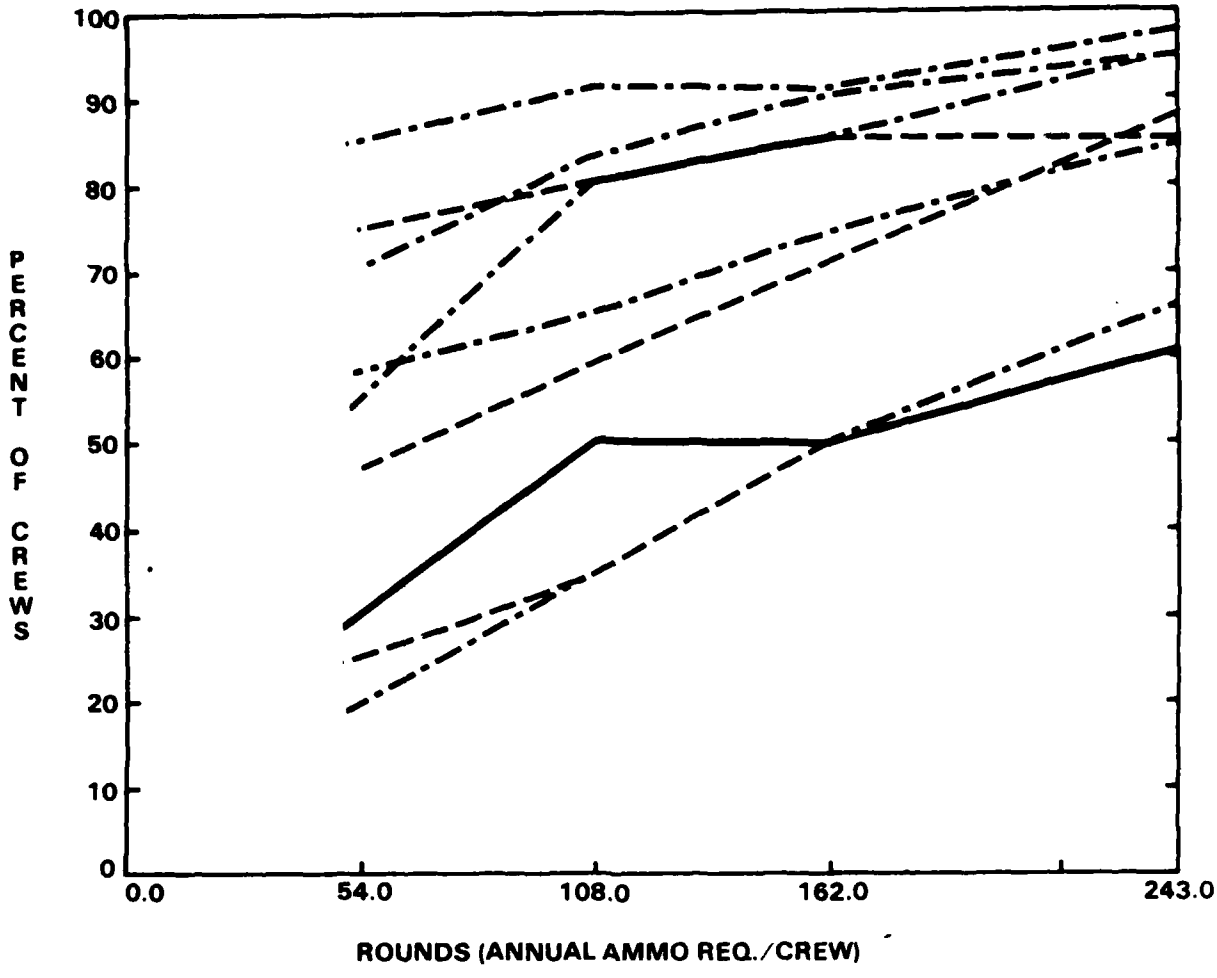
The above review serves as a reminder of the FMF training environment in which the study group attempted to form positive and productive conclusions and recommendations.

H. TANK GUNNERY

Lack of hard data from unit training records and MCCRES tests required a collection effort which resulted in the development of questionnaires administered by mail to selected USMC tank gunnery experts. The survey was designed for company commanders and battalion training officers calling for judgments from their experience in conducting and evaluating tank crews progressing through gunnery training to achieve and maintain proficiency. This provided data that permitted an analysis which compared the impact on training proficiency of the utilization of varying amounts of full and sub-caliber training ammunition.

Typical data from the survey are shown in Figure I-1 for the percentage of crews qualified as a function of the number of rounds of full caliber ammunition fired annually. The total number qualified includes three categories, qualified, superior, and distinguished. Each line on the graph represents the response from one survey participant showing his estimate of the percent of tank crews expected to qualify at 70 percent or better proficiency as a result of firing all full caliber (no sub-caliber) ammunition at four annual rates. The tank gunnery questionnaire was specifically structured to parallel the Army tank gunnery test program so that data resulting from the tests can be applied to the tank gunnery methodology developed in this study. The figure demonstrates the wide spread of estimates obtained from the respondents to the survey. At the normal allocation of 162 rounds per year, the estimates of the proportion of crews qualifying varies from 50 to 91 percent. The estimates also vary considerably in terms of the change in the proportion of crews qualified as the ammunition allocation is reduced.

Mean scores were computed for each full caliber ammunition allocation case for crews undergoing their first qualification and those in a subsequent annual qualification. There was little variation in the mean score as the ammunition was varied from one-third the normal allocation to 1 1/2 times the normal allocation. If the ammunition allocation were reduced to one-third of the current amount, the mean estimate indicated a reduction of



NOTE: EACH CURVE REPRESENTS THE SURVEY RESPONSE OF ONE EXPERT

Figure I-1. Individual Estimates of Proportion of Crews in Total Qualified Group as a Function of Full Caliber Rounds (First Qualification)

four percentage points in the percent of maximum score. Increasing the ammunition allocation to 1 1/2 times the normal would be expected to increase scores by only one percentage point. It is obvious from the data obtained that there was no concensus on the current scores achieved by tank crews. Furthermore, even if the mean score for the normal allocation of ammunition were to be determined accurately, there still remains uncertainty as to how scores would change with a change in ammunition allocation.

Effects of turbulence obtained from the survey are significant in both crews and platoons. Crew turbulence was estimated to produce a change of as much as 40 percent in the proportion of crews expected to qualify when three or four of the crew change. The mean estimate was 27 percent. Platoon turbulence was estimated to produce anywhere between a 20 and a 90 percent change in the proportion of crews qualifying when five new crews are present in the platoon. Hard data are needed to identify more precisely the effects of both crew and platoon turbulence, but it is evident that it most likely is a most important factor in performance.

A major concern is the degree to which changes in the allocation of ammunition will effect total Marine Corps training ammunition requirements. The usual approach in changing ammunition allocation is to change the amount given to each crew or platoon with no variation across the board. A slightly different approach is possible, however. It is inferred in Army Field Manual FM17-12 that crews or platoons not qualifying be allowed to reshoot until they achieve the necessary proficiency. This would suggest that the ammunition allowance might be reduced in general, but that those crews or platoons not qualifying be issued an additional allocation until they do qualify. The idea of reducing allocations and then providing additional ammunition for unqualified crews to continue shooting until they do qualify was analyzed in the following sequence:

(1) Since there are no hard data to identify accurately the proportion of crews qualifying under the current allocations a nominal point had to be picked for analysis. It was assumed that

the mean value of the proportion of crews qualifying under the normal allocation is representative of the current situation.

(2) Each of the questionnaire responses was normalized to the mean value selected in Step 1. As a result, each respondent's curve on the estimated proportion of crews qualifying for various ammunition allocations passed through the mean value point.

(3) The maximum, minimum and mean values of the proportions of crews qualifying under different conditions was determined. It was assumed that the qualifying crews fired only their allocation of ammunition. It was assumed that the crews not qualifying with the original allocation would shoot the average number of times indicated from the survey.

The sequence of events followed on this training concept and the numbers assumed to represent the amount of ammunition are shown in Figure I-2. The resulting use of ammunition is shown in Figure I-3. The effect of reducing the initial allocation and allowing those not qualifying to reshoot is to reduce the total amount of ammunition for training when the initial allocation is as low as 1/3 of what is currently provided.

The effect on the Marine Corps budget of reductions on the scale of those shown in Figure I-4 would be significant. If all 210 tank crews were to fire the ammunition allocations suggested in TC 25-3, the cost would be 37.3 million dollars per year. Going to one-third of the current allocation would reduce the expenditure of ammunition by 55 percent for a savings of $4.0 million.

Before these analytical results can be treated as truly indicative of the performance of Marine Corps crews and the requirements for ammunition, more data are needed. The data that need to be collected are described below. It is noted that the concept of reducing the initial allocation of training ammunition to each crew or platoon and then providing additional ammunition to those that do not qualify can work only if crews and platoons have access to ranges to reshoot as required.

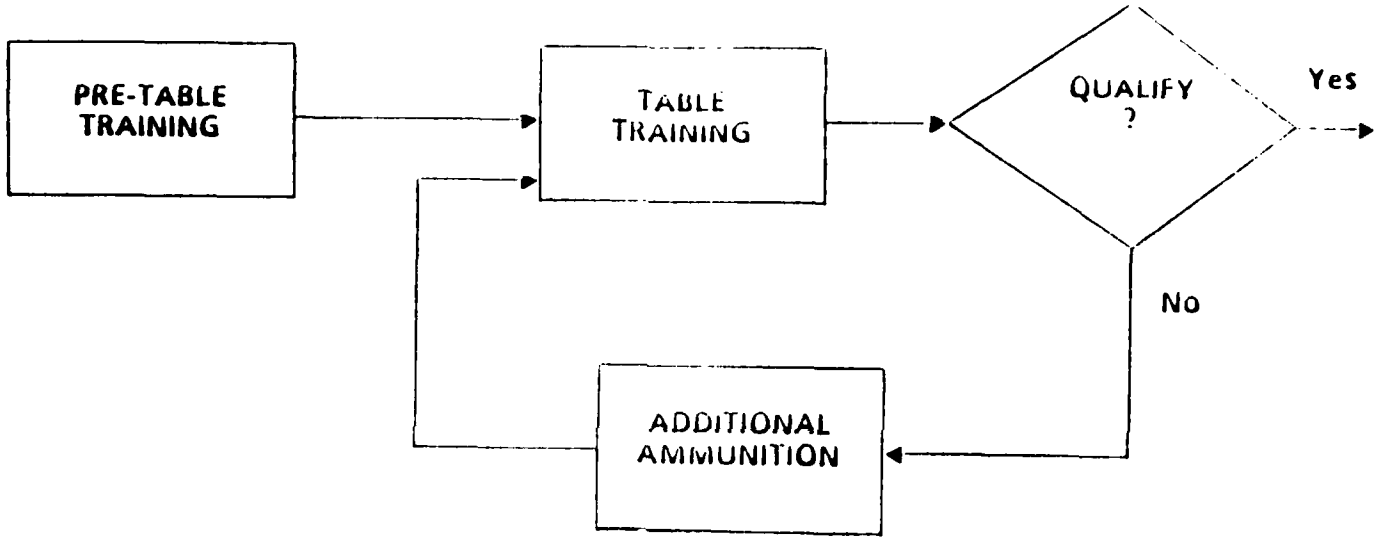


Figure I-2. Reshoot Concept

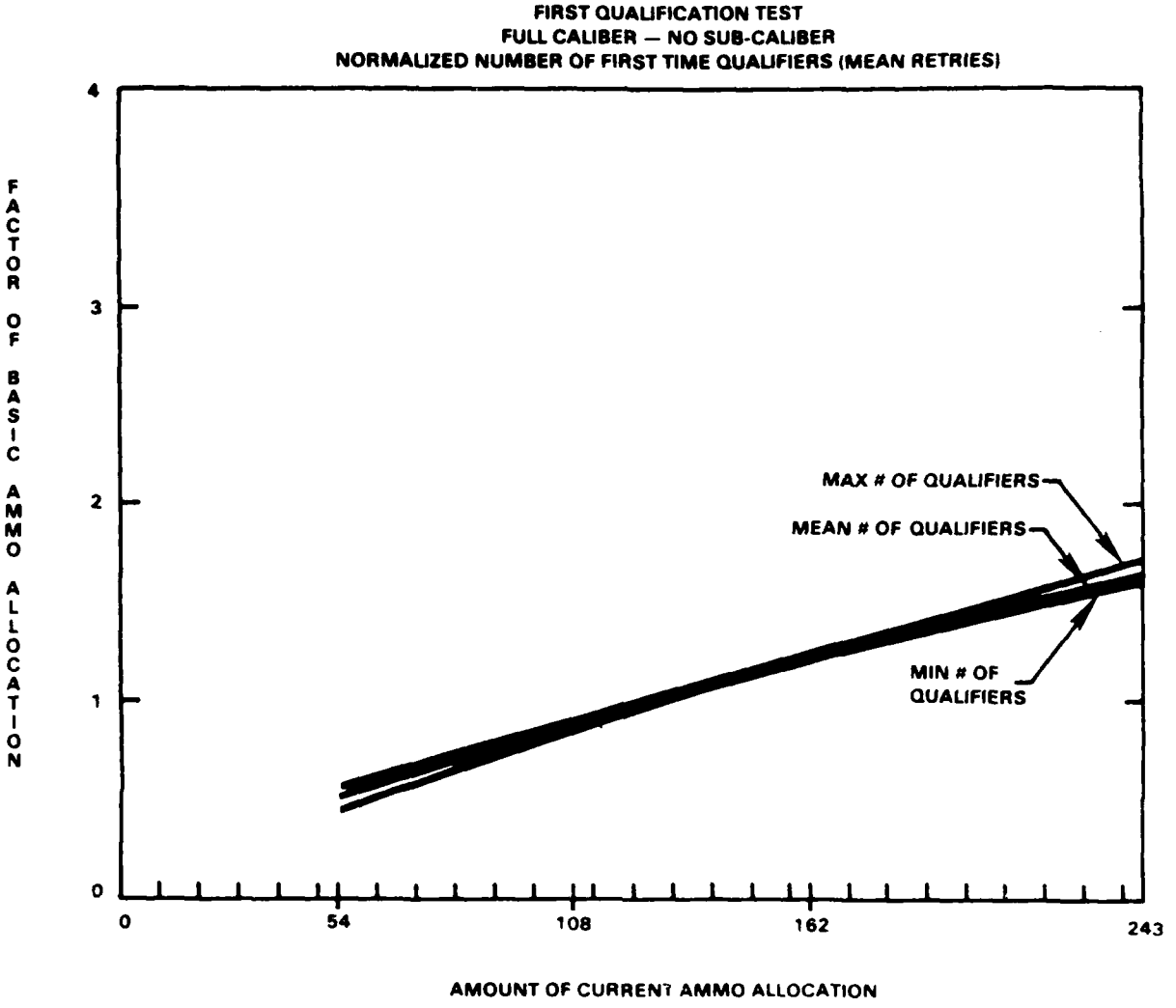


Figure I-3. Total Ammunition Usage as a Function of Allocation

The testing data collection and analysis proposed are intended to help determine the following:

(1) The effect of the variation of full caliber ammunition allocations on crew and platoon performance;

(2) The effect of the use of sub-caliber ammunition and simulation as substitutes for full caliber;

(3) The effect of training profiles and mission requirements; and

(4) The effect of turbulence.

The following steps are required to obtain usable guidelines for the allocation of training ammunition:

(1) Specify and enforce clear standards for tank firing training. Currently the Marine Corps is supposed to be using the standards specified in the US Army Field Manual (FM) 17-12. Standards more directly suited to the Marine Corps may be developed. However, it is more important that a set of standards be used consistently now than to spend time developing a new set and delay the collection the needed hard data. Therefore, immediate enforcement of the use of FM 17-12 is recommended. If the Marine Corps does develop new standards tailored more to its own needs they can be introduced later.

(2) Hard data must be collected from the Marine Corps training program on the performance of tank crews and platoons against the standards. It is necessary to obtain training results for different amounts of ammunition used. Two alternatives are suggested in Chapter III, Section B.4. The first is a rigidly structured test, such as described in Figure I-4. The other uses results as they can be obtained from the current Marine Corps training program. The type of data that need to be collected and the forms to use in the collection process are shown in Figure I-5 and in detail in Chapter III.

(3) Mathematical models will be used to obtain least square estimates of the proficiency of crews and platoons as a function of the amount of ammunition used. The equations are described later in

Number of Platoons	Number of Tanks	Ammunition Allocation	Pre-Table Simulation (%)	Organization/Mission
1	7**	Nominal	0	1 TNK Bn
1	7**	"	"	3 TNK Bn
1	7*	"	"	2 TNK Bn/Pre-deployment
1	7*	"	"	2 TNK Bn/Post-deployment
1	7*	"	"	Hawaii/Pre-deployment
1	5	"	"	Okinawa
1	7*	Nominal	90	1 TNK Bn
1	5	"	"	3 TNK Bn
1	7*	"	"	2 TNK Bn/Pre-deployment
1	5	"	"	2 TNK Bn/Post-deployment
1	5	"	"	Hawaii/Predeployment
1	7*	"	"	Okinawa
1	7*	2/3 Full-cal.	0	1 TNK Bn
1	7*	"	"	3 TNK Bn
1	7*	"	"	2 TNK Bn/Pre-deployment
1	7**	"	"	2 TNK Bn/Post-deployment
1	5	"	"	Hawaii/Post-deployment
1	5	"	"	Okinawa
1	5	2/3 Full-cal.	90	1 TNK Bn
1	7*	"	"	3 TNK Bn
1	5	"	"	3 TNK Bn
1	5	"	"	2 TNK Bn/Pre-deployment
1	5	"	"	2 TNK Bn/Post-deployment
1	5	"	"	Okinawa
1	5	1/3 Full-cal.	0	3 TNK BN
1	7*	"	"	2 TNK Bn/Pre-deployment
1	5	"	"	2 TNK Bn/Post-deployment
1	5	"	"	1 TNK Bn

Figure I-4. Tank Test Organization

Number of Platoons	Number of Tanks	Ammunition Allocation	Pre-Table Simulation (%)	Organization/Mission
1	5	"	"	1 TNK Bn
1	5	"	"	1 TNK Bn
1	7*	"	"	Okinawa
1	7*	1/3 Full-cal.	90	1 TNK Bn
1	5	"	"	1 TNK Bn
1	5	"	"	2 TNK Bn/Pre-deployment
1	5	"	"	2 TNK Bn/Post-deployment
1	5	"	"	Okinawa

*Includes two company command element tanks

**Includes two battalion command element tanks

Figure I-4. Tank Test Organization (Continued)

Data Will Be Collected Quarterly
a. Ammunition Use and Proficiency

COLUMN 1	2	3	4	5	6
PLATOON	CREW	PERCENT OF MAXIMUM SCORE	AMMUNITION USED		SIMULATION TYPE/#EVENTS
			FULL CALIBER ROUNDS	SUBCALIBER ROUNDS	
1	-				
	2				
	3				
	4				
	5				
2	-				
	1				
	2				
	. . .				

b. Chronology of Events for Platoons (Example)

Platoon ____

EVENT	CREW	DATE
Table VI	2	11/23/83
Table IV (M55)	1	12/03/83
New Crew Member	2	12/06/83

Figure I-5. Tank Training Data Requirement

Chapter III. The best starting point for representing the proficiency of crews and platoons as a function of the amount of ammunition used is an experimental formula. A hypothetical result is shown in Figure I-6. Linear or quadratic forms might be best for the relationships between the use of simulation or subcaliber and proficiency, and the effect of turbulence on proficiency.

(4) The selection of the amount of simulation and subcaliber to use will be a function of the cost of each and the practical number of times they can be used by crews and platoons. The procedure for determining the amount of simulation and subcaliber to use will also be described later in Chapter III.

These mathematical models and analytical procedures are the best possible alternatives available, given the amount and type of currently available data, coupled with state-of-the-art of learning theory, as it relates to crew performance in direct fire weapons. The exponential curve, shown in Figure I-6 , was selected because it possesses the basic characteristic which exemplifies that the amount of increase in score for a given increase in ammunition decreases as the total amount of ammunition becomes larger. For example, assume a tank crew has been allocated 100 rounds for training and scores 70 percent of the maximum number of points. Adding 20 more rounds for a total of 120 might increase the score to 75 percent. If the crew then gets 20 more for a total of 140, their score may increase to 78 percent. Thus, the first increment of 20 rounds increased the score by 5 percentage points, and the second increment of 20 rounds increased the score by only 3 percentage points. The data to be collected will resolve how much scores will change in response to increases in ammunition.

The substitution of simulation and subcaliber, based on the best available information, results in no essential proficiency change, or slight reductions. Figure I-7 shows how the impact of subcaliber use might appear. The impact might be linear or non-linear. Again, test data will resolve the issue.

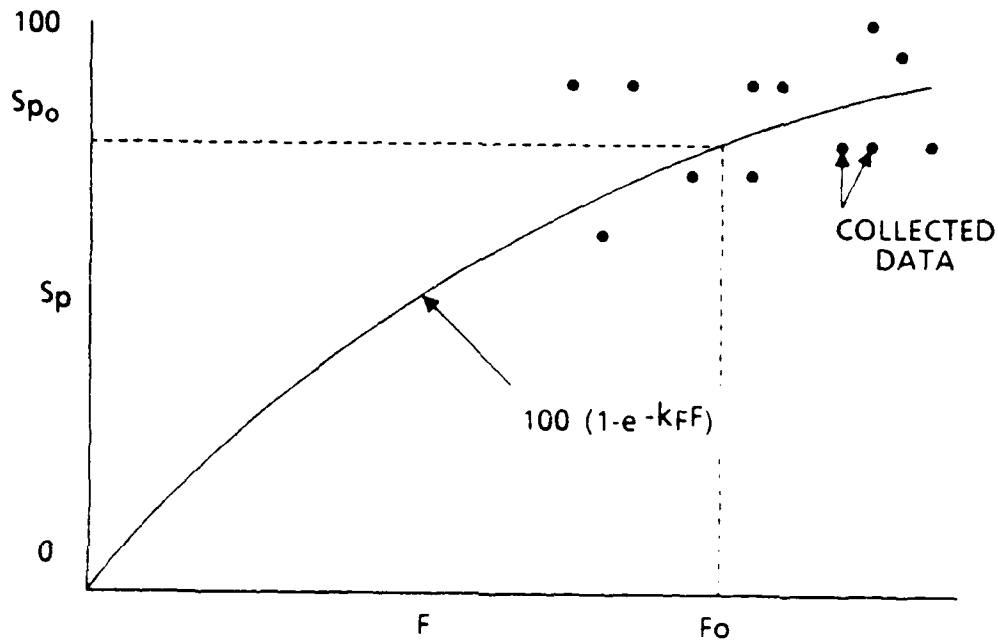


Figure I-6. Least-Squares Fit of Proficiency Curve to Data

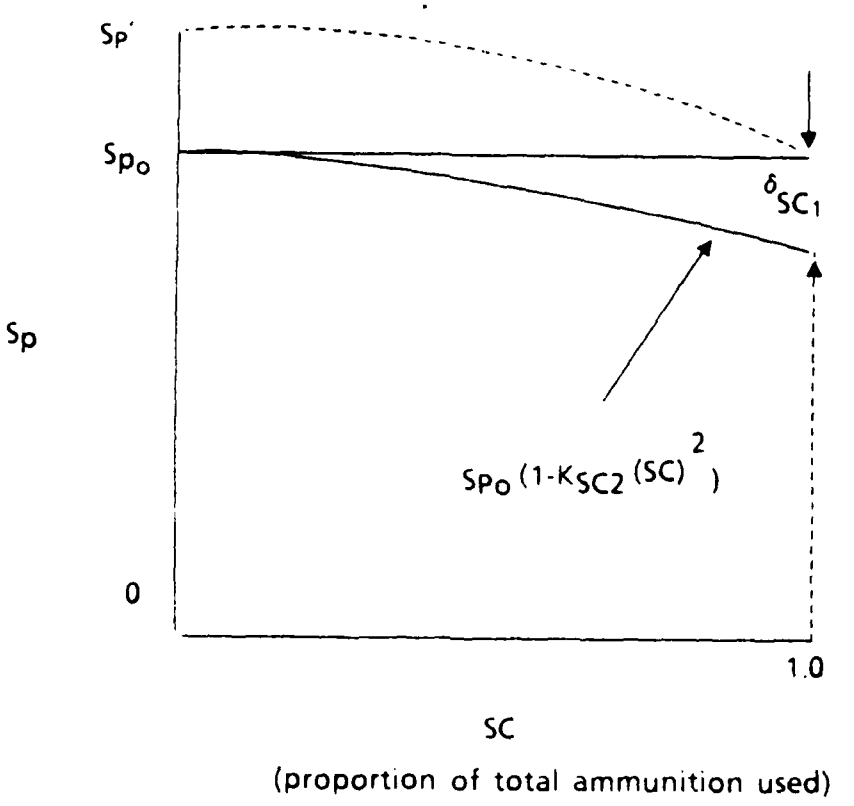


Figure I-7. Effect of Subcaliber Use on Proficiency

Turbulence effects are less defined than the effects of ammunition levels, and the substitution of simulation or subcaliber. As discussed in Chapter III, new measures and associated data are needed. Preliminary methods to guide the analysis are provided in Chapter III.

The methods proposed will provide ammunition allocation as a function of proficiency and budget constraints. When new weapons or tactics are introduced, the same general methods will apply. New data will be needed, beginning with operational tests of the weapons and tactics, and new equations might be required. The latter decision will be determined by the data obtained from tests, and the understanding gained from the methods developed from the models presented in this report.

I. INDIRECT FIRE

The purpose of the indirect-fire methodology is to help the Marine Corps to decide how much ammunition it needs to train its crews serving on indirect-fire weapon systems. It organizes both the data and the "decision variables", not only into a logical form, but also into a quantitative relationship so that values of the decision variables can be equated to some quantity of ammunition.

The basic decision variable which the Marine Corps must provide is the level of proficiency, or readiness, that it desires indirect-fire weapon crews to exhibit. This "proficiency level" should be expressed in terms of some standard, and the Marine Corps has specified the MCCRES standards to be used in this study. To this end, the data gathered pertain to likely MCCRES scores achievable by an indirect-fire unit under various circumstances--these scores being estimated through answers to questionnaires given to Marine Corps' experts.

The methodology provides information linking some number of live-fire (and non-live-fire) exercises with some amount of achievable "proficiency". It does not determine how many rounds to train with per exercise (in fact, the data gathered are inconclusive in this regard), but it assumes the current value from data of about 60 rounds per live-fire exercise.

Intuitively, the more live-fire exercise days, and consequently the more ammunition, the greater the proficiency, and the methodology describes this relationship quantitatively.

When training at the same specified number of exercise days per year, some units will exhibit higher and some units lower proficiency if tested. For planning training ammunition requirements based on proficiency, we need some concept of Marine Corps-wide, long-term, "steady-state" proficiency. The methodology provides this concept:

(1) By averaging, in a particular way, the subjective data (essentially subjective estimates of the likely outcomes of MCCRES tests) gathered from Marine Corps experts.

(2) By establishing a measure of proficiency based on "average maintainable proficiency".

In general, personnel turnover (turbulence) within a unit will lower the maintainable level of proficiency in that unit unless compensated for by an increased number of exercise days. The indirect-fire methodology makes personnel turnover a decision variable (along with proficiency) so that the Marine Corps can judge the proficiency tradeoff between personnel turnover and exercise days. In this way the current turnnover rate is not "built in".

Since indirect-fire weapon crews' activities involve basically procedural tasks, there can be considerable "forgetting" during periods when training is not performed. Thus, the level of proficiency in time varies depending on when training is conducted, how forgetting occurs in the meanwhile, and how many new crew members replace established crew members. Figure I-8 displays a sample time profile of a unit's proficiency. The average proficiency of 78 percent represents the average proficiency maintainable at the rate of training and the rate of the relationship of this coverage proficiency to the amount of turnover underlying the displayed process.

Profiles such as those displayed in Figure I-8 are characteristic of small crews of indirect-fire weapon system sections such as the elements (forward observer section, fire direction center, and howitzer sections) of

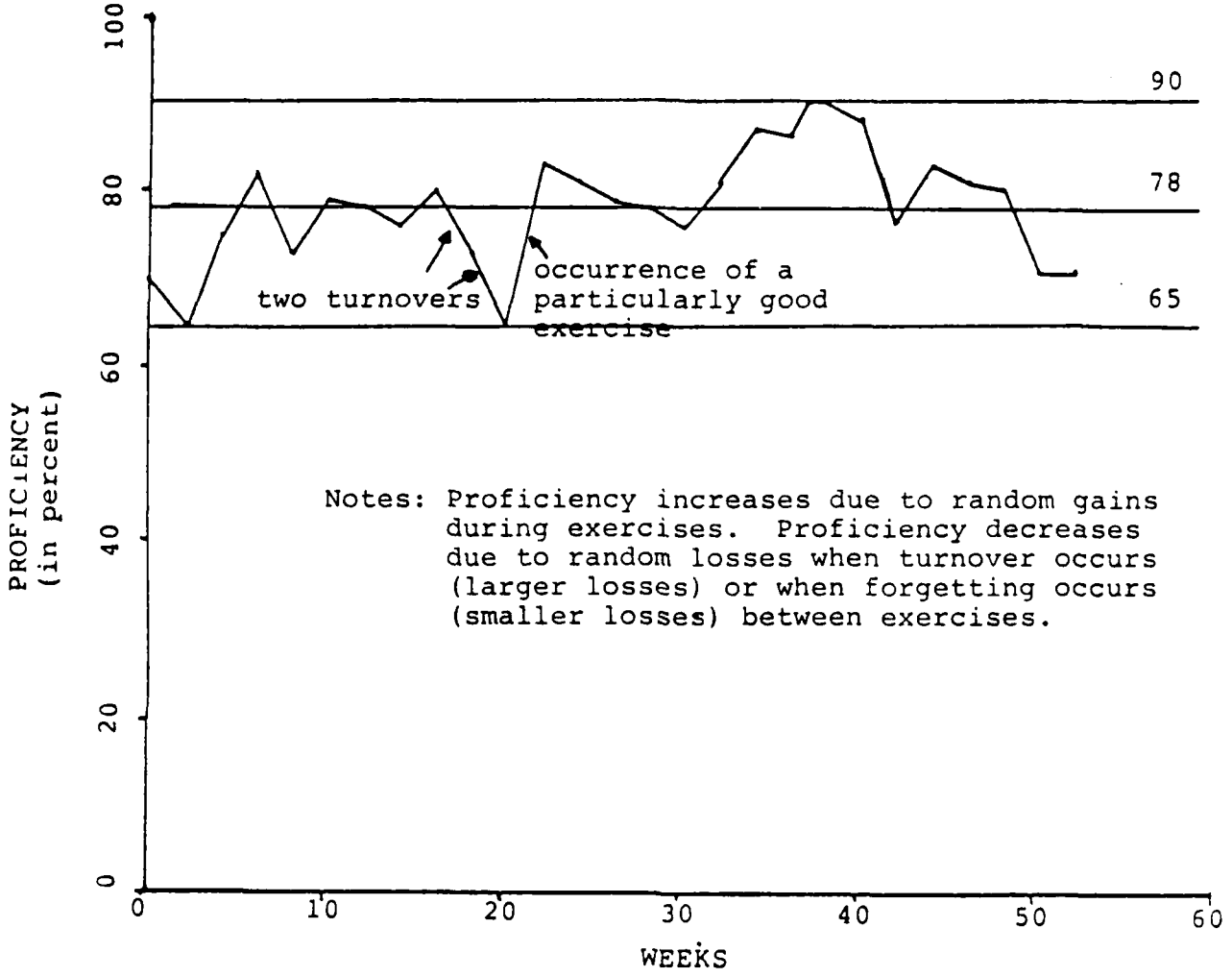


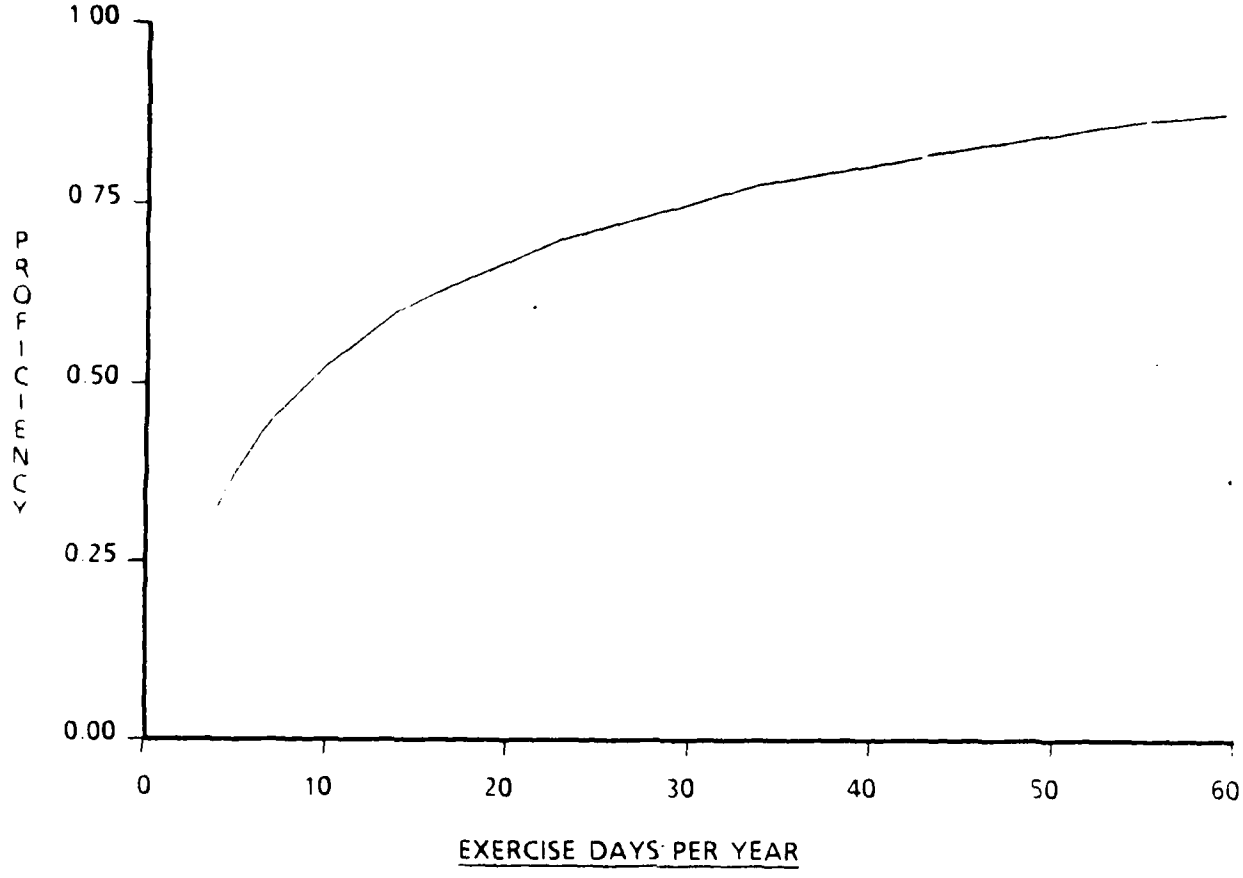
Figure I-8. Sample Proficiency Profile in Time

an artillery battery. The proficiency of the battery, however, is some complicated combination of the proficiencies of each of the elements and the "coordination proficiency" between elements. Thus, the indirect-fire methodology provides two models. One to describe the proficiency of the elements, and one to combine the element proficiencies into a battery proficiency.

The proficiency of an element can be described by a simple training model which relates a crew's proficiency to the amount of training it receives and the amount of personnel turnover it experiences. This model can evaluate the gain in proficiency when a newly assembled crew trains, and the level of maintainable proficiency as a mature crew trains and changes. The model can also be used to evaluate the efficacy of predeployment intense training to boost proficiency. Figure I-9 displays a sample "proficiency maintenance" curve for an element's crew. As expected, the more exercise days per year, the higher the maintainable proficiency.

The performance success of a battery depends on the ability of an element's crew to perform those subtasks endemic to their function with accuracy and timeliness. However, different missions make different demands on each element's crew and require the elements to interact differently among themselves. The indirect-fire methodology contains a battery proficiency model which uses the MCCRES standards applicable to different missions and mixes representative missions in order to relate element proficiency to battery proficiency. This model is tuned to the implied "coordination proficiency" extracted from the subjective data provided by the questionnaires.

Figure I-10 displays the sample relationship between exercise days per year and artillery battery proficiency. This curve is a basic output of this study. It applies under the assumption that the battery trains together with no differential training given to any element. The difference between 33 and 38 pure live-fire exercise days per year (at 60 rounds per day) is about 2 percentage points (74 percent versus 76 percent). Also to maintain the higher proficiencies, one needs proportionately more 50/50 live-fire/non-live-fire training than pure live-fire training (45 pure



For training at the average rate of n exercise days per year, the average maintainable proficiency will be of the form:

$$P(n) = \frac{n}{n+C}$$

for some value of C depending on the model parameters and the turbulence rate.

Figure I-9. Maintenance Proficiency

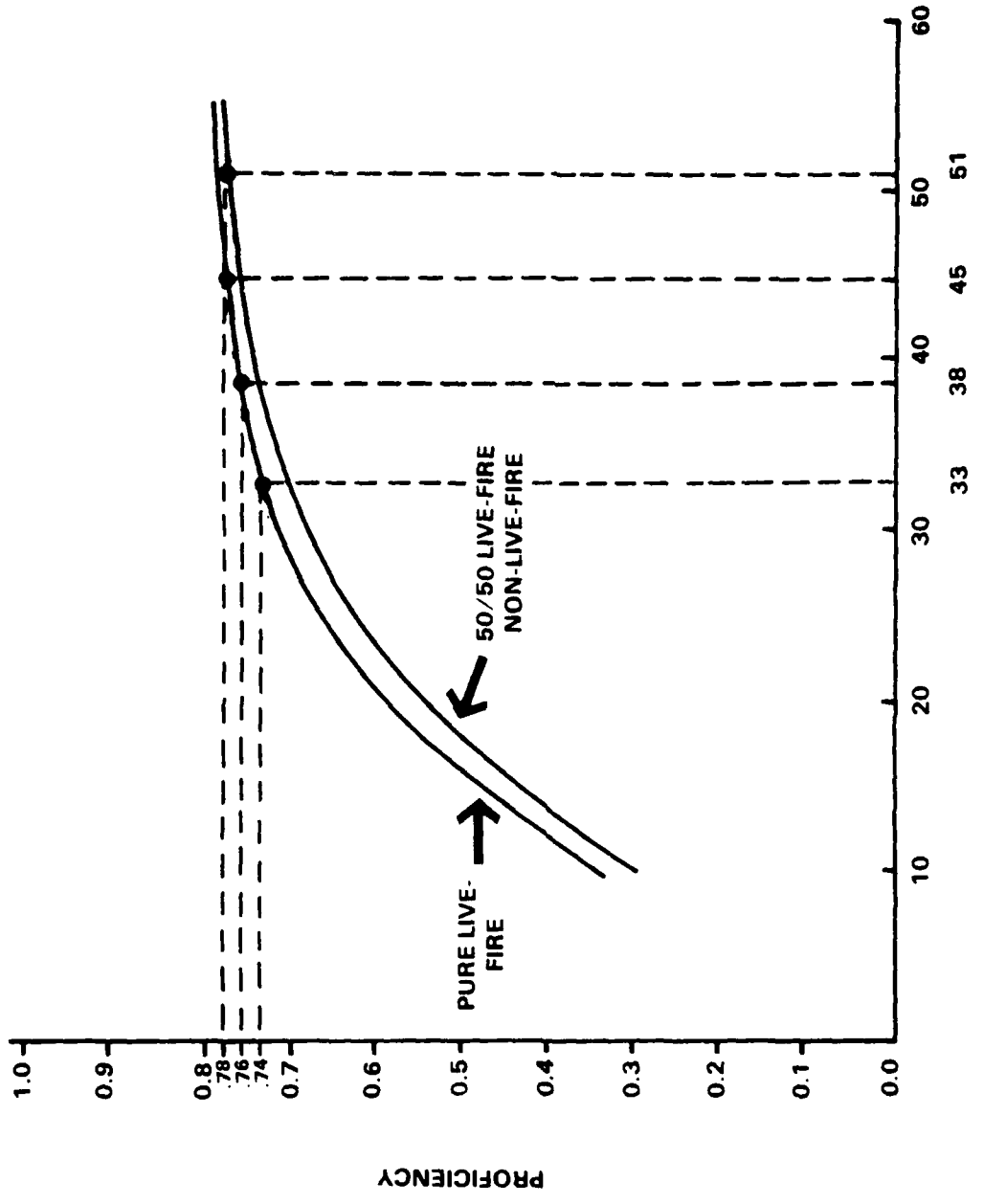


Figure I-10. Battery Maintenance Proficiency

live-fire days to maintain 78 percent but 51 mixed 50/50 days to maintain the same proficiency.)

The battery proficiency model, linking element proficiencies as represented in Figure I-9 to battery proficiency as represented in Figure I-10. has other applications. It allows for the construction of trade-off curves which indicate how element proficiencies trade-off against themselves, while maintaining the same battery proficiencies. For example, increasing the fire-direction center's proficiency by one percentage point allows us to decrease the howitzer sections proficiency by one percentage point with no change in battery proficiency. The battery proficiency model indicates that forward observer (FO) proficiency has about twice the impact on battery proficiency as do each of the other elements. Thus, it seems to pay to overtrain the FOs.

J. OTHER CREW SERVED WEAPONS

Analysis of allowances for other crew served weapons was primarily based on annual consumption data related to the basis of the current allowance and costing considerations. The following paragraphs discuss those crew served weapons identified in the study guidance.

1. TOW and DRAGON

It is understood that the current total inventory of practice and primary missiles for both TOW and DRAGON are such that replacement of training consumption is not required or anticipated over the next few years. However, the number of TOWs and DRAGONS in the FMF will concurrently increase significantly in conjunction with the force structure evolution and eventually generate a requirement for procurement/replacement of improved TOW and DRAGON missiles. The current item replacement costs for TOW and DRAGON missiles are estimated at $9,950 and $8,000 respectively. Although current allowances appear minimal, item costs seen in conjunction with an increasing inventory and potential use of the MILES XM62 and XM64 training devices appear to warrant reconsideration of the basis of these allowances. Specifically, experimentation with variable

organizational allowances similar to those discussed for tanks and artillery would provide a means of determining if a more cost effective allowance basis was feasible.

2. Air Defense (HAWK AND STINGER)

The annual allowances of VX80, GM HAWK MIM-23B are three missiles per battery in the active force structure and two per battery in the SMCR. The unit cost of the missile is $244,000. While the allowances can be considered minimal the high unit cost appears to warrant additional experimentation with variable organizational allowances both at and below current allowances.

The current annual allowance of VX81, GM REDEYE M41A2 is one per gunner. It is understood that this allowance was possible due to a very large inventory as related to only 60 gunners in the active force structure. However, the active force structure has been increased to two full batteries each containing 150 Gunners. In light of the increased structure and high cost of the STINGER missile, the Marine Corps has developed a STINGER Launch Simulator which will be used to qualify all FMF gunners on an annual basis. Therefore, there are no plans to institute an annual FMF training allowance of the STINGER missile.

3. Machine Guns (M60 and .50 Caliber)

The annual consumption history of the high density .50 caliber ammunition shows wide variations in annual consumption which tend to validate a need for a management system providing more control over training allowances. This need is not exclusive to .50 caliber consumption but extends to all infantry crew served weapons. Perhaps the best example of the need is the introduction of the M249 Squad Automatic Weapon. It is understood that the procurement will total 10,264 weapons which has the potential of generating an annual consumption of 40-50 million rounds. As the focal weapon of the Marine Fire Team, field requirements or "demand" for high or liberal allowances can be anticipated. Assistant gunners as well as gunners need to be qualified. In addition, the fire team and squad leaders will need to be fully trained in directing and coordinating the fire of the M249 in a variety of tactical situations. Concurrently, the

Marine Corps needs a cost effective approach in determining reasonable training allowances that will be predictably stable over a number of years. It is believed this example points toward transition to an organizational training allowance system as the C series infantry battalion is introduced into the force structure.

K. VARIABLE ORGANIZATIONAL ALLOWANCE CONCEPTS

The methodologies defined above lead to the predictable premise that differing hard data curves will evolve through testing. Due to the many variables included in the methodology it seems highly improbable that any two battalion level organizations will produce matching curves. One could attempt to normalize these curves to derive standard allowances for all FMF units. However, such an approach would not take advantage of the data gathered or the magnitude of differences in force posture, mission tasking, personnel turnover, and range location/availability that are existent in the FMF. The study group believes it is entirely feasible to set different (or variable) FY84 allowances through judgmental analysis of the current curves and an evaluation of organizational location, mission tasking, personnel turbulence and live fire range constraints. A variable organizational annual allowance tailored to mission tasking and other basic factors should form the basis of a more cost effective allowance management system.

L. CHANGES IN FORCES, WEAPONS AND DOCTRINE AND BUDGET LEVELS - IMPACT ON TRAINING AMMUNITION ALLOWANCES

Military forces are in a continuing state of evolutionary change. New weapons and equipment are constantly being integrated into the military inventory. This, in most cases, requires changes in doctrine and training procedures. The overall policy governing the acquisition of major systems is set forth by Department of Defense in DOD Directives 5000.1 "Major Systems Acquisition," DOD 5000.2 "Major System Acquisition Process" and DOD 5000.3 "Test and Evaluation." The developmental process of a weapon systems is all inclusive, and includes the development of the doctrine of

employment, the training and support packages to field and maintain the item, and the personnel skill requirements to operate and sustain the system under field conditions.

The overall acquisition process for new materiel is divided by DOD into four (4) major phases:

(1) Conceptual,

(2) Validation,

(3) Full Scale Development, and

(4) Production and Development.

Training concepts and requirements should be studied, tested and/or evaluated during each phase in development process. At the major decision points at the termination of each phase, impact on training is a pertinent decision-making factor to be considered prior to the development entering the next phase.

At the culmination of the development phase, the engineering development prototype is thoroughly tested and evaluated to determine whether the system meets the requirements and should transition into production. The training support package should be thoroughly tested and evaluated in the Operational Test II (OTII). There is a tendency in the development process, due to budgetary constraints and project urgency, to minimize the testing of Integrated Logistic Support (ILS) items in the OTII test program. As a result, the development of the ILS items tends to fall behind the development of the prototypes. This lag in ILS development and testing has a tendency to be carried through to the production phase, and systems are frequently deployed with the training package incomplete, and not thoroughly tested. This impacts on training ammunition requirements which are developed late with insufficient and inadequate testing. Hence, it is extremely difficult under the circumstance to provide adequate and timely justification for budgetary purposes for training ammunition which is being produced concurrently with the system to meet deployment schedules.

Greater emphasis must be placed in assuring that doctrine, organizations, tactics, personnel skill requirements and, above all, the total

training package are progressively and concurrently developed with the materiel system. Training must be a major consideration in each phase of development.

In regard to training ammunition requirements, the evaluation should answer critical issues pertaining to the development of the optimum operational proficiency of individual and unit skill level in the most economic manner. To develop these requirements troop unit tests which determine acceptable proficiency versus the optimum combination of live and sub-caliber fire and simulation should be conducted. The methodology developed in this study for tank gunnery and artillery battery training should provide a valuable evaluation tool in this test process.

All military materiel systems are ever changing. Systems undergo a number of product improvements over their useful life. Also training processes and procedures are evolutionary - constantly in a state of change. Hence, the training ammunition allocation should be under constant scrutiny to assure it dovetails with the training procedure. Data on ammunition uses and proficiency attained must be gathered on a constant or periodic basis. The data utilizing the methodology developed in this study will provide a justification for the live-fire ammunition requirement related to readiness proficiency.

The military is constantly faced with budgetary constraints that impact on the amount of training ammunition available for troop use. Major caliber ammunition, i.e., artillery, tank and mortar, form a majority of training ammunition budgetary requirements. Hence, there is constant pressure by DOD and Congress to reduce the requirements for the high cost ammunition items. Emphasis is placed on substituting sub-calier firings and various other training devices in lieu of live firings using the major caliber weapon ammunition.

Field training under simulated combat conditions offers a challenge in the development of training aids and techniques. Currently, training techniques using new technology is undergoing dynamic development. There are indications brought out in this study that an increase in weapons proficiency is not proportional to ammunition expended. Hence, to meet the

continuing budget crunch, efforts must continue to seek non-economic means of achieving combat proficiency with our weapons systems. It is essential that we seek new non-live fire training techniques which, coupled with required live-firing, will meet the individual and crew proficiency requirements. Only in this manner can the battle of budget constraints be successfully overcome. The methodology developed in this study will prove a useful tool.

M. FINDINGS

The following summarizes the study findings resulting from the research, survey and analysis:

1. General

Annual missions and deployments of USMC units are a major factor which should determine individual MAF element training programs, and ammunition requirements and allocations.

Hard data on tank gunnery and indirect-fire battery performance are virtually non-existent. This lack of hard data resulted in the need to use subjective questionnaires as a survey tool in this study.

The judgments of personnel surveyed showed considerable variance in absolute values of expected results. For example, estimates of the crews qualifying in one case varied from 40 to 85 percent. However, there is consistency in trends as reflected in the direction and slope of curves.

Training ammunition expenditures for tank gunnery and artillery live firings are not available on a battery/tank platoon basis. Hence, no correlation between performance and expenditures could be made.

2. Tank Gunnery

The evident lack of consistency identifies data collection needs. Data should be collected on the following for each tank crew and platoon:

(1) Qualified or not on first MCCRES test,

(2) Number of retests to qualify,

(3) Amount of full caliber ammo expended by test table,

(4) Amount of subcaliber ammo expended by table,

training package are progressively and concurrently developed with the materiel system. Training must be a major consideration in each phase of development.

In regard to training ammunition requirements, the evaluation should answer critical issues pertaining to the development of the optimum operational proficiency of individual and unit skill level in the most economic manner. To develop these requirements troop unit tests which determine acceptable proficiency versus the optimum combination of live and sub-caliber fire and simulation should be conducted. The methodology developed in this study for tank gunnery and artillery battery training should provide a valuable evaluation tool in this test process.

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Field training under simulated combat conditions offers a challenge in the development of training aids and techniques. Currently, training techniques using new technology is undergoing dynamic development. There are indications brought out in this study that an increase in weapons proficiency is not proportional to ammunition expended. Hence, to meet the

(5) Proportion of simulation used in pre-table training (crews only).

(6) Crew longevity to reflect turbulence, and

(7) Platoon longevity to reflect turbulence.

The following concepts can be tested to determine the effects of changes in ammunition allowances, both full and subcaliber:

(1) Reduce the ammunition allowance for selected crews and platoons. Set aside the unused portion of each crew's and platoon's normal allowance. Design the test so that crews or platoons not qualifying have access to the set-aside ammunition, either until they qualify or until they have exhausted their normal allocation.

(2) Test the substitution of subcaliber for full caliber, repeating tests until the crews/platoons involved in the test qualify.

(3) Vary pre-table use of simulation.

After the collection of hard data over a one-year period, the methodology presented in Chapter III will permit more precise definition of training ammunition requirements.

3. Indirect Fire Weapon Systems

Analysis of the questionnaires revealed:

(1) A great variation in judgmental MCCRES performance in relation to days of live-fire/simulator training and rounds fired per day, and

(2) Occasional judgmental contradictions within the same respondents questionnaire.

The effect of changes in training ammunition allowances is highly uncertain.

The basis for structuring hard data collection is found in our proposed methodology. The indirect-fire methodology developed in this study requires as input (for each battery element and for the battery overall):

(1) The MCCRES scoring, and for the prior year,

(2) The number of days of training,

(3) The rounds expended per day (live-fire and subcaliber), and

(4) The personnel turnover.

The analysis provides a basis for testing to determine the effects of ammunition use on proficiency. Since battery proficiency depends a great deal upon the coordination of elements, testing must be devised to elicit some measure of the effect of training the battery together versus training the elements separately.

The updated procedures proposed in the methodology can be used to determine ammunition allowances needed to achieve a specified average battery proficiency, once testing has provided a relationship among:

(1) "Rate of learning" and rounds expended per day (both live-fire and subcaliber) at the element level,

(2) The effects of turnover at the element level, and

(3) A measure of the increase in "coordination" (e.g., coordination times) between elements as a function of mutual training.

4. Other Crew Served Weapons

High cost missile systems training ammunition expenditures are very tightly controlled; hence these offer little opportunity for savings. A potential saving might be made by reducing the HAWK missile annual training allocation per battery from 3 to 2.

Machine gun training ammunition, which has a low unit cost but has a high expenditure rate, is not tightly controlled and its allocation rate varies widely on a year to year basis. There appears to be no valid justification for this fluctuation in allocations.

5. Impact on Ammunition Training Allowances of Changes in Weapons, Tactics, Doctrine and Budget Constraints

Emphasis must be placed on the concurrent development of systems and their training procedures to include training ammunition allowance beginning at the latest in the full scale development phase of the acquisition process.

As weapon systems develop and mature, the training procedure should be under constant review with the goal of optimizing crew performance and training costs.

N. CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions:

(1) The methodologies developed in this study provide a valid basis for determining tank and artillery ammunition training allowances. (Chapter III, Section B.4 and C.5 and 7)

(2) Specific changes in ammunition training allowances should commence on an experimental basis in FY84. (Chapter III, Section B.4.c and C.7.h)

(3) There is a need to collect hard data on both direct and indirect fire weapons systems; the basis for structuring this collection effort is identified in Chapter III. (Section B.4 and C.7)

(4) There is a need to introduce and refine a more definite and responsive ammunition allowance management system. (Chapter III, Section B.1, B.3, and C.3)

(5) Variable organizational allowance concepts should be tested throughout the FMF in FY84 to determine the effects of changes in ammunition allowances, both full and subcaliber. This should be instituted in conjunction with directed increased use of other training devices. (Chapter III, Section E)

(6) A logical alternative to the current annual allowance system is an organizational basis of allowance vice a per weapon basis. Further, annual organizational allowances could be developed in conjunction with a quarterly allocation and expenditure reporting system. (Chapter III, Section E)

(7) Transition to an organizational basis of allowance in conjunction with adoption of the methodology presented in Chapter III would provide a management system responsive to changes in weapons, tactics, doctrine, force structure, and budget constraints. (Chapter III, Section F)

2. Recommendations:

(1) That current allowances be sustained during FY83. (Chapter III, Section B.4.b and C.7.h)

(2) That, commencing with FY84, a system to collect hard data be instituted as defined in Chapter III. (Section B.4.c, and C.7)

(3) That, commencing with FY84, variable organizational allowance concepts be tested throughout the FMF. Proposed FY84 allowances for tank and M-198 artillery units are depicted in Chapter III, Sections B and C, respectively.

(4) That the Marine Corps consider transition to an organizational basis of allowance system for all FMF weapons systems. It is further recommended that early transition to an organizational allowance system be considered for M-198 artillery battalions and C Series infantry battalions. (Chapter III, Section E)

CHAPTER II
INTRODUCTION

A. PROBLEM

The purpose of this study is to determine the ammunition expenditure necessary to attain and maintain required levels of proficiency. Allowances for training ammunition are currently promulgated by a Marine Corps Order published by the Deputy Chief of Staff for Installations and Logistics. These allowances have been based on a combination of usage data, budget constraints, and numerous unvalidated requests from users. Little consideration has been given to levels of skill attainment, alternative means of training, or recognized standards of proficiency. The increasing costs of ammunition, sophistication of weapons systems, and training area constraints require a more effective and efficient means to allocate training ammunition. To establish that means, a measure of ammunition expenditure considering the above parameters and relative to skill attainment and proficiency, must be determined.

B. STUDY OBJECTIVES AND MODIFICATIONS

1. Objectives

The major objectives of this study effort are to:

(1) Recommend Marine Corps ammunition training allowances based on:

(a) Attainment of required training standards for individuals in units (IAW appropriate Marine Corps Combat Readiness Evaluation System (MCCRES) volume).

(b) Maintenance of required training standards of individuals (IAW appropriate MCCRES volume).

(c) Attainment of required training standards of teams, batteries, etc. (IAW appropriate MCCRES volume).

(d) Maintenance of required training standards of commands (IAW appropriate MCCRES volume).

(e) This study shall not address Battalion Staff or Regimental Staff expenditure of training ammo requirements or M-16 training requirements.

(2) Recommend a method by which subcaliber and simulator training can be assigned a quantitative value relative to the value of live-fire training.

(3) Recommend a methodology through which training allowances are responsive to changes in weapons, tactics, doctrine and budget constraints.

2. Modifications

In this study major emphasis has been placed on artillery and tank training ammunition requirements; they constitute the major annual training ammunition expense. However, the study does consider the following other systems:

(1) Mortars: 81mm and 60mm,

(2) Anti-tank systems - TOW and DRAGON,

(3) Machine Gun, 7.62 mm M-60 and .50 Caliber, HB flexible, ground mounted, and

(4) Air Defense Systems - Improved HAWK and STINGER/REDEYE.

This study modification was agreed to by the study sponsor and project officer.

C. FACTS BEARING ON THE PROBLEM

The USMC conducts progressive training to attain and maintain proficiency in crew-served weapon systems.

Training publications such as Technical Manuals (TMs), Field Manuals (FMs), and Marine Corps Combat Readiness Evaluation System (MCCRES) provide guidance and weapons specific instructions for crew-served weapon system training. However, commanders are authorized flexibility in the conduct of

training to meet mission requirements, constraints of training facilities and time, budget limitations, and unit readiness proficiency.

Crew-served weapons training is intended to improve combat readiness of individual and weapons system teams to meet specific mission requirements and operational standards.

Current level of mission commitments including deployments and training and readiness exercises will continue for the foreseeable future.

D. MAJOR ASSUMPTIONS

That the standards of proficiency in the Marine Corps Combat Readiness Evaluation System (MCCRES) are valid.

That the standard of proficiency to be attained at Marine Corps schools can be provided.

That the mission of the Marine Corps, as outlined in the Marine Corps Midrange Objective Plan (MMROP) will remain substantially unaltered.

E. STUDY FOCUS, LIMITATIONS, AND RATIONALE THEREFORE

This study emphasizes crew-served weapon systems training in active Fleet Marine Force units. Reserve unit training is not considered.

Only current weapons and simulators are considered. These included the 155mm howitzer M-198, the M-60A1 tank, 60mm light weight company mortar, and the 81mm mortar.

Priority and emphasis is given to examining weapons systems with medium costs and high volume ammunition requirements (artillery, mortars, and tanks). Low priority is given to examining weapons systems with high cost and low volume ammunition requirements (TOW, DRAGON, REDEYE/STINGER, and I-HAWK).

F. METHOD OF ANALYIS

1. General

To meet the objectives of the study, an analytical plan was developed which outlined the approach, the necessary tasks to be accomplished and their sequencing which would be required for the development of the methodologies for use in estimating ammunition training allowances. The methodologies would be based on proficiency levels and training/budgetary tradeoffs rather than the historically based parametric approach to expenditure rates, and periodic unjustified requests.

2. Overview of Tasks

To accomplish the study, the tasks and their sequencing are illustrated in Figure II-1.

3. Critical Issues

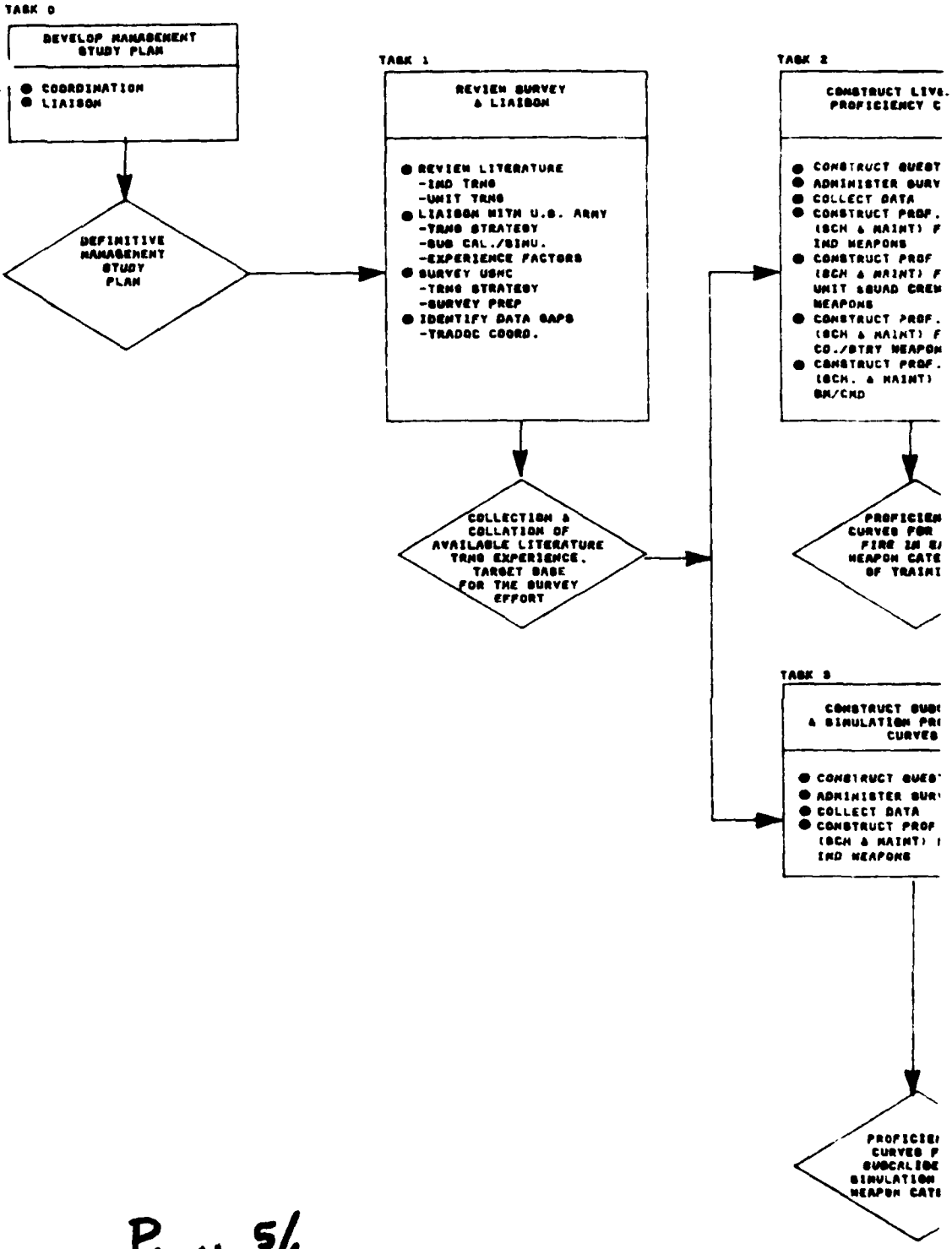
In the approach, the study group felt that the following critical issues to the study problem would be answered:

(1) Have other studies been done that would contribute to the study?

(2) Is there sufficient data available to conduct the study?

(3) Can the data be quantified and organized for analysis?

(4) Is there an existing methodology for the analysis?



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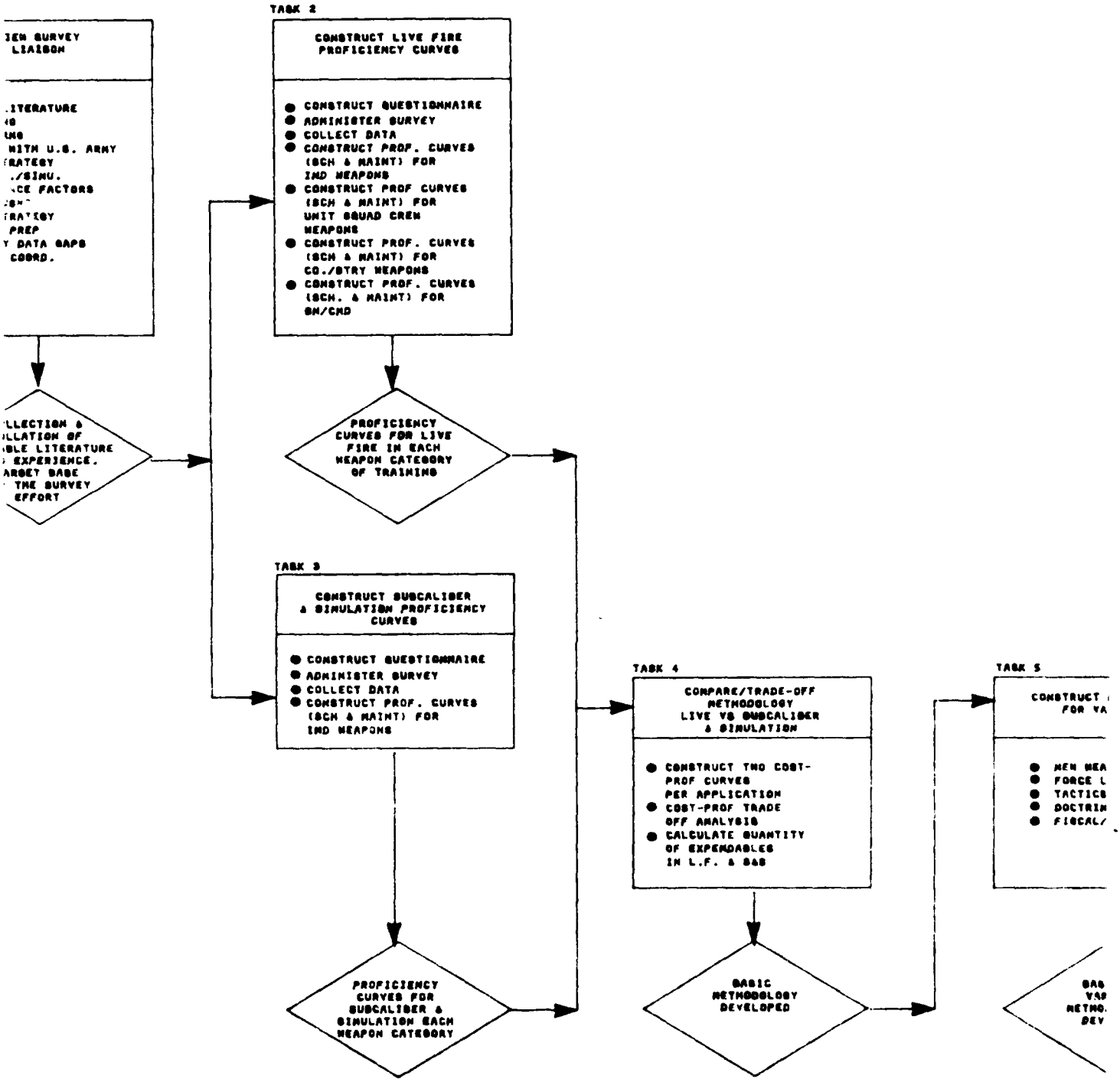
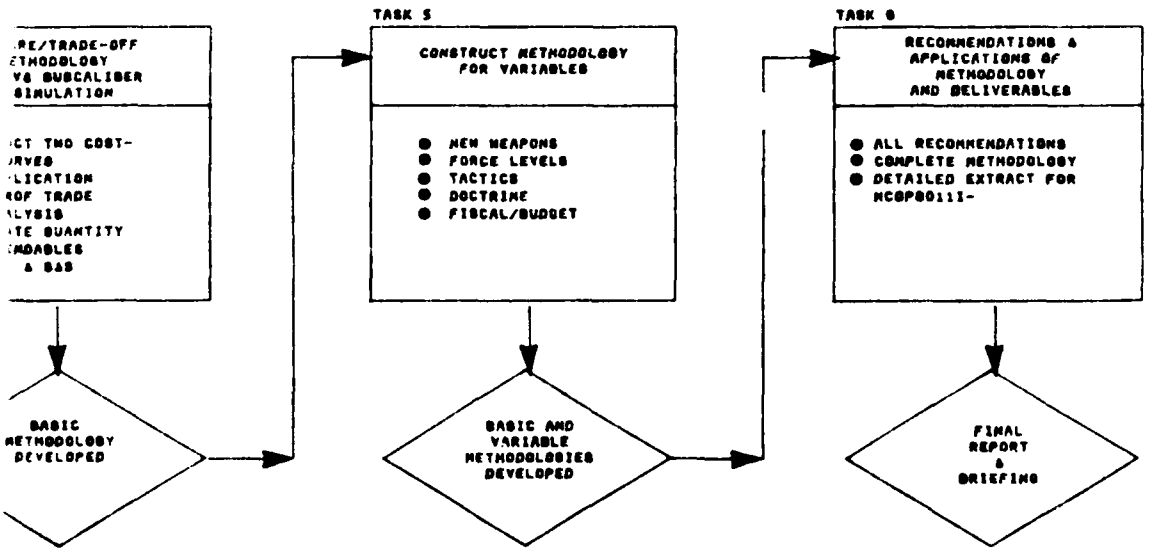


Figure II-1 General Approach to Study Requirements



udy Requirements

CHAPTER III
DISCUSSION

A. THE TRAINING ENVIRONMENT

The Marine Corps' consistent dedication to training readiness is very well known and effectively enunciated in a wide variety of official publications. Also, as a force-in-readiness, the Marine Corps sustains a high operational tempo of peacetime activities. These activities are conducted on a world-wide basis encompassing almost all climatic conditions and terrain variables. Therefore, it is useful to briefly review Marine Corps peacetime commitments, operational tempo, and force posture in order to ensure a contextual picture of the Fleet Marine Force (FMF) training environment. This review will address the Ground Combat Elements of the FMF, the focus of the study effort.

First it should be noted that the Marine Corps maintains a minimum of two forward deployed forces afloat, Marine Amphibious Units (MAUs), on a continuous basis and is expected to be capable of rapidly embarking Marine Amphibious Brigade (MAB) level forces in amphibious shipping to increase the level of forward deployed forces afloat on a world-wide basis. In addition, III MAF is forward deployed in Japan in a "6/9s" configuration to include the 31st MAU (deployed afloat). The five infantry battalions of the 3rd Marine Division (-) are forward deployed to Japan on a unit rotation basis from rotation home bases located in the 1st and 2nd Marine Divisions.

In addition to the basic continuous deployment commitments described above, the Marine Corps is committed:

(1) To provide forces to the Rapid Deployment Joint Task Force (RDJTF) including the 7th MAB related to the Near Term Prepositioning Ship concept,

(2) To provide ready Battalion Landing Team (BLT) level forces in an alert status related to both airlifted and amphibious contingencies, and

(3) To conduct both amphibious and other major exercises on a regular basis in support of JCS and unilateral training objectives.

The other major factors fundamental to the training environment are:

(1) The force basing posture,

(2) The availability/location of appropriate training areas to include live fire ranges, and

(3) The personnel turnover or turbulence generated by the high operational tempo and unit rotation.

In regard to the basing posture related to training areas and live fire ranges, it should be noted that only at 29 Palms, CA, is there an effective match of basing and training areas. All other basing posture-training area combinations are a maze of mismatches. In regard to personnel turnover, it should suffice to state that the perishable nature of unit training in an environment of significant personnel turbulence makes unit training readiness one of the most difficult problems facing today's Marine Corps.

The above review reveals nothing new to the intended readers and evaluators of this report. Rather, it serves as a reminder of the FMF training environment in which the study group attempted to form positive and productive conclusions and recommendations.

B. TANK GUNNERY

1. Introduction

Tank gunnery is predominantly direct fire at a point target by a crew operating from within a single tank. A tank crew normally consists of a commander, driver, gunner, and loader, who are cross-trained for all crew functions and operate as a single entity within a platoon of 5 tanks. The crew observes and selects targets, delivers direct fire on the target, observes strikes, adjusts fire and observes results. The live-firing portion of the MCCRES for tank gunnery measures the proficiency of a crew to attain a "hit" on moving and stationary targets at various ranges within

prescribed time limits. Lack of availability of hard data from unit training records and administration of MCCRES tests required a data collection effort which resulted in the development of questionnaires to be administered by mail to selected USMC tank gunnery experts. The list of experts was selected by the USMC by name and provided to the contractor, who established direct contact with the recipients.

The tank gunnery survey was designed for company commanders and battalion training officers calling for judgments from their experience in conducting and evaluating tank crews progressing through gunnery training to achieve and maintain proficiency. In order to obtain subjective estimates of the probable correlation between qualification scores and ammunition allocation, the questionnaire was structured to examine variations in the amount of full caliber ammunition, sub-caliber and simulation substitution, tank crew experience and turbulence, training frequency and requalification. The tank gunnery questionnaire was specifically structured to parallel the Army tank gunnery test program so that data resulting from the tests can be applied to the tank gunnery methodology developed in this study.

2. Tank Gunnery Survey

a. General Description

To determine the ammunition expenditure necessary to attain and maintain required levels of proficiency in tank gunnery, a course of action was adopted which utilized a questionnaire and personal interview procedure. This provided field data that permitted an analysis which compared the impact on training proficiency of the utilization of varying amounts of full and sub-caliber training ammunition. To provide the field data, a total of nine (9) USMC experienced trainers selected by the project officer were surveyed utilizing a questionnaire procedure.

b. Questionnaire Respondents Experience and Selection

Table III-1 summarizes the experience of the respondents. Officer personnel (8 officers) were in the grade of Lieutenant Colonel, Major and Captain. All had served as platoon leaders and company commanders of tank units. One had served as a battalion commander. Five (5) had

TABLE III-1. SUMMARY OF ARMOR EXPERIENCE OF QUESTIONNAIRE RESPONDENTS

UNIT EXPERIENCE (YEARS)

	RANK	USMC SERVICE (YEARS)	ARMOR EXPERIENCE (YEARS)	PLAT LDR	COMPANY EXO/CO	BN & SCHOOL STAFF	BN CO	GUNNERY RANGE EXPERIENCE	USA ARMORED SCHOOL GRADUATE
1.	O-5	20	6 1/2	X	X	X (C)[1]	X	X	X
2.	E-8	13	10 1/2	X[2]	---	---	---	X	---
3.	O-4	15	8 1/2	X (C)[1]	X (C)[1]	X	---	X	X
4.	O-5	18	8 1/6	X	X (C)[1]	X	---	X	X
5.	O-4	11 1/2	7	X	X	X	---	X	X
6.	O-5	16	4	X (C)[1]	X (C)[1]	X	---	X	---
7.	O-3	9 1/2	4	X	X	---	---	X	X
8.	O-3	7	3 1/4	X	X	X	---	X	X
9.	O-4	14	9	X (C)[1]	X	X	---	X	X

NOTE:
1. (C) INDICATES COMBAT EXPERIENCE.
2. SERVED AS CREW MEMBER, SECTION LEADER AND PLATOON SGT. NOW A TANK BN MASTER GUNNER.

served in combat in Vietnam with USMC tank units. All but one of the officers had attended the USA Armored School at Fort Knox. The one officer (Lt. Colonel) who had not attended a course at Ft. Knox was the current USMC Liaison Office at the Armored School.

The Gunnery Sergeant who completed the questionnaire has served approximately all of his military career in tank units (active and reserve). Currently, he is serving as Battalion Master Gunner. In summary, these nine individuals are highly experienced USMC tankers.

c. The Questionnaire

1) General

The tank gunnery questionnaire is appended as Tab A-1 to Annex A. The questionnaire solicits subjective judgments from the respondents in the following aspects of tank gunnery training:

(1) Armor Operations and Training Experience,
(2) First Qualification Test Program,
(3) Requalification Test Program,
(4) Platoon Test Program,
(5) Effects of Turbulence of Crew and Platoon Performance, and
(6) Effects of Frequency on Crew and Platoon Performance.

2) Questionnaire Parameters

The questionnaire utilizes the tank gunnery tests contained in FM17-12 for the main gun. The live fire tables utilized in the questionnaire were:

(1) Zero-Main gun,
(2) VI Static Tank - Static/Moving Targets,
(3) VII Tank Combat Course (Practice),
(4) VIII Tank Combat Course (Qualification), and
(5) IX Platoon Battle Run

The tank gunnery tests were utilized in determining subjective data for the qualification, requalification and platoon proficiency analysis in which varying amounts of ammunition was used.

With full caliber ammunition and sub-caliber as variables, three strategies were used with the amount of simulation increased

from 0 to 30 to 90 percent. In the platoon test the amount of sub- and full caliber fire was varied. Proficiency factors utilized were:

Distinguished - 90 - 100%
Superior - 80 - 89%
Qualified - 70 - 79%
Unqualified - less than 70%

3) Training Devices

The training devices used in questionnaire included the M-55 laser trainer, Brewster device, Telfare device, TXV, Perceptronics, and Detras.

d. Administration of the Survey

The questionnaires were forwarded to each expert. The purpose was indicated and their subjective answers based on their military experience to the questions posed was solicited. The forwarding letter stressed the belief that live rounds must be expended during training in order to attain and maintain combat readiness. On the other hand, with the increased costs of training ammunition, it was believed to be essential that expenditures had to be fully justified in attaining and maintaining mission required combat readiness. A limitation in this survey was the size of the sample which was limited to nine (9) individuals by OMB Rule 5-CSR-1320.

e. General Remarks of Survey Respondents

The general remarks of the tank gunnery survey respondents were as follows:

- Lieutenant Colonel - 6 1/2 years Armor experience

  "Direct supervision as battalion CO of tank gunnery for 40 months of tank crews, platoons and companies. Units fired established gunnery tables both sub-caliber and service ammunition. Was ARMVAL Test Force Commander. Used laser engagement, TV cameras and hit sensors. Tank gunnery experience of a total of 80 months. Served also as Chief Evaluator for 2nd and 3rd Tank Battalions annual qualification."

- Major - 8 1/2 years Armor experience

  "Answers to questionnaire are educated guesses, since little USMC data available on USMC tank battalion qualification percentages. USMC lacks gunnery ranges."

- Lieutenant Colonel - 8 1/2 years Armor experience
"Estimates based on how USMC trains - Once a year sends crews to an Army range to fire unfamiliar tables. Crews have a hard time staying together. Ammunition requirement should be based on ranges to be used. Has never seen a platoon participate in a Table IX exercise. Ranges are not adequate for Table IX."

- Major - 7 years Armor experience
"Have been involved in tank gunnery training in M-48A3 and M-60A1. Trained at Camp Pendleton, 29 Palms, Okinawa, and Camp Fuji. I consider myself an experienced tank officer."

- Lieutenant Colonel - 4 years Armor experience
"Combat experience as a company CO. Trained at Camp Lejeune and participated in gunnery training at Fort Stewart."

- Captain - 4 years Armor experience
"Platoon leader in Okinawa. Tank gunnery there was severely limited. Spent two months at Camp Fuji, but not with tank platoon. However, did observe gunnery. Stationed at 29 Palms during activation 3rd Tank Battalion. I was company commander and executive officer for five months, but due to non-availability of tanks little gunnery was conducted."

- Captain - 3 1/4 years Armor experience
"As a platoon leader conducted all platoon gunnery qualifications. As a company commander conducted gunnery training Tables I-IV and VII to IX."

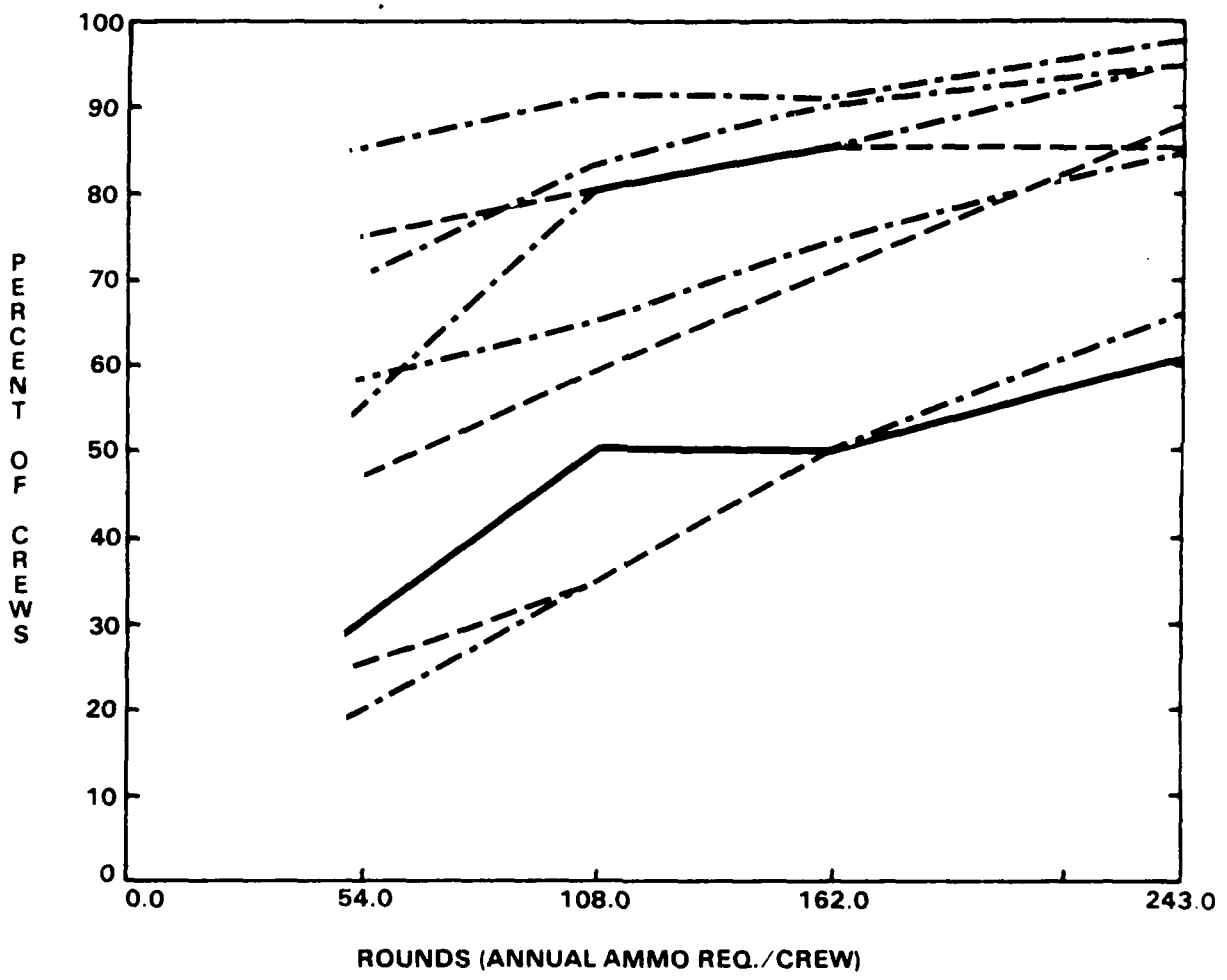
- Major - 9 years Armor experience
"Maintained schools situation tanks and observed/participated in a large portion of officer enlisted crew training. As the OIC tank section Camp Fuji, Japan planned/conducted gunnery training for BLT platoons as they rotated through."

3. Results of the Survey

a. Effects of Ammunition Use on Qualification

1) Total Ammunition Allocation

Typical data are shown from the survey in Figure III-1 for the percentage of crews qualified as a function of the number of rounds of full caliber ammunition fired annually. The total number qualified includes the three categories of qualified, superior, and distinguished. The figure demonstrates the wide spread of estimates obtained from the respondents to the survey. At the normal allocation of 162 rounds per year, the estimates of the proportion of crews qualifying varies form 50 to



NOTE: EACH CURVE REPRESENTS THE SURVEY RESPONSE OF ONE EXPERT

Figure III-1. Individual Estimates of Proportion of Crews in Total Qualified Group as a Function of Full Caliber Rounds (First Qualification)

91 percent. The estimates also vary considerably in terms of the change in the proportion of crews qualified as the ammunition allocation is reduced to a low value of 54 rounds per year from the nominal value of 162 rounds. The minimum estimated change is 5 percent at the minimal allocation, from 90 to 85 percent at 54 rounds. The maximum estimated change is 30 percent, dropping from 50 percent at the normal allocation to 20 percent at 54 rounds. Figure III-2 summarizes the data contained in Figure III-1, showing the mean, the maximum, the minimum and the standard deviations at each ammunition allocation. The large values of the standard deviation emphasize the large spread of estimates. In addition to the variation shown, the respondents indicated that there is a plus or minus 5 to 10 percent uncertainty in their estimates.

The proportion of crews in each qualification category is shown in Figure III-3. Individual lines in the figure represent the estimates of each respondent for the case of a normal full caliber ammunition allocation. It is assumed that the average unqualified score is 65 percent of the maximum score. The minimum, maximum, and mean values of the proportion of crews in each qualification category are shown in Figure III-4. The total mean score for that case is 76.08.

The mean scores were computed for each full caliber ammunition allocation case for crews undergoing their first qualification and those in a subsequent annual qualification. As shown in Figure III-5 for both cases, there is little variation in the mean score as the ammunition is varied from one-third the normal allocation to 1 1/2 times the normal allocation. If the ammunition allocation were reduced to one-third of the current amount, the mean estimate indicates a reduction of four percentage points in the percent of maximum score. Increasing the ammunition allocation to 1 1/2 times the normal would be expected to increase scores by only one percentage point. As would be expected, the results show an estimate that crews returning for subsequent annual qualifications would score consistently higher. The amount of increase is about three percentage points.

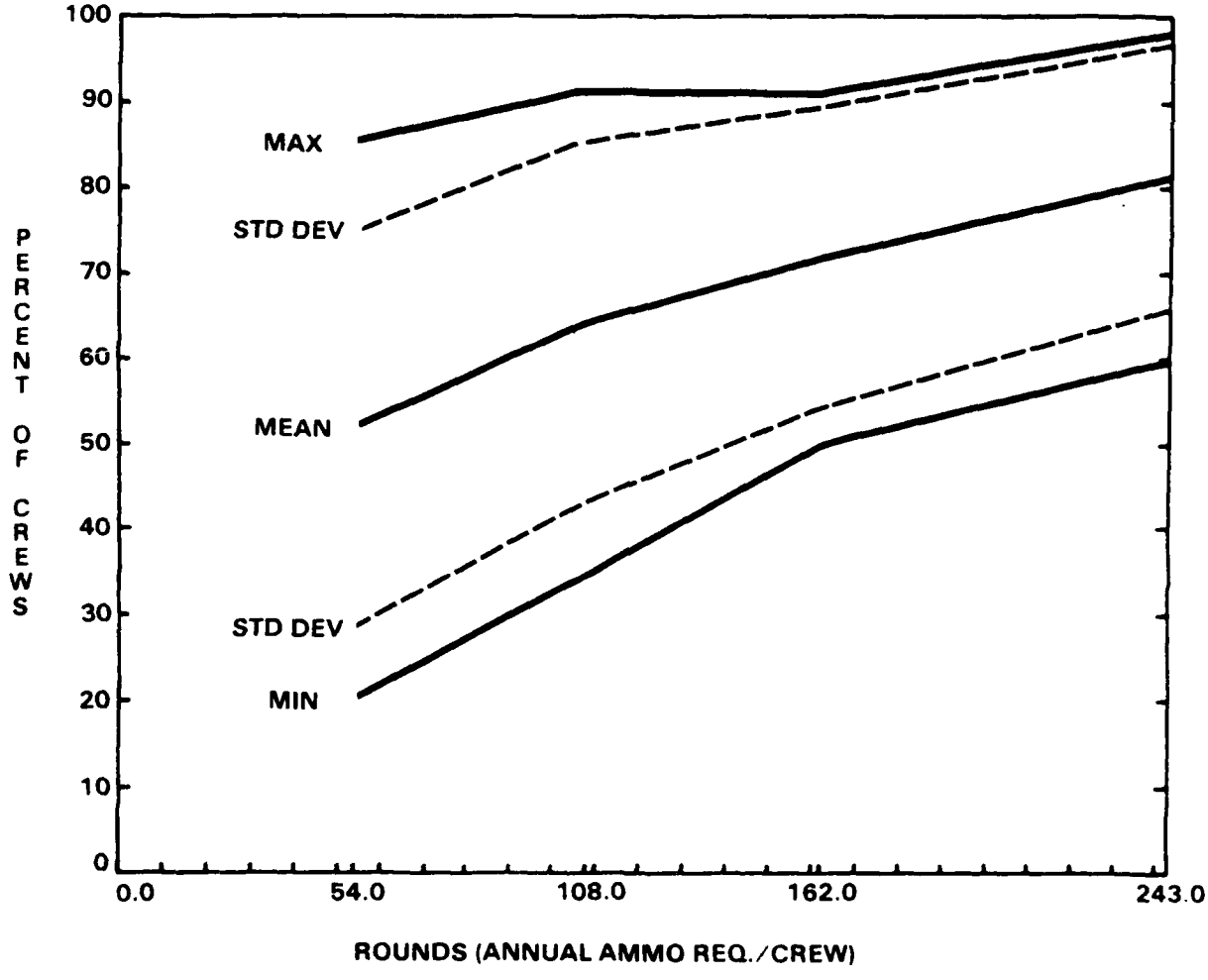


Figure III-2. Summary Data on Total Qualified Crews as a Function of Full Caliber Rounds (First Qualification)

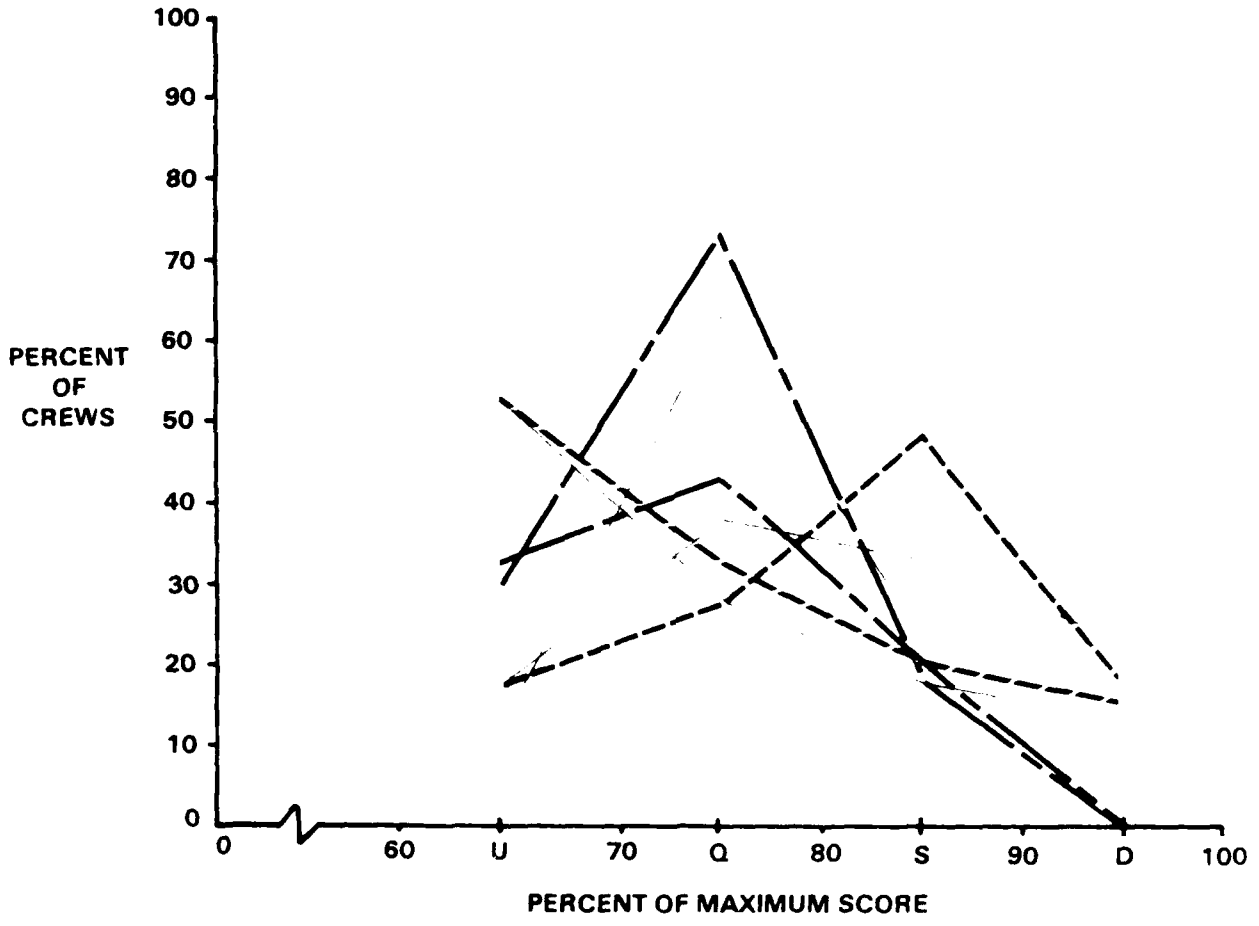


Figure III-3. Individual Respondents' Estimate of Crews in Each Qualification Category - Normal Full Caliber Ammunition Allocation

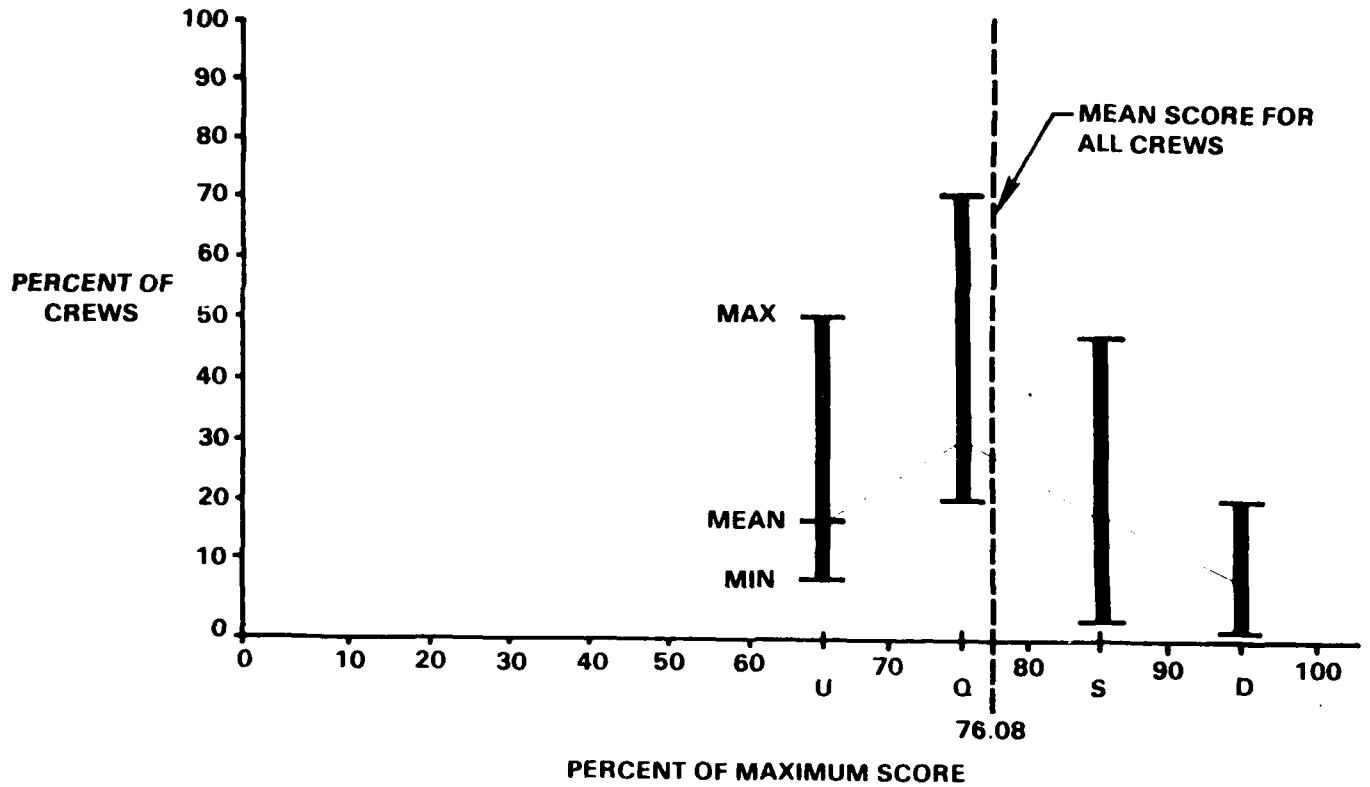


Figure III-4. Maximum Mean, Minimum Percent of Crews in Each Qualification Category - Normal Full-Caliber Ammunition Allocation

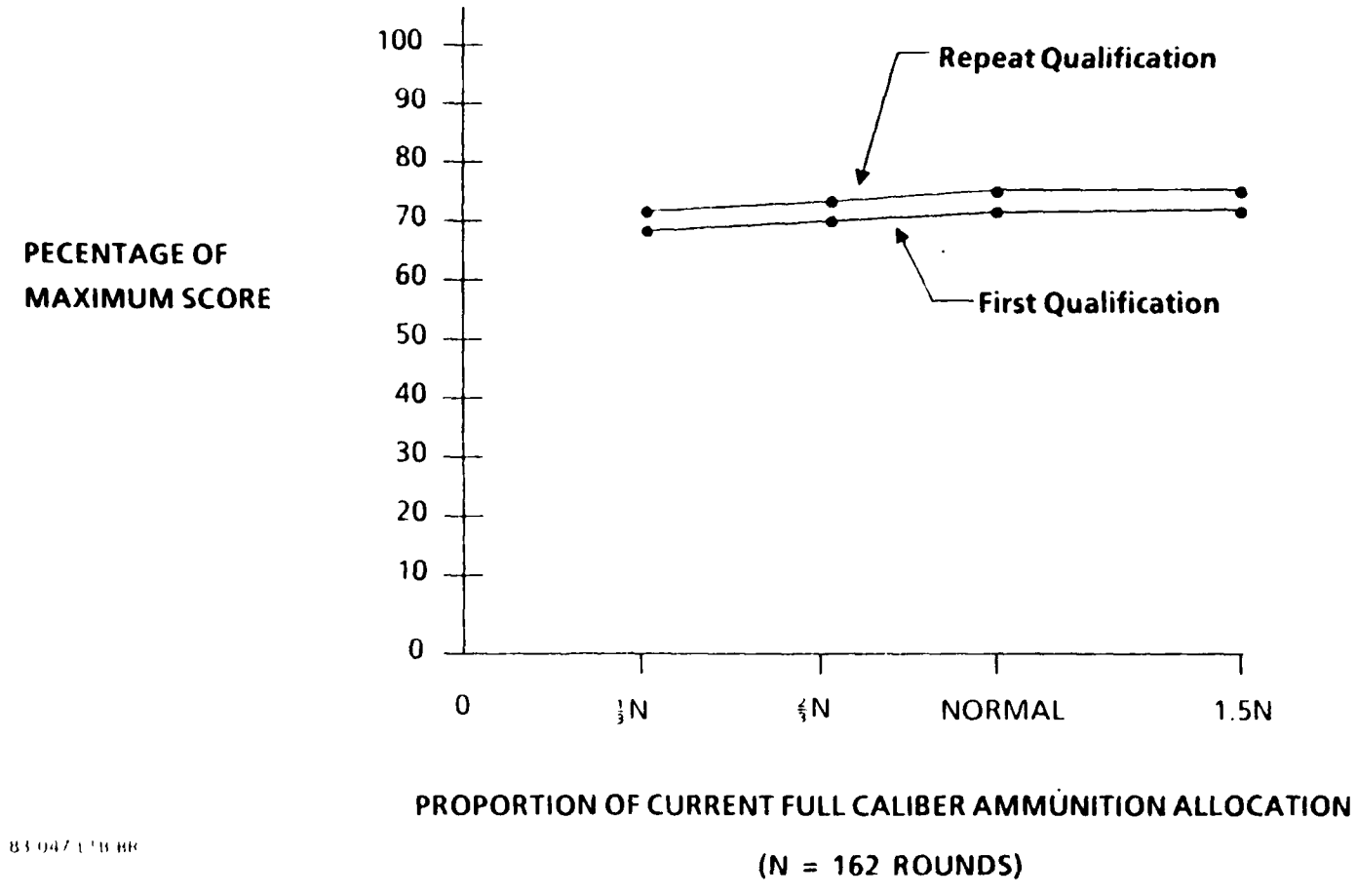


Figure III-5. Mean Crew Scores as Function of Full Caliber Ammunition Allocation

It is obvious from the data presented in Figure III-1 that there is no concensus on the current scores achieved by tank crews. Furthermore, even if the mean score for the normal allocation of ammunition were to be determined accurately, there still remains uncertainty as to how scores would change with a change in ammunition allocation. To gain some understanding of how large the uncertainty might be, the data from Figure III-1 were examined to find the individual estimating the greatest change in score in response to a change in ammunition. The change in score that an individual predicts for a change in ammunition was then compared against the mean values of the estimates. The result is shown in Figure III-6. The worst case differs from the mean by only five percentage points when the ammunition allocation is reduced from the current allocation to one-third of the current level. This shows more consistency among the respondents in estimating the effects of changing ammunition than in estimating the proportion who qualify for any given amount of ammunition.

2) Substitution of Sub-caliber

The effect of substituting sub-caliber for full caliber ammunition and of using various amounts of simulation in the pre-table training are shown in Figure III-7. These results also show little sensitivity of crew score to changes in the amount of full caliber ammunition. There is a drop of only three percentage points in the crew scores when Tables VI and VII are fired with only sub-caliber ammunition. The data also show that crews returning for subsequent annual qualification are expected to score four to five points higher than crews taking the qualifying test for the first time. This effect is much greater than the use of simulation in the pre-table training. The maximum individual estimate of the impact of using sub-caliber ammunition is shown in Figure III-8. It shows a five percentage point drop in score with the use of sub-caliber ammunition in Tables VI and VII.

3) Platoon Effects of Total Allocation and Sub-caliber Substitution

The effects of reducing full caliber ammunition allocations or of substituting sub-caliber for full caliber are shown for tank platoons in Figure III-9. As with the crew results, there is only a small

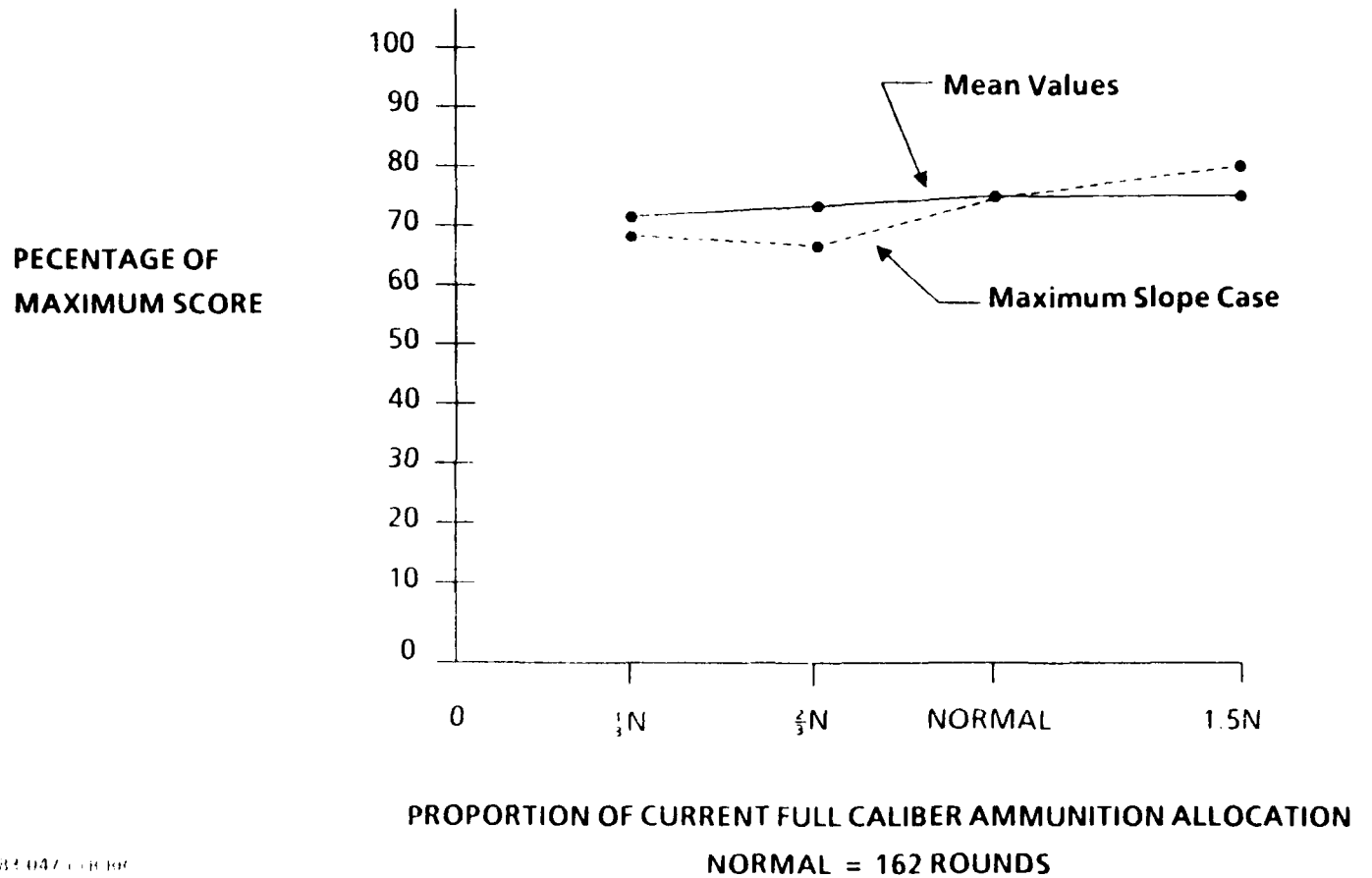


Figure III-6. Maximum Sensitivity to the Amount of Full Caliber Ammunition Allocation

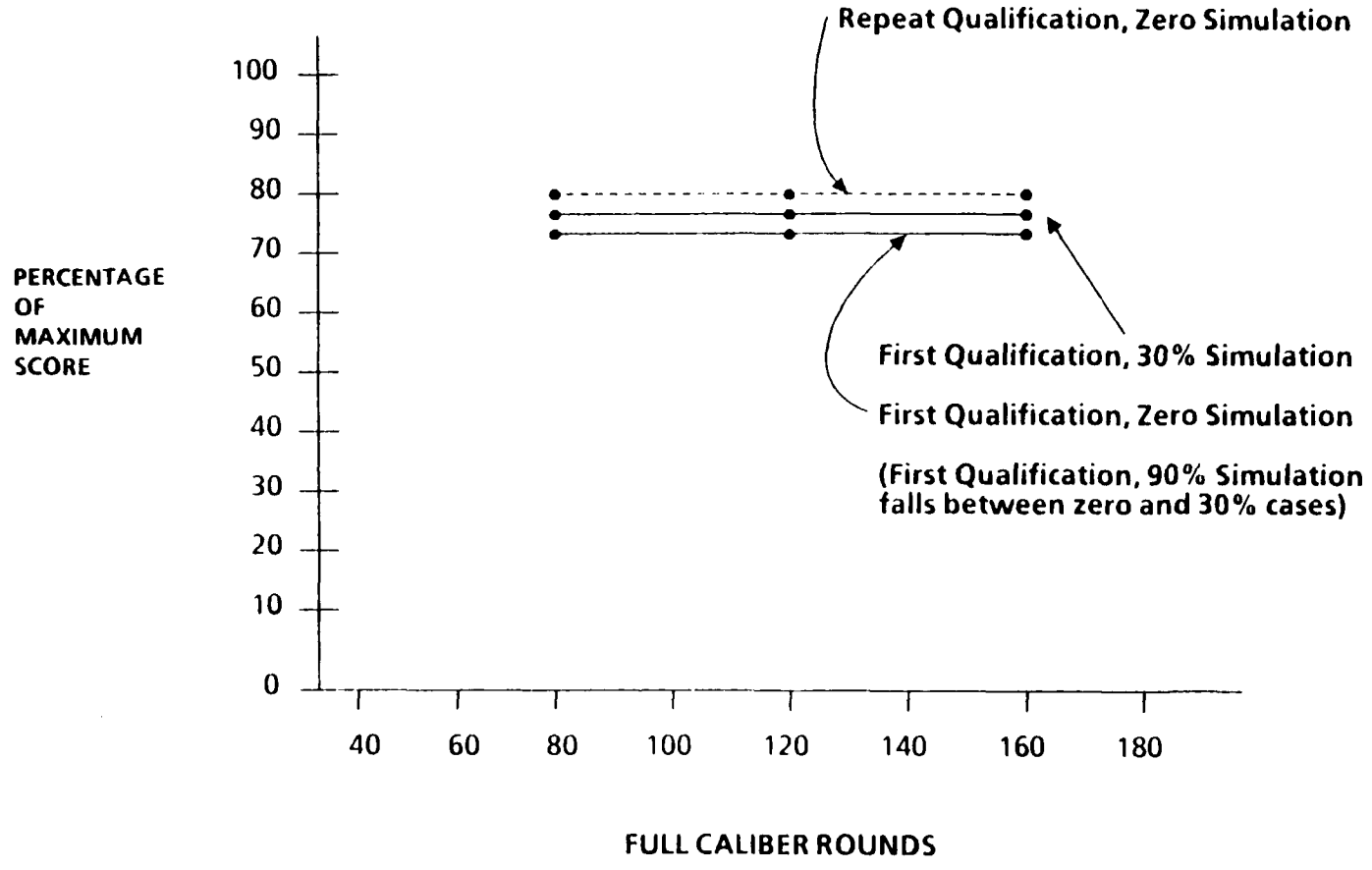


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Figure III-7. Crew Scores with Subcaliber Substitution and Variation in Amount of Simulation in Pre-Table Training

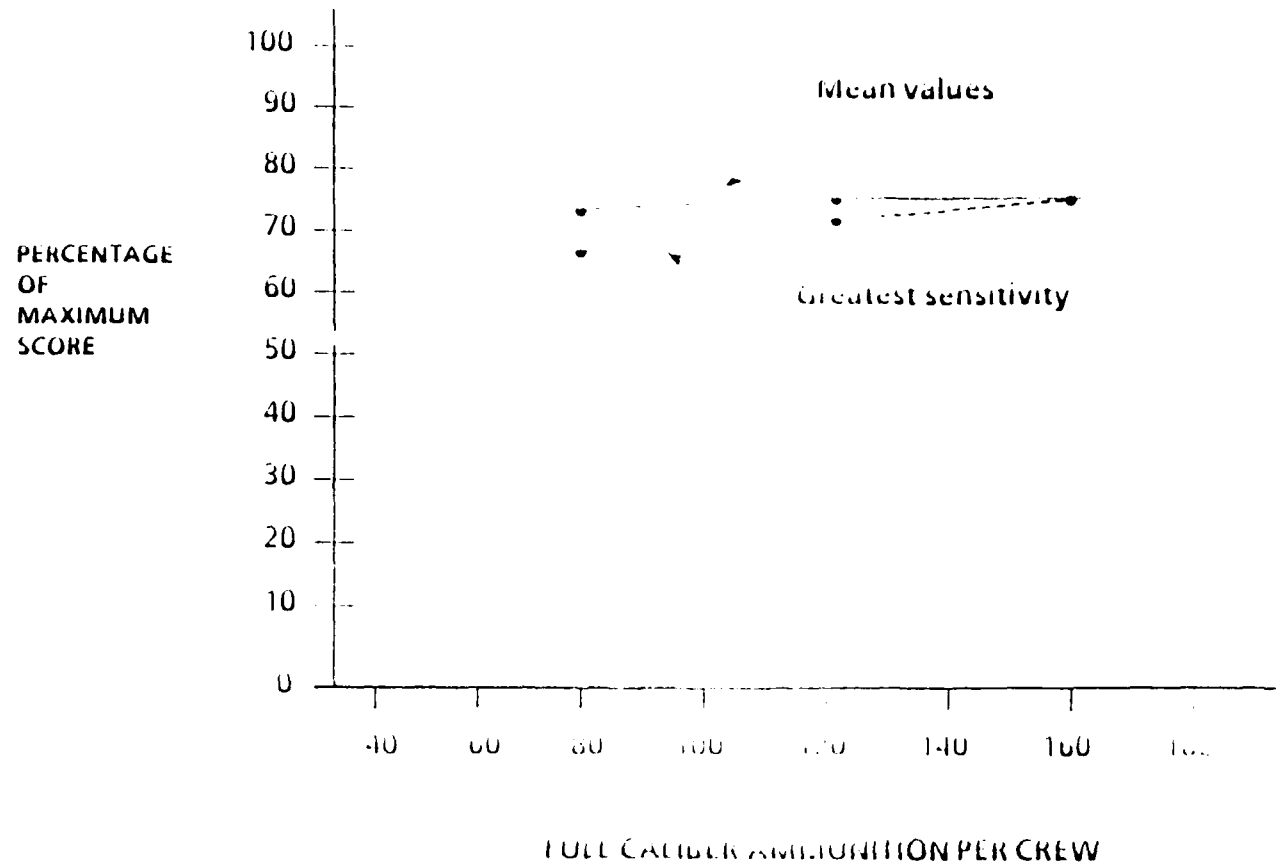

Figure III-3. Greatest Impact Estimate for Subcaliber Substitution

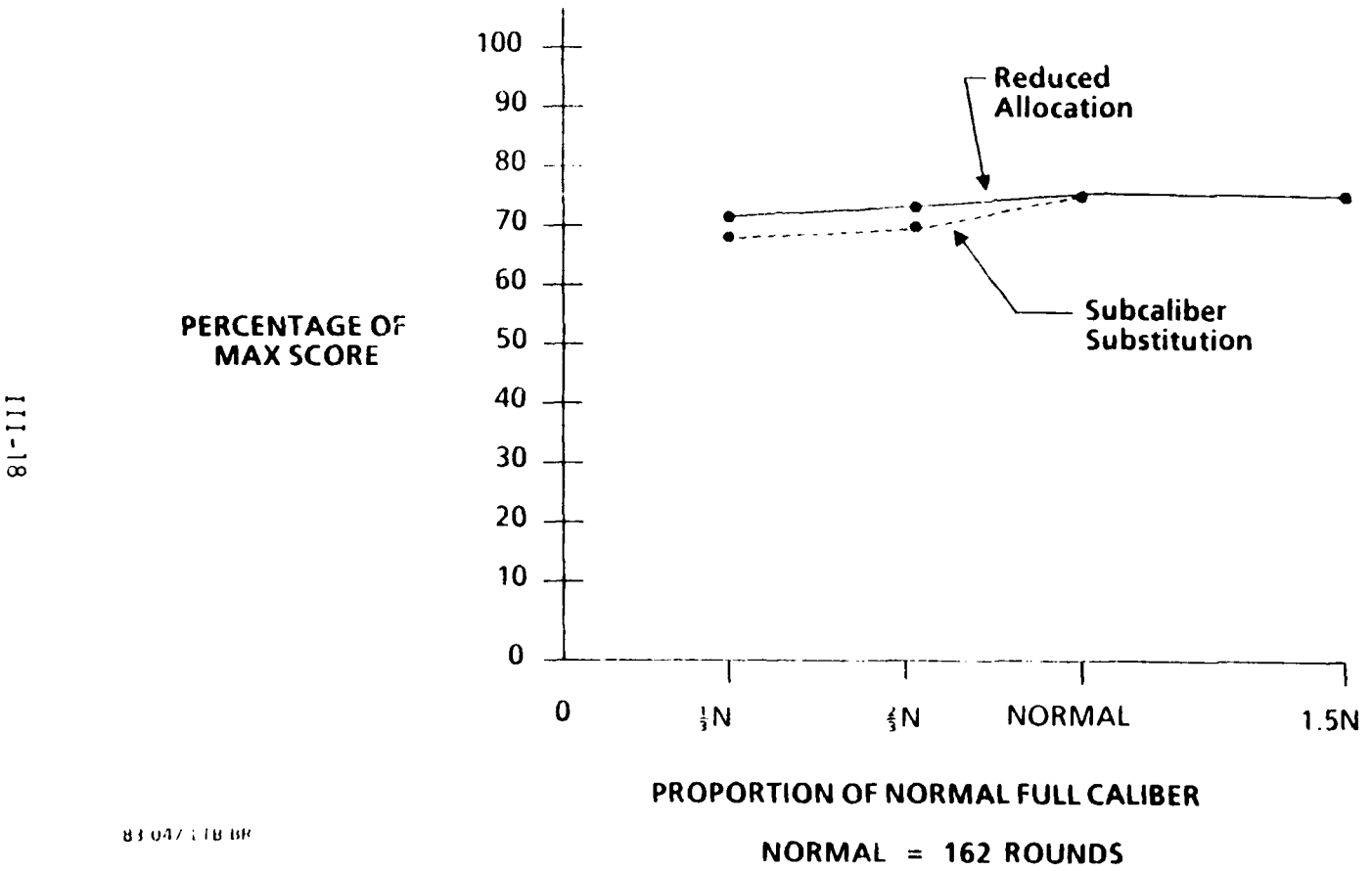

Figure III-9. Platoon Test Results

effect of either changing the allocation of full caliber ammunition or of substituting sub-caliber.

4) Turbulence Effects

Effects of turbulence are shown in Figure III-10 for crews and in Figure III-11 for platoons. The effects are significant in both cases. Crew turbulence is estimated to produce a change of 9 percent in the mean score. This corresponds to a mean change of 27 expected to qualify when three or four of the crew change, as shown in the survey results (see Figure A-10 in Appendix A). Platoon turbulence is estimated to produce a 7 percent change in the mean score when five new crews are present in the platoon. Hard data are needed to identify more precisely the effects of both crew and platoon turbulence, but it is evident that it can be and most likely is an important factor in performance.

5) Frequency of Training

The effects of frequency of training are shown in Figure III-12 for crews and Figure III-13 for platoons. The results for both crews and platoons are very similar. The mean score for each is expected to drop by about one percent per month when there is no training.

6) Conclusion

The major result of the data obtained from the survey is that sharp reductions in ammunition appear to be possible. Collection of training data is needed to verify these conclusions and to identify specific reductions. Procedures to collect and analyze the needed data are described in Paragraph III-C4, Methodology.

b. Effects of Allocation on Total Ammunition Use

A major concern of the current study is the degree to which changes in the allocation of ammunition will effect total Marine Corps training ammunition requirements. The usual approach in changing ammunition allocation is to change the amount given to each crew or platoon with no variation across the board except for differences in mission or current status. With this approach, a decrease in the allocation of ammunition can be expected to produce a small decrease in the number qualified. A slightly different approach is possible, however. It is inferred in the

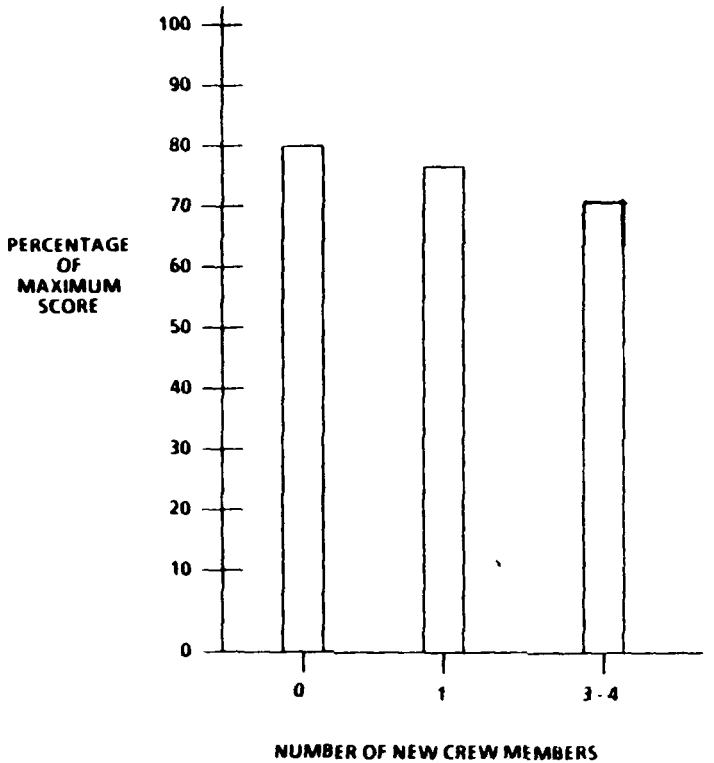

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Figure III-10. Effects of Turbulence on Crew Performance

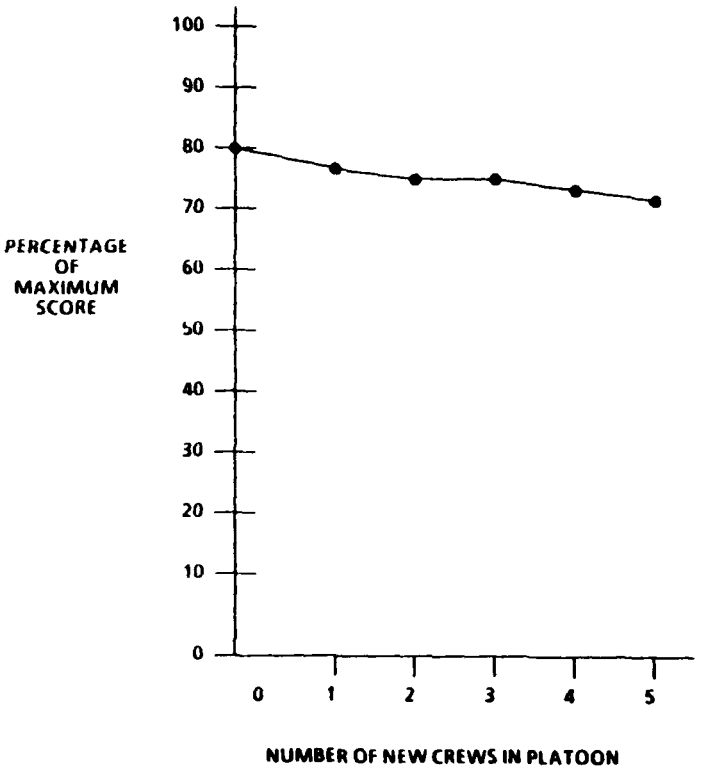


Figure III-11. Effects of Turbulence on Platoon Performance

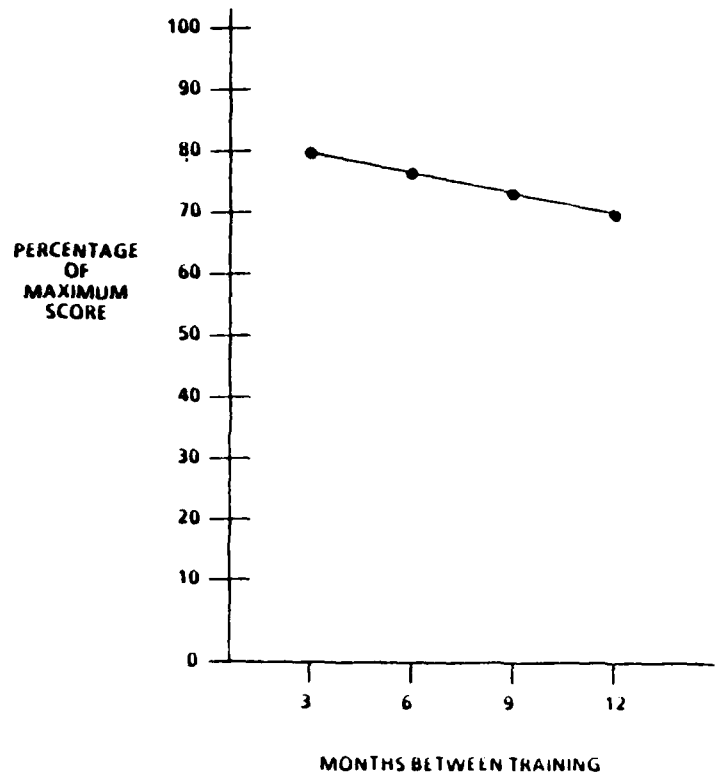


Figure III-12. Frequence of Training on Crew Performance

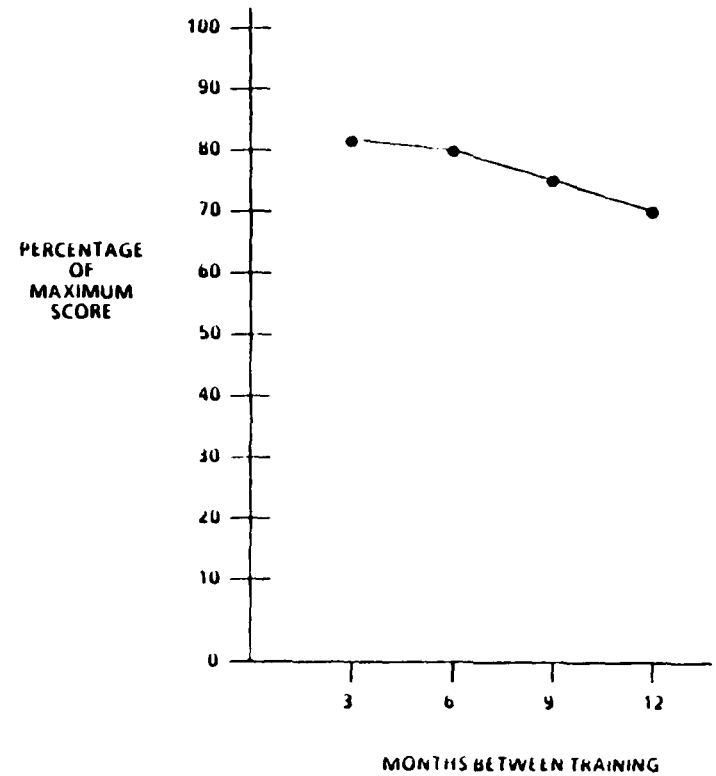


Figure III-13. Frequence of Training on Platoon Performance

suggestion in the Army Field Manual FM17-12 that crews or platoons not qualifying be allowed to reshoot until they achieve the necessary proficiency. This would suggest that the ammunition allowance might be reduced in general, but that those crews or platoons not qualifying be issued an additional allocation until they do qualify. It is not immediately clear whether this would result in a net saving of ammunition or not. An analysis was conducted to see if there are potential savings to be found in that approach.

The idea of reducing ammunition allocations and then providing additional ammunition for unqualified crews to continue shooting until they do qualify was analyzed in the following sequence of steps:

(1) Since there are no hard data to identify accurately the proportion of crews qualifying under the current or normal ammunition allocations a nominal point had to be picked for analysis. It was assumed that the mean value of the proportion of crews qualifying under the normal allocation is representative of the current situation.

(2) Each of the questionnaire responses was normalized to the mean value selected in Step 1. As a result, each respondent's curve on the estimated proportion of crews qualifying for various ammunition allocations passed through the mean value point as shown in Figure III-14.

(3) The maximum, minimum and mean values of the proportions of crews qualifying under different conditions was determined, as shown in Figure III-15. It is assumed that the qualifying crews fired only their allocation of ammunition. It was assumed that the crews not qualifying with the original allocation would shoot the average number of times indicated from the survey. (The survey included a question on how many reshoots would be typically required for a crew that did not qualify the first time.)

The sequence of events followed on this training concept and the numbers assumed to represent the amount of ammunition are shown in Figure III-16. The resulting use of ammunition is shown in Figure III-17.

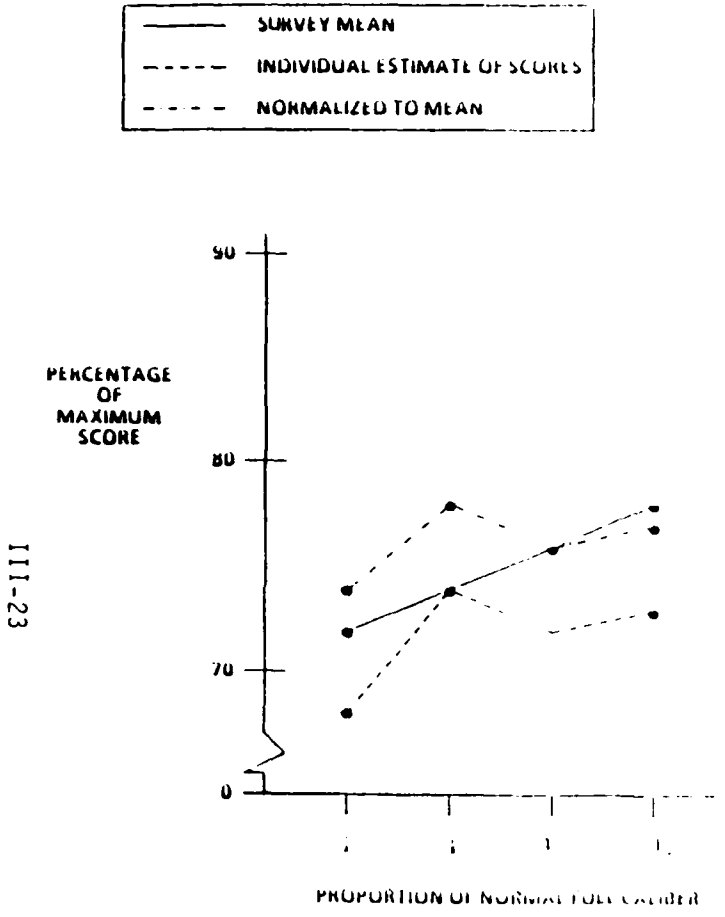


Figure III-14. Normalization of Individual Estimate Scores

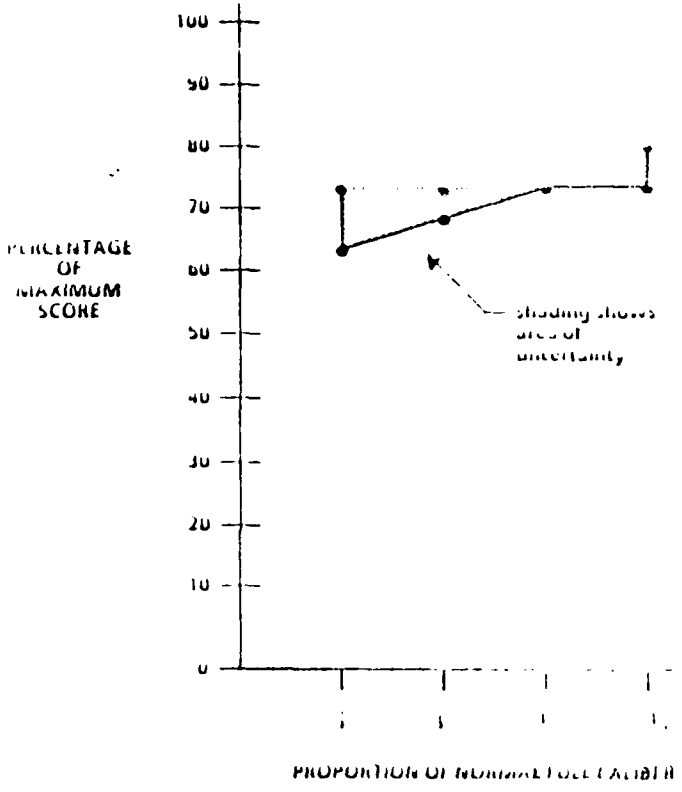


Figure III-15. Uncertainty in Estimated Scores

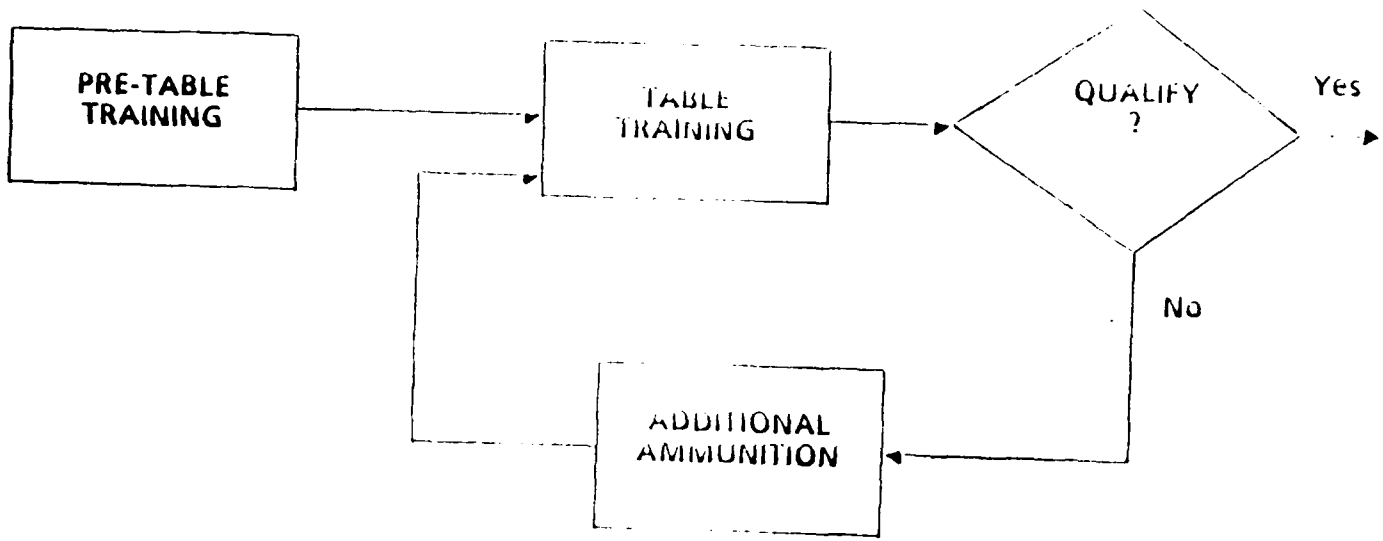


Figure III-16. Reshoot Concept

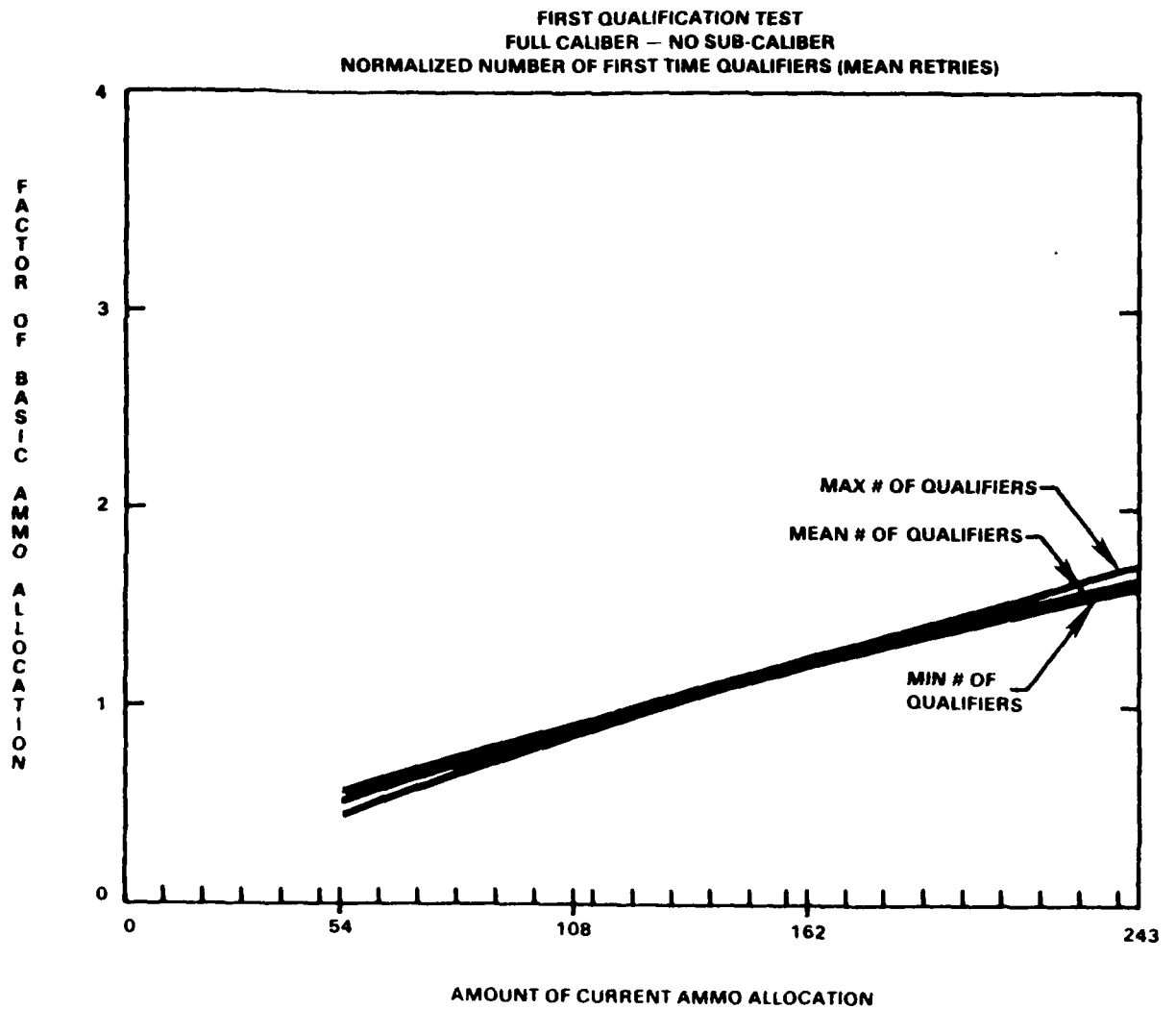


Figure III-17. Total Ammunition Requirement as a Function of Full Caliber (First Qualification, Mean Retries)

The effect of reducing the initial allocation and allowing those not qualifying to reshoot is to reduce the total amount of ammunition for training when the initial allocation is as low as 1/3 of what is currently provided.

The effect on the Marine Corps budget of reductions on the size of those shown in Figure III-17 would be significant. If all 210 tank crews were to fire the ammunition allocations suggested in TC 25-3, the cost would be $7.3 million dollars per year. Going to one-third of the current allocation would reduce the expenditure of ammunition by 55 percent for a savings of $4.0 million.

The possible explanation for the result of Figure III-17 is shown in Figure III-18. Apparently, crews qualify before they fire their total allocation. The remaining ammunition does not contribute to their qualification, although, it may raise their proficency. If the initial allocation of ammunition is reduced, many crews will achieve qualification without firing the full current, or nominal allocation. The unused difference between the reduced and the nominal allocation is available to be used by crews that do not qualify and need additional training. In fact, the net result is that the unused ammunition is more than enough to provide reshoot capability to the unqualified crews. Therefore, there is a net saving in total ammunition. This result is achieved assuming each reshoot uses the same amount of ammunition as the initial attempt. FM17-12 suggests using less ammunition for reshooting. That might further reduce the total amount needed.

Before these analytical results can be treated as truly indicative of the performance of Marine Corps crews and the requirement for ammunition, more data are needed. The data that needs to be collected are described in the following paragraph on methodology. It may also be noted that the concept of reducing the initial allocation of training ammunition to each crew or platoon and then providing additional ammunition to those that do not qualify can work only if crews and platoons have access to ranges to reshoot as often as needed. The approach is offered as a suggestion to the Marine Corps to be examined in greater detail when additional

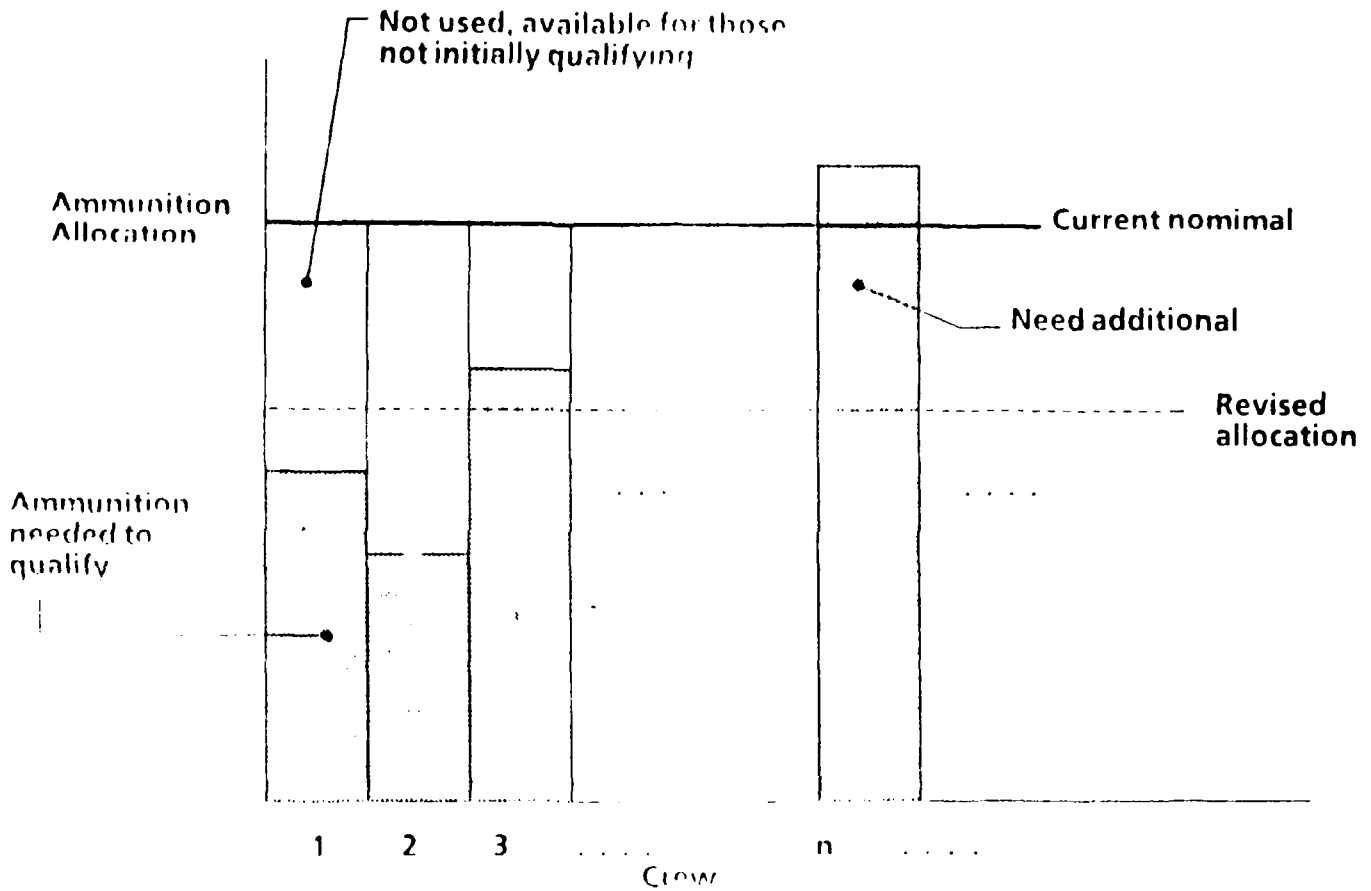


Figure III-18. Reallocation Concept

data become available on the relation between proficiency and the use of ammunition.

4. Training Ammunition Allocation Methodology

a. Basic Requirements

The subjective data obtained from the survey is not consistent nor sufficiently conclusive to derive reasonable ammunition allocation decisions from the results. Gunnery training performance records are inadequate for MCCRES below battalion level, so there are no hard data providing information on crew or platoon performance.

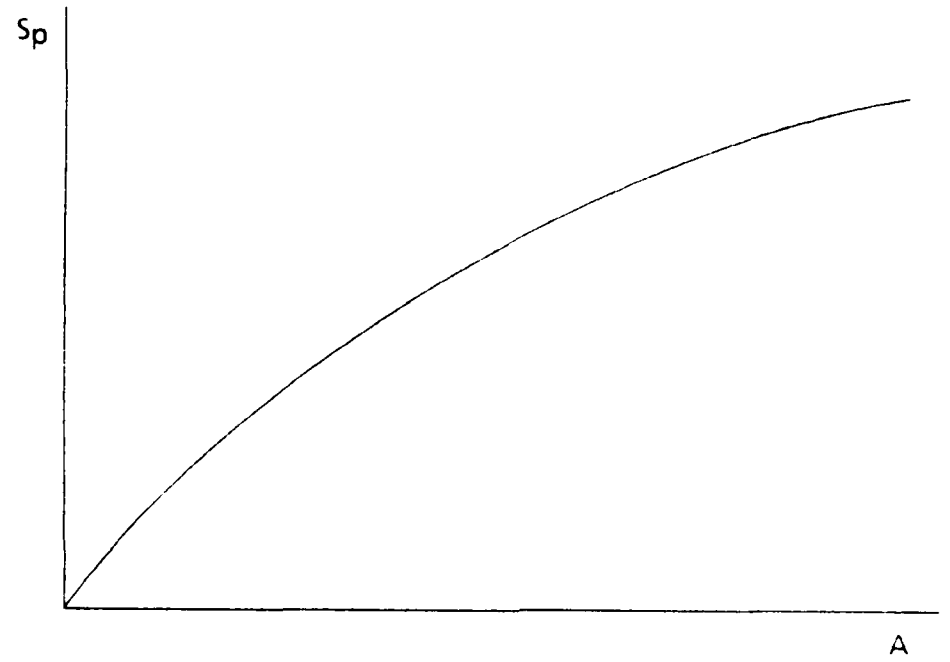
Furthermore, there are no adequate learning theory models to support decisions on ammunition allocation. Learning theory provides some support to use a curve of the general shape shown in Figure III-19. The lack of solid research for the cases we are examining means that you could select almost any arbitrary shape provided it has the general characteristics shown in the figure.

From our general review of the literature and the survey results, it is essential that hard data be obtained directly from US Marine Corps training activities. The following section describes an approach which will provide for the collection, compilation, and analysis of the needed data.

b. Approach

The following steps are required to obtain usable guidelines for the allocation of training ammunition:

(1) Specify and enforce clear standards for tank firing training. Currently the Marine Corps is supposed to be using the standards specified in the US Army Field Manual (FM) 17-12. Standards more directly suited to the Marine Corps may be developed. However, it is more important that a set of standards be used consistently now than to spend time developing a new set and delay the collection the needed hard data. Therefore, immediate enforcement of the use of FM 17-12 is recommended. If the Marine Corps does develop new standards tailored more to its own needs they can be introduced later.



KEY
S_p = Proficiency score as percentage of maximum score
A = Ammunition used

Figuer III-19. Relation Between Proficiency and Ammunition Use

(2) Hard data must be collected from the Marine Corps training program on the performance of tank crews and platoons against the standards. It is necessary to obtain training results for different amounts of ammunition used. Two alternatives are suggested in the next subsection of this chapter ranging from a rigidly structured test to the use of results as they can be obtained from the current Marine Corps training program. The type of data that need to be collected and the forms to use in the collection process are described later in this chapter.

(3) Mathematical models will be used to obtain least square estimates of the proficiency of crews and platoons as a function of the amount of ammunition used. The equations are described later in this chapter but basically consist of an exponential formula for proficiency of crews and platoons as a function of the amount of ammunition used. Linear or quadratic forms are proposed for the relationships between the use of simulation or subcaliber and proficiency, and the effect of turbulence on proficiency.

(4) The selection of the amount of simulation and subcaliber to use will be a function of the cost of each and the practical number of times they can be used by crews and platoons. The procedure for determining the amount of simulation and subcaliber to use will also be described later in the chapter.

c. Data Collection

The data collection and analysis are intended to help determine the following:

(1) The effect of the variation of full caliber ammunition allocations on crew and platoon performance;

(2) The effect of the use of simulation and sub-caliber ammunition as a substitute for full caliber;

(3) The effect of training profiles and mission requirements; and

(4) The effect of turbulence.

The training profile and mission requirements vary considerably for different units in the Marine Corps. The training profile

differs from unit to unit depending on the availability of ranges for live firing, the availability of simulation, and the time available for training. Mission requirements vary considerably for individual units. Some are in a pre-deployment status, others are afloat or stationed in Okinawa or Hawaii, and others are in a post-deployment status after returning to their original units. The number and type of training events that take place throughout the year will be considerably different for each of these units. A description is needed of the sequence of training events if the analysis is going to be able to isolate effects due primarily to ammunition usage.

There are two principal options for obtaining the hard data on crew and platoon performance.

(1) A structured test in which the amounts of ammunition used by each crew and each platoon are rigidly controlled according to a test plan.

(2) The use of available data from the current training program. This last approach assumes that there is enough variation in the use of ammunition under current procedures to provide useful information for the analysis.

In developing a structured test there are three major factors to be reflected in the allocation of ammunition:

(1) The amount of full caliber ammunition given to each crew and platoon, and the amount of sub-caliber ammunition substituted for full caliber.

(2) The amount of pre-table simulation and the type of simulator.

(3) The organization and mission of each crew and platoon.

Each combination of full caliber, full-caliber/sub-caliber mix, amount of simulation, and organizational and mission requirement represents a test element. The assignment of platoons to each test element is a function of its organization and mission. The Marine Corps therefore, will have to make the final allocation. A typical test allocation is suggested in Figure III-20.

ALL MAJOR FACTORS INFLUENCING PROFICIENCY MUST BE INCLUDED

Number of Platoons	Number of Tanks	Ammunition Allocation	Pre-Table Simulation (%)	Organization/Mission
1	7**	Nominal	0	1 TNK Bn
1	7**	"	"	3 TNK Bn
1	7*	"	"	2 TNK Bn/Pre-deployment
1	7*	"	"	2 TNK Bn/Post-deployment
1	7*	"	"	Hawaii/Pre-deployment
1	5	"	"	Okinawa
1	7*	Nominal	90	1 TNK Bn
1	5	"	"	3 TNK Bn
1	7*	"	"	2 TNK Bn/Pre-deployment
1	5	"	"	2 TNK Bn/Post-deployment
1	5	"	"	Hawaii/Predeployment
1	7*	"	"	Okinawa
1	7*	2/3 Full-cal.	0	1 TNK Bn
1	7*	"	"	3 TNK Bn
1	7*	"	"	2 TNK Bn/Pre-deployment
1	7**	"	"	2 TNK Bn/Post-deployment
1	5	"	"	Hawaii/Post-deployment
1	5	"	"	Okinawa
1	5	2/3 Full-cal.	90	1 TNK Bn
1	7*	"	"	3 TNK Bn
1	5	"	"	3 TNK Bn
1	5	"	"	2 TNK Bn/Pre-deployment
1	5	"	"	2 TNK Bn/Post-deployment
1	5	"	"	Okinawa
1	5	1/3 Full-cal.	0	3 TNK BN
1	7*	"	"	2 TNK Bn/Pre-deployment
1	5	"	"	2 TNK Bn/Post-deployment
1	5	"	"	1 TNK Bn

Figure III-20. Tank Test Organization

ALL MAJOR FACTORS INFLUENCING PROFICIENCY MUST BE INCLUDED

Number of Platoons	Number of Tanks	Ammunition Allocation	Pre-Table Simulation (%)	Organization/Mission
1	5	"	"	1 TNK Bn
1	5	"	"	1 TNK Bn
1	7*	"	"	Okinawa
1	7*	1/3 Full-cal.	90	1 TNK Bn
1	5	"	"	1 TNK Bn
1	5	"	"	2 TNK Bn/Pre-deployment
1	5	"	"	2 TNK Bn/Post-deployment
1	5	"	"	Okinawa

*Includes two company command element tanks

**Includes two battalion command element tanks

Figure III-20. Tank Test Organization (Continued)

The recommended assignment of platoons to each test element assumes 36 platoons in the Marine Corps. The control group for the test is represented by the 6 platoons allocated a normal amount of ammunition with zero simulation. One platoon is selected from each of the organization/mission combinations. The five remaining groups vary the ammunition allocation and the amount of simulation. Each platoon in each group represents one of the six organization/mission combinations.

Whether using a structured test or current training program, an example of the platoon reporting form shown in Figure III-21 which is proposed to gather information on each of the five tank crews in the platoon. These forms can be collected quarterly by each battalion S-3 and forwarded to the Marine Corps Development and Education Center at Quantico.

d. Analysis

1) Regression Analysis Methodology

Standard least squares regression methods such as found in Statistical Package for the Social Sciences (SPSS) and other commercial statistical computer programs, should be used to determine proficiency as a function of full caliber ammumition use, and the effects of substituting subcaliber or using simulation. It is recommended that the following equation be used to represent proficiency as a function of full caliber ammunition use:

$$Sp = 100 (1 - e^{K_F F})$$

where Sp = proficiency score as a percentage of the maximum score (from column 3 of data form, Figure III-21a)

F = annual use of full caliber ammunition (from column 4 of data form)

K_F = constant

Other forms can be used to represent the shape of the curve in Figure III-19. The final selection depends on the familiarity of the analyst with particular forms, and the regression computer package available. This discussion assumes the exponential form given above.

Data Will Be Collected Quarterly
a. Ammunition Use and Proficiency

COLUMN 1	2	3	4	5	6
PLATOON	CREW	PERCENT OF MAXIMUM SCORE	AMMUNITION USED		SIMULATION TYPE/#EVENTS
			FULL CALIBER ROUNDS	SUBCALIBER ROUNDS	
1	-				
	2				
	3				
	4				
	5				
2	-				
	1				
	2				
	.				

b. Chronology of Events for Platoons (Example)

Platoon ____

EVENT	CREW	DATE
Table VI	2	11/23/83
Table IV (M55)	1	12/03/83
New Crew Member	2	12/06/83

Figure III-21. Tank Training Data Requirements

The result of the reqression analysis will be the determination of a value for K_F and a curve relating Sp to F as shown in Figure III-22. That curve provides the basic information on the amount of ammunition needed to achieve a selected mean score.

2) Simulation and Subcaliber Substitution

The next step in the analysis is to determine how much simulation and subcaliber ammunition should be used. First, consider the use of subcaliber ammunition.

Using data collected on the form in Figure III-21, the scores associated with the use of subcaliber should be processed in a least squares regression to obtain a curve of the type shown in Figure III-23. A quadratic equation form is probably the most realistic:

$$Sp = Sp_o (1 - K_{SC2} (SC)^2)$$

where Sp_o = score for all full caliber ammunition of amount F_o

SC = amount of subcaliber ammunition

K_{SC2} = constant

It may be appropriate to try a least squares fit on a linear function of the form:

$$Sp = Sp_o (1 - K_{SCI}(SC))$$

This option should be examined by the analyst when hard data are available.

When a form has been selected and a curve determined by regression, the next step is to determine how much subcaliber is required to substitute for a given amount of full caliber. Until hard data are available it is reasonable to assume that the amount of subcaliber ammunition to substitute for each round of full caliber will increase as the proportion of subcaliber in the training ammunition allocation increases. That is, as you rely more and more on subcaliber ammunition for training, its deficiencies become more apparent and you have to substitute more subcaliber rounds for each full caliber round to keep the same proficiency.

Assume a particular proficiency score Sp_o, is selected as desired mean proficiency level. Then, Figure III-22 shows there is a requirement for F_o rounds of full caliber ammunition. Now you want to find out how much subcaliber you can substitute for full caliber and still have

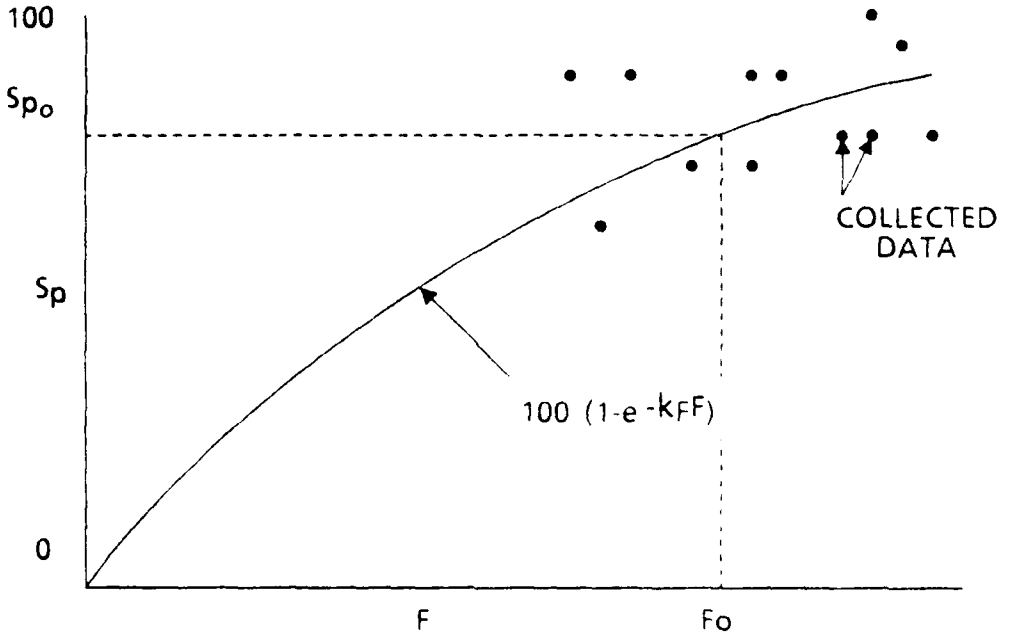


Figure III-22. Least-Squares Fit of Proficiency Curve to Data

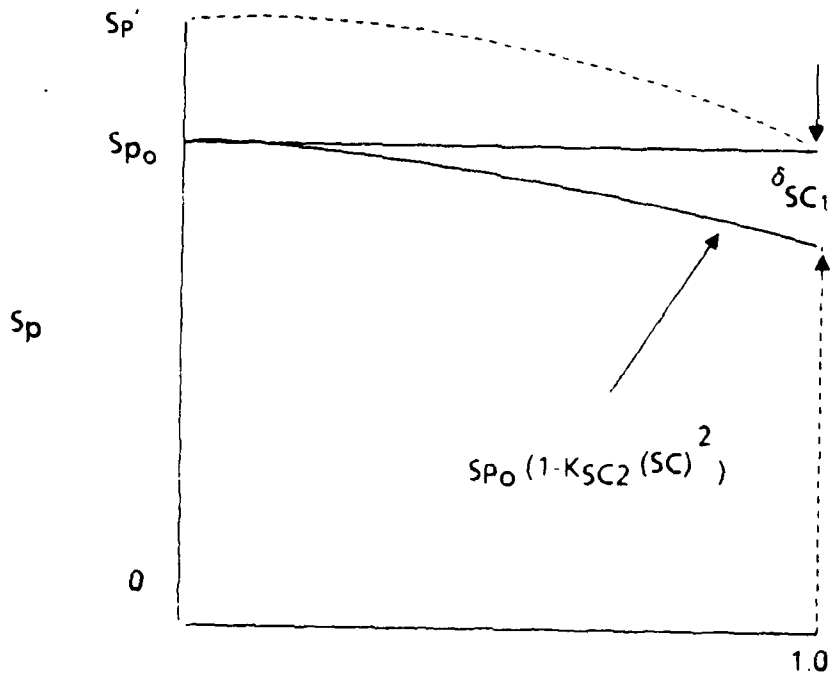


Figure III-23. Effect of Subcaliber Use on Proficiency

a score of Sp_o. You need a new curve as shown in Figure III-24 for the amount of subcaliber as a function of the amount of full caliber. At $F = F_c$ you have no substitution. At $F = 0$ you have all subcaliber. From Figure III-23, this implies a drop in score to $Sp_o - S_{SC1}$. If we assume the shape of the curve in Figure III-23 is the same regardless of the value of Sp_o, then we can obtain an estimate of how much subcaliber is needed to maintain Sp_o as follows:

(1) Compute $Sp' = Sp_o + S_{SC1}$

(2) From Figure III-22 find F' corresponding to Sp'.

F' is the amount of full caliber ammunition such that, when you substitute all subcaliber, you drop back to a score of Sp_o. That is , F' is the number of subcaliber rounds that will give a score of Sp_o. By repeating this process for different proportions of subcaliber you will get a curve like the one shown in Figure III-24.

Since subcaliber is cheaper than full caliber, it is desirable from a cost standpoint to use as much as possible. Two problems arise, however. One is that at some point the score may never be achieved without some full caliber. The other is that so much subcaliber firing may be needed as a substitute for each full caliber round that it takes too long to train with subcaliber. Both problems may impose limits as shown in Figure III-24. The final decision on the level of substitution will be a matter of judgment until more is known from hard data.

The effect of pre-table sumulation should be treated in the same manner, but using pre-table ammunition amounts. The difference is that cost is a factor in simulation. The cost of the simulator is fixed, so per-use cost declines as use increases. There will be a curve as shown in Figure III-25 showing the substitution of simulation for pre-table training. At a certain level of use, SIM_C, and above, the simulator cost is lower than ammunition use. Time required on the simulator and training effectiveness limits may also be contrained as shown in Figure III-25. The analyst will have to determine this for each type of simulation.

The same approach would be taken in analyzing simulation as a substitute for table firings.

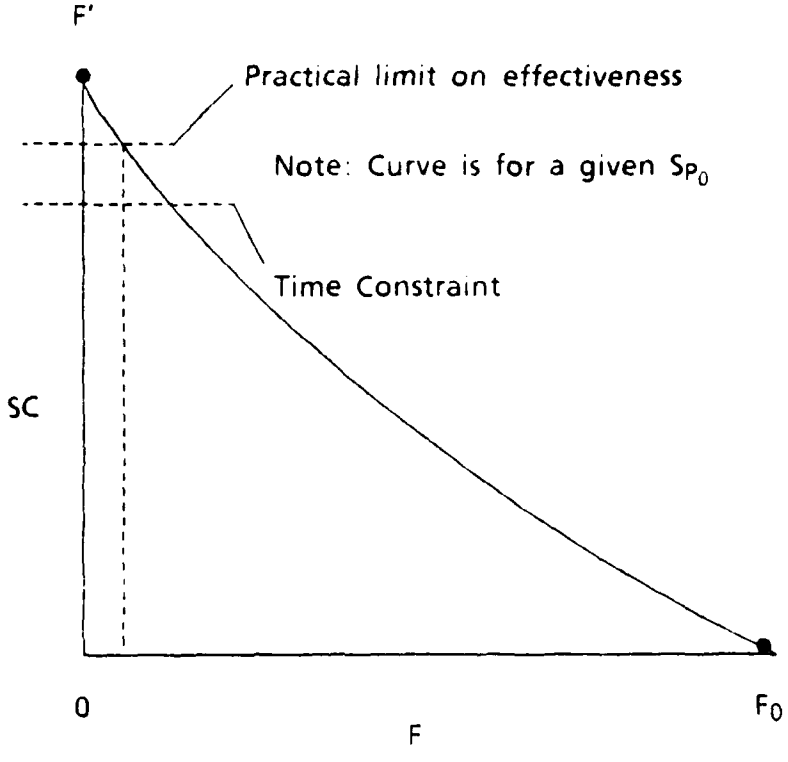


Figure III-24. Amount of Subcaliber to Substitute for Full Caliber at a Given Score

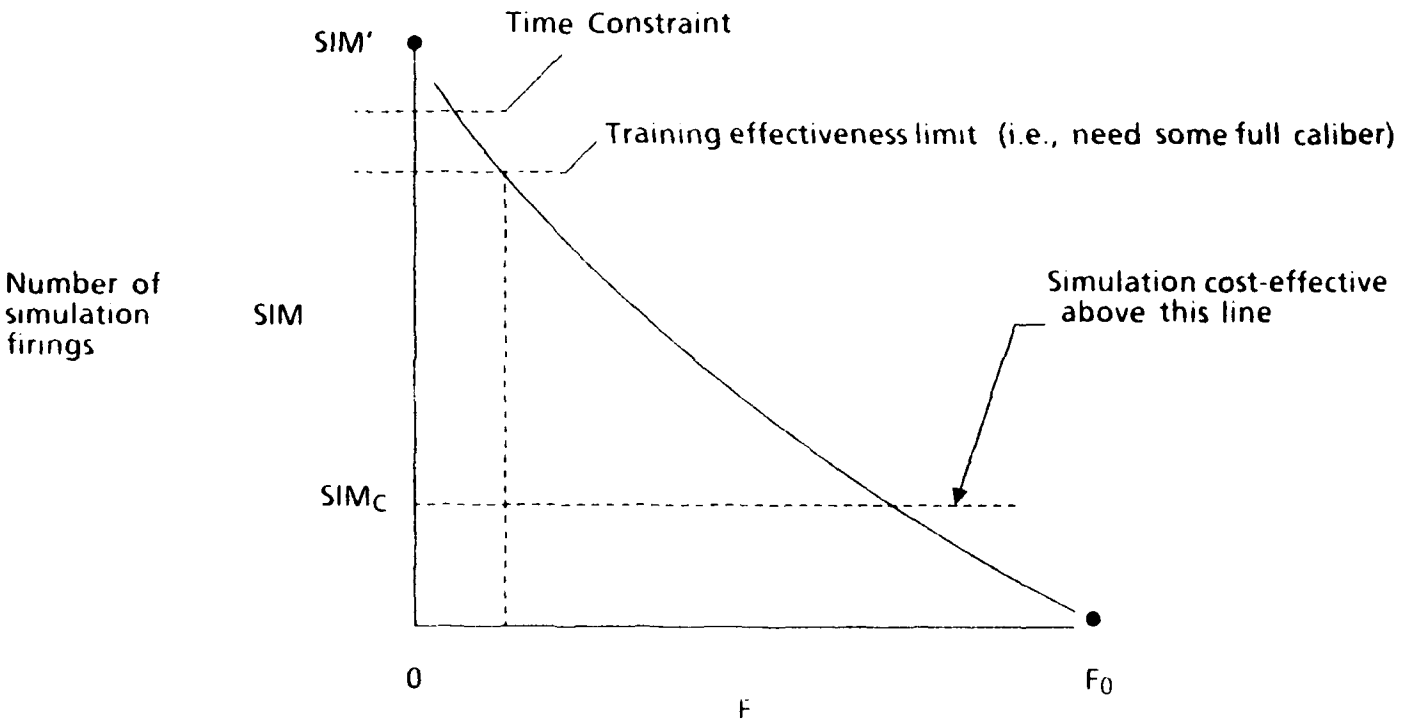


Figure III-25. Simulation as a Substitute for Full Caliber

3) Turbulence

The effects of turbulence can be represented as a plot of scores against a turbulence measure defined as follows:

$$T_c = \sum_{i=1}^{4} m_i$$

where

T_c = crew turbulence measure

m_i = months member i has been with the crew prior to test, but not more than the number of months since the crew was last tested.

or

$$T_p = \sum_{j=1}^{5} m_j$$

where

T_p = platoon turbulence measure

m_j = months crew j has been with the platoon prior to the test, but not more than the number of months since the platoon was last tested.

If all four crew members have been together since the last test, one year prior to the current test,

$$T_c = 12 + 12 + 12 + 12 = 48$$

If one new member joined the crew two months prior to the current test,

$$T_c = 12 + 12 + 12 + 2 = 38$$

As turbulence increases, i.e., more crew members or crews in a platoon have been with their crew or platoon for only a few months, the value of T_c or T_p decreases. The concept is shown in Figure III-26.

The shape of the scores as functions of T_c and T_p could be linear or non-linear. The linear form would be:

$$S_{Tc} = S_{Tc_o} + k_{Tc}T_c$$

$$S_{Tp} = S_{Tp_o} + k_{Tp}T_p$$

where S_{Tc} = score as a function of T_c

S_{Tp} = score as a function of T_p

S_{Tc_o}, S_{Tp_o}, k_{Tc}, and k_{Tp} are constants

Non-linear forms will have to be determined by the analyst based on the data plots. They could be quadratic or exponential. Figure III-27 shows a linear example for crew turbulence, and a non-linear example for platoon turbulence.

e. Summation of Methodology

In summary, the following steps are to be taken in collecting and analyzing data on ammunition allocation:

(1) Data will be collected on the forms of Figure III-21 on a quarterly basis for all USMC tank platoons.

(2) The data for all-full-caliber training will be processed in a least squares routine to obtain proficiency curves for crews and platoons as a function of full caliber ammunition, producing results of the type shown in Figure III-22.

(3) Data for training with simulation and subcaliber ammunition will be processed to produce least-squares curves of the type shown in Figure III-23.

(4) Substitution requirements of subcaliber and simulation will be determined as described earlier, resulting in curves of the type shown in Figure III-24 and III-25.

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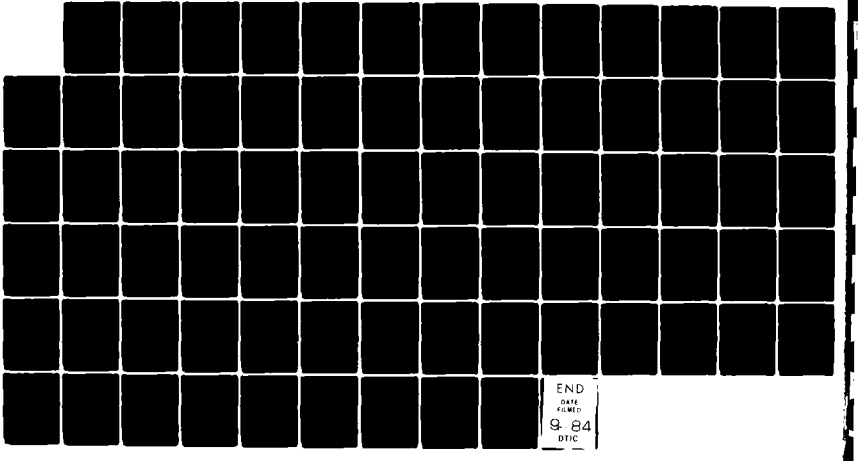
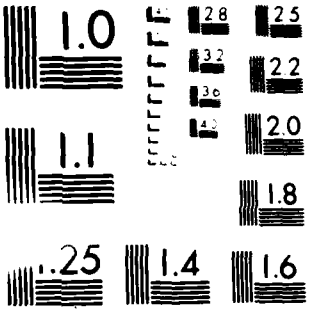




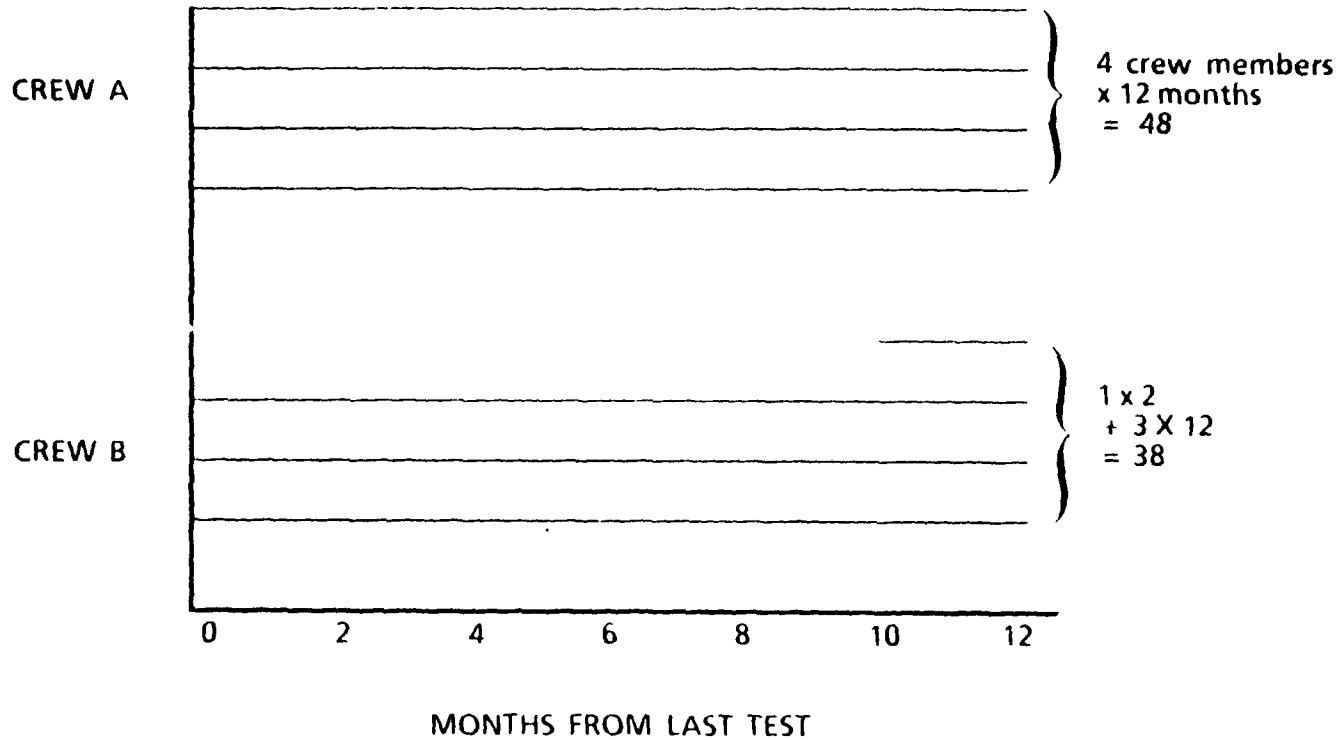
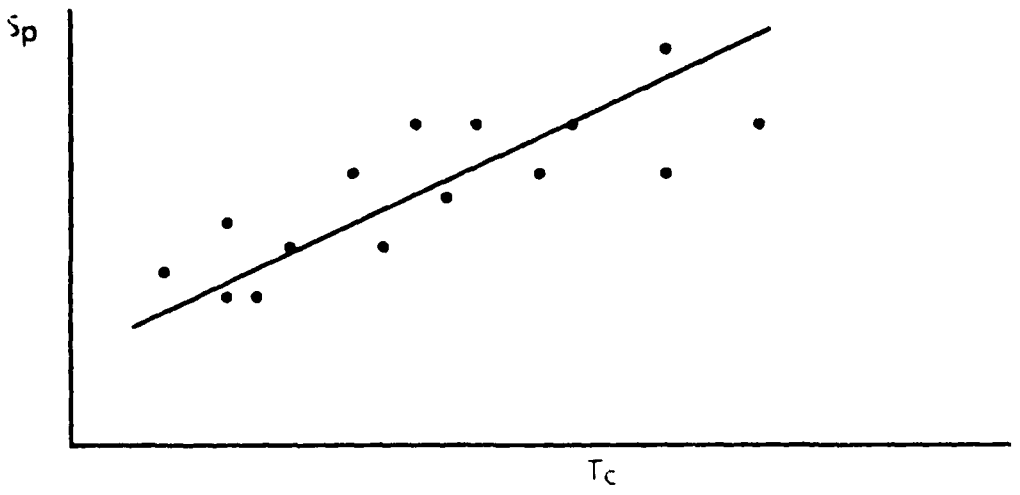
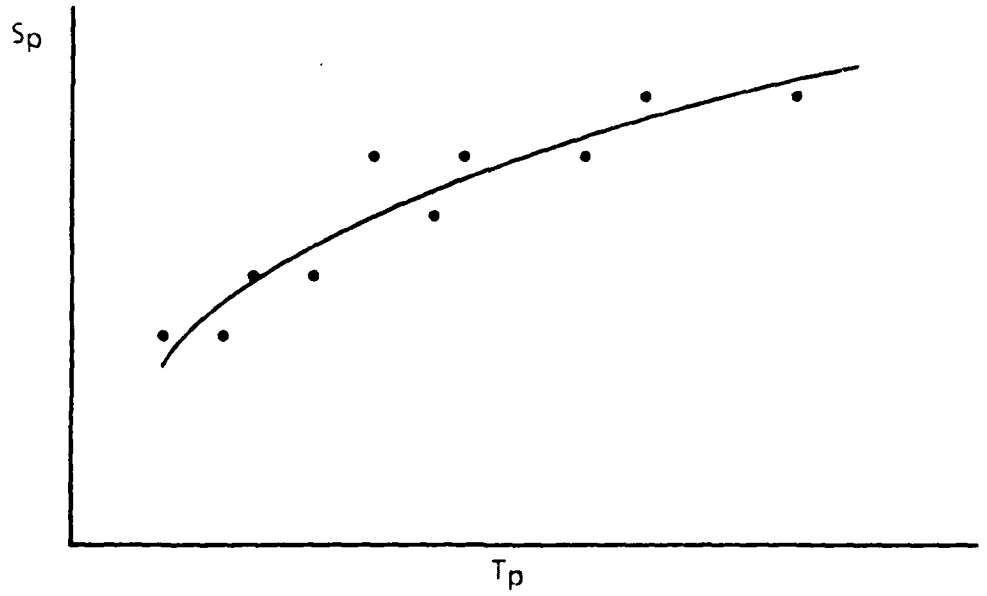


Figure III-26. Turbulence Measure



a) Hypothetical Linear curve Fit for Crew Turbulence

NOTE: Both T_c and T_p could be either linear or non-linear



b) Hypothetical Non-linear curve Fit for Platoon Turbulence

Figure III-27. Turbulence Effects

(5) Combinations of full caliber, subcaliber and simulation will be determined as described earlier, using the results of the type shown in Figures III-21, III-24 and III-25.

(6) Data collection will continue to monitor the effects of using the allocations determined in step (5).

f. Revised Allocation

When the data have been analyzed, a desired proficiency selected, and the associated ammunition allocation determined, the Marine Corps must still determine which units will receive the selected allocation, and which might still be involved in testing different allocations. During the three-year period of the recommended test program, it is expected that continuing uncertainty in different aspects of the training will require continued testing of variations from the selected normal allocations to obtain better data. It is also expected that the normal allocation will vary by mission and organization requirements. The specific procedures for determining the allocation will have to be developed after the initial set of data are collected and analyzed. However, as a starting point and subject to verification through the test program, a Proposed Tank Ammunition Allowance, MCO P8011, for FY84 is at Table III-2.

TABLE III-2. PROPOSED TANK AMMUNITION ALLOWANCES IN MCO P8011 FORMAT

j. 105 mm Tank, M60A1

DODIC	ITEM	CURRENT ALLOWANCE/BASIS	RECOMMENDED ALLOWANCE/BASIS	APPLICABLE UNITS
C508	HEAT-T	34/Wpn	a. 325 Per Plt b. 216 Per Plt c. 108 Per Plt d. 1,296 Requalification Reserve (108 rds per plt)	a. One third of all Plts as designated by USMC b. One third of all Plts as designated by USMC c. One third of all Plts as designated by USMC d. Requal Plts if req.
C520	TPDS-T	91/Wpn	a. 470 Per Plt b. 313 Per Plt c. 157 Per Plt d. 1,884 Requal Reserve	a. One third of all Plts as designated by b. One third of all Plts as designated by USMC c. One third of all Plts as designated by USMC d. Requal plts if req.
C510	TP-T	46/Wpn	a. 15 Per Plt b. 10 Per Plt c. 5 Per Plt	a. One Third of all Plts as designated by USMC b. One third of all Plts as designated by USMC c. One third of all Plts designated by USMC

NOTES:

1. Allowances in subcategory "a" are based on analytic nominal. Subcategories "b" and "c" reflect 2/3s and 1/3 of the Nominal allocations. The reserve allowance permits requalification of up to 100% of the Plts at the lower allocation level.

2. These allocations are exclusively designed for crew/platoon proficiency and therefore do not include special allowances for other purposes such as combined arms exercises, demonstrations, etc.

C. INDIRECT FIRE

1. The Nature, Components and Functioning of the Indirect Fire Weapon System

For purposes of this discussion, an Indirect Fire Weapon System is one which is capable of effectively engaging a target other than by sighting the weapon directly at the target. Artillery is the most representative category of the Indirect Fire Weapon System.

The mission of the artillery is to provide effective fire in support of the maneuver forces on the battlefield. The artillery must be capable of surviving the enemy threat and providing responsive and accurate fires at the time and place required. It is a major component of the air, ground, and naval gun supporting arms team.

Marine Corps artillery is organized into regiments, battalions and batteries. Of these battery is the most appropriate level to consider for the purposes of this study. While the battery is organized to perform a variety of functions, (operations, administrative, logistic, security, etc.) this study effort is directed to the operational functions which directly involve the acquisition and engagement of targets.

a. Functioning of Artillery and Its Impact on this Study

Training, in a broad sense, affects all battery functions, and contributes to the overall proficiency of the unit. In establishing measures of proficiency, this study addresses itself to those operational functions which are "gunnery" or "marksmanship" oriented. In this context, the battery has three basic elements:

(1) The Forward Observer/Team, the target acquisition agent,

(2) The Fire Direction Center, or control agent, and

(3) The firing battery, its headquarters, and the howitzer sections which provide the weapon delivery capability.

These three elements comprise an Indirect Fire Weapon System.

Indirect Fire Weapon System inherently presents a much more complex gunnery or marksmanship problem than that experienced by a Direct Fire Weapon System. In the Indirect Fire Weapon System, the acquisition element can "see" or acquire the target but cannot directly exercise the

weapon delivery system. The weapon delivery element can deliver the effect on the target, but cannot "see" the target and does not know the location either of the target or of the acquisition element. The third element, the Fire Direction element, usually cannot see either the target or the acquisition element, and frequently cannot see the weapon delivery element. Thus, the Indirect Fire Weapon System not only presents a difficult gunnery problem, it presents an exceptional challenge to any methodology which attempts to measure how well this gunnery team performs.

The battery gunnery team functions in the following idealized manner. The Forward Observer (FO) detects and determines the location of appropriate indirect fire targets within his zone of observation. In order to initiate action to engage the target, the FO transmits a request for fire to the Fire Direction Center (FDC). If the mission is approved, the FO will adjust the fire onto the target, when required, and will provide surveillance and evaluation of the effects of fire on the target. The FDC receives the request for fire from the FO. From the data provided in the FO request, the FDC plots the target location (manually or by FADAC), and determines the chart and firing data. This data is converted into fire commands for the firing battery. The firing battery receives the fire commands, and executes the mission by the howitzers firing the appropriate data.

b. Ingredients of Battery Performance

In order to effectively perform its mission, the battery must be capable not only of firing in an accurate manner, but also of performing "on demand." It must be responsive both with respect to the needs of the supported unit and to the nature of the target under engagement. Timeliness and accuracy become, then, the two dominant measures of how well or how poorly the battery performs.

How well the battery performs is dependent upon: a) the proficiency level of each of the three (3) elements of the battery (the Forward Observer, the Fire Direction Center, and the howitzer sections (also called the Gun Crews)), and b) the battery's ability to effectively

coordinate the activities of these three elements. In turn, the proficiency level of each element depends upon: a) the individual proficiency of each member of the section in performing his assigned task in the firing operation, and b) the ability of the element personnel to perform in conjunction with each other so that the element function (FO, or FDC, or GC) is accomplished in an accurate and responsive manner.

One can begin to see the complexity involved in measuring the performance of a battery in terms of accuracy and time. The battery can fail to perform to the required standards of accuracy and time under any of the following conditions:

(1) All three sections could be highly proficient but their activities with respect to each other (inter section) could be improperly coordinated, and hence unresponsive.

(2) All three sections could be very effectively coordinated, but the proficiency of one or more sections is such that it causes the battery to fail to meet either the accuracy or time criteria. The errant section may not be capable of performing to the required degree of accuracy, or more likely, it can satisfy the accuracy criteria, but not within the designated time criteria.

(3) Individual FO, FDC, and howitzer sections can perform to the required degree of accuracy, and can do this within the required time parameters, but cannot perform this function "on demand", that is, in the proper sequence and timed with other battery firing functions. The result is the same: at the battery level, the battery fails to meet the proficiency standards.

c. <u>The Role of Procedural Skills and Judgment In Battery Performance</u>

The effectiveness of the application of artillery fire is heavily dependent on the skill and coordination of the battery and its elements. The skills involved vary from section to section, but in general, they can be said to be heavily procedurally oriented.

The FDC is the most procedurally oriented of the sections. For any given type of mission, there is a well defined procedure or sequential steps that are followed by each member of the FDC team. These procedures are frequently complex and involved. To be proficient, the FDC members not only must know the procedures and be able to perform them to the required degree of accuracy in the required time, but also they must perform them at the time required by other members of the team. The leadership within the FDC must, in addition, understand what procedures to direct and when to direct them.

While virtually every type of mission has a greater or lesser unique procedural aspect with respect to the activities of the FDC, the degree of uniqueness is less distinct for the FO and for the howitzer sections. The howitzer sections are procedurally oriented with respect to the sequential activities required to conduct a given type of mission. While there are many different types of missions, there are a limited number of variations in the sequence of firing the howitzers. The forward observer is procedurally oriented in that he must follow a sequence of actions in order to initiate, adjust and terminate a mission. The FO, however, is more exposed to making judgments, the results of which flow into a procedural form. The FO makes the judgment on the target to be engaged. He makes the judgment on the location of the target. He makes the judgment on whether an adjustment is required. He makes the judgment recommending the manner in which the target is to be engaged with respect to type of ammunition and the volume of fire for effect. He makes the judgment on the corrections to adjusting rounds, and, finally, he makes the judgment on the evaluation of the effects of the fire on the target.

We do not imply that the FO is the most important player in the gunnery team. There is no one most important player since all sections must perform accurately and responsively to maintain an efficient battery. We do imply that the overall gunnery team is heavily procedurally oriented in skills, that the FO is inputing a major number of decisions or judgments into that procedural system, and that the value of these judgments will

have some positive or negative effect on the ability of the battery to perform.

Judgments are obviously made within the FDC and in the conduct of firing the howitzers so one cannot conclude that the judgments made by the FO are of greater or lesser importance than those made in the other sections. However, because of their number, the FO judgments are likely to affect battery proficiency to a greater degree and on a more frequent basis, than those made by the other sections.

Furthermore, the FDC and the howitzer sections each have intrinsic procedures to limit errors by cross checks and supervisory action, whereas the FO's judgment is extremely difficult to cross check either within the FO section or by the FDC. Therefore, the experience of the Forward Observer and his state of training exert a major influence, positive or negative, on the battery proficiency.

2. Basic Issues for Resolution

There are two fundamental issues that this study must address and resolve. The first concerns the number of live rounds needed to attain and maintain the proficiency of a gunnery team. The second concerns the utility of non-live-fire training in the same regard. Overall, the principal objective of this study is to formulate a methodology which quantitatively relates training, in terms of exercises and rounds, to proficiency.

One of the principal difficulties of this study is to formulate a methodology which deals with an abstract terms called proficiency. At any level, that is element or battery, proficiency is the ability to perform functional firing tasks to some specified parameters of accuracy and time. The identification of these specific performance parameters, and the relationship between this study and these parameters, are discussed at length in the (next) paragraphs dealing with the Marine Corps Combat Readiness Evaluation System (MCCRES).

This section concentrates its discussion on the issues of attainment and maintenance training, the impact of skill degradation and personnel turnover (turbulence), and the impact of non-live-fire training, on "proficiency".

These issues address abstract subject matter on which there is little or no "hard data." The relationship of the concept of proficiency, based on accuracy and time parameters, to training device and live fire exercises is a complex one. As we examine these relationships in closer detail, we will find a second level of complex relationships between battery proficiency and section proficiency, due to the changes of proficiency due to skill degradation and personnel turnover.

a. Attainment and Maintenance of Proficiency

The first issue to be resolved is the relationship between the attainment and maintenance of a proficiency level and the number or frequency of "training events". In this context, a "training event" is typically characterized as a field exercise involving or culminating in live firing. (A section can also achieve some level of proficiency through classroom instruction, non-live firing "training events", and through self application.) The proficiency of a section will tend to rise after its participation in a live-fire training event or exercise. As the section experiences continued exposure to such exercises, its proficiency will tend to increase to some satisfactory level. In order to maintain the unit proficiency at a minimum acceptable level, the training event must be repeated at some point in time.

Underlying the whole issue of live-fire training and proficiency is the following question. Does a unit or section proficiency increase as a result of learning skills and coordination in the live firing environment, or is the live firing event primarily a validation process to verify the unit training proficiency already previously acquired? The confidence level of an individual or unit or its commander in the ability to perform, is a factor in this proficiency, and the proficiency of individual sections is affected by live firing in attaining skill. Our point is that after a unit has attained a given skill level, is the repetition of live firing exercises a learning vehicle or a validation vehicle? Secondary points are: 1) should the unit use live firing as a learning vehicle or are there other less expensive or more effective approaches" and 2) if the

live firing is used as primarily a validation process, how frequently must proficiency be validated?

Nevertheless, the basic question to be resolved can be summarized as:

(1) What do our current training events consist of in terms of ammunition expenditures, and days of live firing?

(2) How does the FO, FDC, GC, and overall battery proficiency change as the result of participation in the training event?

(3) What is the required frequency of training events to obtain and maintain a given proficiency level?

b. Degradation Factors to Proficiency

The second issue to be resolved is the effect on section and battery proficiency caused by skill degradation (forgetting) and personnel turnover. If there were no personnel turnover within the sections, and if personnel did not lose skills through inactivity, we could more easily determine the frequency of training events necessary to maintain a given level of proficiency. Experience indicates that while many factors exert an influence on individual or unit proficiency, the two most important factors that tend to decrease proficiency are skill degradation due to "forgetting", and turnover of personnel.

Motor skills, such as loading a howitzer, tend to degrade only slightly over very extensive periods of time. Skills which are heavily oriented toward procedures, particularly complex procedures, such as those of a forward observer, tend to be "forgotten" much more rapidly through periods of inactivity or non-training. If one could determine the rate at which a particular skill degrades in terms of proficiency, then one could determine that point in time when another training event is required to again restore or maintain the proficiency level above the required minimum. Thus, a frequency of training events over any given time period could be quantitifed.

Recognize, however, that each of the sections of the battery have distinct skill characteristics. Some skills are more difficult to maintain than others, and, therefore, skills degrade at different rates

over identical time periods. This makes the frequency of training events section-dependent and, thus, might suggest differential section training.

When a section attains and maintains a degree of proficiency, essentially that degree of proficiency reflects the cumulative effects of the individual MOS skills and the manner in which those skills are applied and coordinated in a team effort. All members of the team contribute to the total team effort, but the tasks performed by some members may have greater impact on the proficiency of the section than tasks performed by other members. Those tasks having greater impact may result from the influence on the team from the leadership or supervisory position of the team member or because of the potential impact of his error. For example, an error in cutting the charge or setting the deflection or quadrant elevation has much greater impact than an error in the function of ramming the round into the tube.

When a crew member is separated from the team and is replaced by another, the proficiency of the section is affected. If the replacement has the same proficiency in the MOS skill as the member who was replaced, the section proficiency will degrade only to the extent that the new member is not used to working with the other members of the team. Frequently, the replacement does not have the same proficiency in the MOS skill as that possessed by the departing member. In this case the unit proficiency degrades because of both the inferior skill of the replacement and his lack of experience in working with the other members of the team.

To summarize this discussion, with the frequent replacement of team personnel the proficiency of the unit would tend to degrade in relation to:

(1) The number of members who were replaced over a given period of time,

(2) The MOS proficiency skill of the replacements, and

(3) The error impact potential of the position to be filled, particularly those of the supervisory type.

The basic questions to be resolved are:

(1) At what rate do sectional skills degrade due to forgetting?

(2) At what rate can these degraded skills be restored as a function of a training event?

(3) Can a personnel turnover rate (number of personnel per month) be related to a predictable change in proficiency level?

(4) Given a degradation of proficiency level resulting from personnel turnover, how many training events, or what frequency of training events, are required in order to restore the pre-turnover proficiency level?

c. Non-Live-Fire Training

The third basic issue to be resolved is the capabilities and limitations of sub-caliber devices and other training devices as tools for attaining and maintaining proficiency. In an abstract study of this nature, this issue is very difficult to address. In large part, training devices have various, but limited, characteristics which they are capable of simulating. These characteristics that can be simulated may have great value to the training of one section but limited value to the training of another.

For example, the M31 trainer, a widely used device in the artillery, is an excellent device for the training of the FDC. Within its design capability to simulate, it provides a definite assist to the FO in some but not all functions. On the other hand, it has limited value to the training of howitzer sections simply because it cannot simulate the physical environment in which the howitzer section must function.

This study's task is to evaluate the extent to which current existing devices can contribute to proficiency. It does not address the issue of the optimum potential of future simulators to contribute to training proficiency. This study is able to make such quantitative recommendations.

3. Marine Corps Combat Readiness Evaluation System

This section discusses the general nature and scope of the Marine Corps Combat Readiness Evaluation System (MCCRES) and its relationship to this study. This discussion is not intended as a critical analysis of the MCCRES, for this is not a task of the study, nor does the study group find

a reason to critize the concept. There are, however, sharp distinctions between the application of the MCCRES standards to a given unit under evaluation and the application of the study methodology in establishing the relationship between proficiency levels and live fire/simulated fire training. The MCCRES and the study have different objectives and different applications and the reader should understand this distinction.

a. What is MCCRES?

Marine Corps Order 3501.6 established MCCRES within the Marine Corps and directed implementation of the system for training use. The MCCRES provides the performance standards for use in the evaluation of the combat readiness type units and their subordinate components.

The MCCRES mission performance standards attempt to provide a comprehensive means to evaluate all functional areas of a Marine Air Ground Task Force. In the application of MCCRES to the Field Artillery Battery and its sections, MCCRES establishes standards of performance for many fuctional tasks. These tasks include both firing and non-firing activities or tasks as well as tactical and equipment oriented tasks.

The MCCRES embodies the detailed performance standards for virtually every type of indirect fire task at the unit and element level. This document has received very wide distribution, and has exerted a measurable effect on unit and element training programs. The personnel involved in performing indirect fire missions and tasks are very aware of the performance levels established in the MCCRES.

It is the opinion of the study group, and of the overwhelming majority of the personnel interviewed, that the MCCRES parameters are fair and attainable, but that there is little "slack" in the criteria, particularly at the battery level. This seems desirable that the "coordination factor" of the battery's elements is implicit in the MCCRES standards. It is the most difficult factor to measure. Probably the best indicator of inter-element coordination is the timing and length of the communications or data transfers between elements as we discuss later.

b. MCCRES In Application

It is in the application of the MCCRES, that is, the evaluation of a series of specific batteries or battalions, that its value as a general measure of combat efficiency can be misread. First of all, the conduct of a MCCRES evaluation represents a substantial effort in terms of time, personnel resources, ranges and ammunition. Substantial personnel support from other units is required to evaluate the unit undergoing the MCCRES evaluation. Substantial time is required in preparation for the MCCRES.

Based purely on the limitation of physical resources, MCCRES evaluations cannot, as a practical matter, be conducted frequently on the same unit. It appears that the frequency of evaluation of a given unit could extend to 18 - 24 months. It does appear, in application, that many units are evaluated by MCCRES just prior to some event, such as a deployment outside CONUS or an extended training exercise in CONUS.

Because of the Marine Corps many operational commitments, there is frequently substantial intra-regimental transfers of personnel from other units into the unit designated for deployment, and designated to take the MCCRES evaluation. There is no argument that the unit passing the MCCRES test is well qualified to perform. However, there is a danger that after reviewing a series of many units scoring well on the MCCRES evaluation, someone may come to the conclusion that the MCCRES evaluation of these units represents the current training status of all like type Marine Corps units at any given time. It appears that personnel transfers to the unit designated to be evaluated under MCCRES, and to deploy, exert a negative influence on the status of proficiency of the transferring units. If it were physically possible to administer the MCCRES on all like type units simultaneously, then the scoring would likely be substantially different than the scoring currently being achieved by those units who have been augmented prior to testing and deployment.

We recognize that this simultaneous testing is not feasible. We recognize the MCCRES is an effective approach to evaluate a specific unit. We merely caution any general conclusion concerning the general

state of training of any given type unit category based on the results of one or many individual MCCRES unit evaluations.

c. The Relationship Between MCCRES and This Study

The establishment of a body of specific performance criteria and the wide-spread knowledge of this criteria by the personnel in indirect fire military occupational specialties was a very significant assist to this study. It provided a common basis of communication through the medium of questionnaires where the interrogators and respondents used the same performance criteria.

This study has the task of establishing a relationship between a proficiency level and the number of training events, hence the scope of the study relates only to that portion of the MCCRES which deals with live firing/simulated live firing. This is an important distinction. The study methodology is capable of predicting the "proficiency level" of a unit or section. given certain inputs, however the "proficiency level" relates to the ability of the battery or section to perform to MCCRES standards only with respect to live or simulated firing.

This study examines how crews, sections and batteries acquire skills, maintain skills, and how those skills are degraded by changes in training frequency and by personnel turnover. The MCCRES examines how crews, sections, and batteries performed at the time of evaluation, measuring actual performance against established standards in all types of functional tasks.

This study provides a tool or methodology to help predict the quantity and frequency of live firing and simulated firing to achieve and maintain a designated level of proficiency for an indirect fire type unit (e.g., field artillery battery) on a Marine Corps wide basis. It is universal in application. In concept, MCCRES provides a most valuable set of criteria which can be readily translated into training objectives, and in this respect MCCRES has universal application to any given type Marine Corps unit.

There is one final distinction between the MCCRES and this study. The MCCRES is correctly concerned that the battery being evaluated

is capable of performing each and every type of live fire mission (precision registrations, mean-point-of-impact registrations, adjust-fire missions, smoke, illumination, coordinated illumination, and others). This study is concerned that whatever the composition of quantity and types of missions fired by a battery in normal live fire training, that the battery is capable of satisfying the MCCRES standards for each of those missions.

d. MCCRES and the Definition of Proficiency

It is therefore not only conceivable but highly likely that there may be marked differences between the evaluation of a unit under all the tasks encompassed by MCCRES and the proficiency level predicted by the study methodology based only on live firing/simulated firing. While the study's relationship between live firing/simulated fire events and proficiency level represents some overall average, not all units are evaluated with all of the same tasks in a MCCRES evaluation, and non-firing events are weighted differently than firing events in the MCCRES scoring.

In applying the abstract term "proficiency" in a practical manner, this study's position is that if a battery or section satisfies the accuracy and time parameters for a given type mission, that battery or section is 100 percent proficient in that type mission. If the section or battery failed to satisfy the accuracy and time parameters for a given type mission, its proficiency in that type mission is zero. The accuracy and time parameters for all missions are those established by MCCRES. The "proficiency level" of a battery or section then is determined by its ability to perform the required functions within the MCCRES time and accuracy criteria for the total missions fired.

For example, assume a battery live firing exercise consisted of one (1) Precision Registration, six (6) adjust fire missions, one (1) illumination mission, and two (2) Fire-for-Effect missions (a total of ten (10) missions). Assume the battery satisfied the MCCRES accuracy and time criteria in the Precision Registration mission, in five (5) of the six (6) Adjust Fire missions and in the two (2) Fire for Effect missions, but failed to meet the criteria in one (1) of the Adjust Fire missions and the one (1) illumination mission. This study would rate the "proficiency

level" of that battery at 80 percent since it satisfied the performance criteria in eight (8) of the ten (10) missions fired.

e. MCCRES and Element Performance

As previously noted, the great value of MCCRES is the establishment of a body of performance standards. Since this study is concerned with battery and section proficiency and its relationship to live and simulated firing, the study group reviewed in detail the MCCRES performance parameters and standards relating to indirect fire units. At the section level and at the battery level, the standards for any firing related task are very specific and are explicitly expressed in terms of accuracy and time.

For example, in the conduct of any type mission, the forward observer (FO), the fire direction center (FDC) and the howitzer sections (HS) each have a number of specific tasks involved in the accomplishment of their section missions. Each task has a time and accuracy parameter associated with it. The FO must be able to determine the location of the target within certain accuracy parameters and transmit that target location to the FDC within certain time parameters. The output of the FDC effort is measured in terms of accuracy (mils in Deflection and Quadrant Elevation time in fuze setting) and time.

Upon receipt of firing data from the FDC, the howitzer sections have specific time and accuracy parameters in which they must perform. In the case of an adjust fire mission, for example, the parameters for each section are different for the initial round, the adjustment rounds, and the fire-for-effect rounds. Therefore, with such a well-defined and detailed body of explicit time and accuracy parameters for each task of each battery section for each phase in each type mission, the adaptation of this body of parameters in this study's "proficiency level" methodology is greatly facilitated. In addition, as noted, the MCCRES body of parameters serves as a common basis for communication between the study group and those operational personnel who have provided the benefit of their experience in addressing the issues of this study relating to proficiency.

f. MCCRES and Element Coordination

While MCCRES explicitly provides specific parameters in time of accuracy and time for virtually every task at the section and battery level, there are also implicit parameters. If one examines the time and accuracy parameters for the overall indirect fire system, it becomes readily apparent that the "time" parameter dominates the success or failure of a section or battery in satisfying the MCCRES criteria. If one examines the time parameters for each section in performing its individual tasks in each phase of a mission, and totals all the time increments of all the sections, one finds that the total is less than the time parameter at the battery level to conduct a given type mission.

This is obviously logical. The implication however, is that each section must not only be capable of satisfying its time criteria for each given task in a mission, but it must perform "on demand." It must perform proficiently in conjunction with other sections in the timely evolution of a battery level mission. This is implicitly a parameter of coordination.

For example, the FO, FDC, and howitzer sections of a battery may individually be capable of consistently satisfying the MCCRES criteria for any type mission. When those individual sections are required to perform "on demand", that is, in conjunction with the other sections at the time and place of the evolution of a battery level mission, the battery may prove incapable of satisfying the MCCRES time criteria. This is because the sections are not coordinating their efforts in a responsive manner to bring effective fire on the target. As we have already mentioned, probably the best indicator of inter-element coordination is the timing and length of the communications/data transfers between elements.

4. Overview of the Methodology

a. General

The purpose of this study is to provide the Marine Corps with a methodology which will assist the Marine Corps to decide how much ammunition to use to train its crews serving on crew-served weapons. Fundamentally then, the methodology, and the results therefrom, must be

oriented toward decision-making. The job of the methodology is to organize the necessary data and the decision variables into a logical form, so that when those data are inserted and the decision variables selected, they can be related to some quantity of ammunition.

Our methodology requires two decision variables: first, the Marine Corps must specify the level of MCCRES proficiency an element or battery should maintain. Second, the Marine Corps must specify the amount of personnel turnover (turbulence) expected within those elements. The output of the methodology is the number of exercise days per year, with an associated number of rounds of ammunition per exercise. This number of exercise days and rounds will insure that an element or battery will maintain the specific level of MCCRES proficiency, in an average sense, in spite of the specified turbulence.

The data required by the methodology is moderate in size. Much of that data comes from the MCCRES itself, and will only change when MCCRES standards change. Other more changeable data concern the relationship between learning and rounds expended in "learning situations", and the amount of "unlearning" due to the effects of turbulence and forgetting. We have evaluated these data through an organized subjective means as a first cut, but these data will change in time as hard data becomes available. The methodology provides a means of including these new data.

b. Use of the Maintenance Approach

What is the measure of a unit's readiness? For the purposes of this study, the Marine Corps has specified the measure. The MCCRES standards will be the measure, and this study interprets readiness in terms of proficiency as measured with respect to the MCCRES. A unit's proficiency with respect to MCCRES will be taken as the unit's score in a MCCRES evaluation.

For a given number of exercise days per year, some units would be MCCRES-evaluated at higher levels of proficiency than others. There are innumerable reasons for this. A unit's proficiency depends not only on the number of exercises it participates in, but also on the quality

of that training, the preparation for it, the morale of the unit, the leadership provided, the history of personnel turnovers, etc. For this reason, we wish to measure proficiency in some average sense. For example, we might take the average of all measured proficiencies from all like units identically trained and tested under identical MCCRES circumstances.

For the purpose of establishing a training requirement for ammunition, the Marine Corps must decide on the average MCCRES proficiency that it wants the units to exhibit. We do not wish to measure this proficiency as if it were the result of a specialized one-shot attempt to do well on a MCCRES. Rather we wish this proficiency to reflect the current state of readiness Marine Corps wide. We wish to calculate the amount of live-fire and/or non-live-fire exercise days per year which will "maintain" the units at the specified average proficiency level.

For this study, we interpret the average proficiency level to be a level which is "maintainable" in some long-term sense. Within any single unit the proficiency will fluctuate due to the occurrence of exercise periods, the turnover of personnel, the skill decay between exercises, etc. The proficiency we want to use is the time-averaged proficiency, the "steady-state" level which notionally results when all the transient effects befalling a new unit are smoothed over.

In this sense, we regard the attainment of proficiency as just a "ramping up" to the steady-state level. It is the steady-state level we are interested in as our measure of the impact of changes in training rate. We are looking to measure the average maintainable proficiency of the units as they train, forget, and experience changes in members.

c. The Effects of Turbulence

Personnel turnover, called turbulence, within a unit will lower the maintainable level of proficiency of that unit, all other things being equal. This effect can be compensated for by an increase in the number of exercise days. This will allow the new members of the unit to "catch up" to the skill levels of the old members of the unit.

It seems obvious, then, that the lower the turbulence, the higher the maintainable proficiency at the same rates of training. Similarly, with lower turbulence, any specified proficiency can be maintained at a lower rate of training, and, thus, with a lower consumption of ammunition. In fact, from our review of military training documents and interviews, this is exactly the case. Among US allies, where units may stay together for almost a decade, higher proficiencies of marksmanship have been achieved with a substantially lower consumption of ammunition.

Any acceptable methodology addressing the relationship between ammunition consumption and training effectiveness must embody explicit consideration of turbulence. It must be able to quantify the saving in training exercises associated with any reduction in turbulence. The methodology developed in this study does this. It evaluates a unit's maintainable proficiency in relation to the number of exercise days per year and the number of personnel replaced per year.

Although the maintainable proficiency of a mature crew must include the factor of turbulence, the attainment of proficiency might be evaluated without it. We might assume that a new crew will keep together, at least for some reasonable period of time. Also, if there is any consideration of the effect of intense pre-deployment training on proficiency, this might be also evaluated without respect to turbulence. However, the methodology of this study is general enough to allow the consideration of turbulence even in these cases.

d. Days of Fire and Expenditures Per Day

The total number of rounds expended in training a unit's crew during one year is the product of the number of exercise days of fire enjoyed by that crew with the average number of rounds expended per exercise day. In order to determine the effect of a one year training allowance, we need to know the benefit of one typical exercise day. And the effect of that one day is somehow dependent on the number of rounds fired during that day.

In our conduct of this study, we were explicit in stating that we would not make suggestions concerning how to train, but only how

much to train. We did not wish this study to recommend the number of rounds to be used in one exercise day. Rather, we would conduct this study with the view of recommending how often training days should occur under the current training doctrine used by Marine Corps. Nevertheless, we do address the issue briefly. Intuitively, more rounds per exercise is better, up to the point of fatigue. Also intuitively, some minimal number of rounds needs to be fired to justify the preparation that has gone into the training event itself. Thus, there may be some "threshold" number of rounds in excess of which little training effect is discernable. In fact, it may well be that the preparation for a live-fire field exercise is the most important aspect of the training, and the event itself is merely a validation of the effect of that preparation.

After any exercise day, the benefit to the crew will be a variable depending on the preparation for the exercise, the concentration during the exercise itself, the rounds actually fired, and whatever chance happenings affected the execution of that exercise. Our point is that there seems to be so many influential variables in a training exercise, and the data (including subjective data) so sparse that it is probably futile to discover any simple relationship between the number of rounds fired and the specific skill enhancement that number engendered.

Although we will gather data to investigate the effect of rounds-per-day on training effectiveness, the only possible means of drawing any conclusion in this regard is to conduct rather thorough field tests. Thus, for ammunition planning purposes, we will use an average number of rounds to represent one day's firing. And we will associate with those rounds an average learning "rate" which we will extract from data.

e. The Acquisition of Data

The previous subsections have discussed the variability in impact which can be expected from any training exercise involving a crew (or an individual for that matter). Thus, any methodology purporting to describe the relationship between training exercises and the acquisition of

proficiency, necessarily needs extensive hard data if it is to be scientifically precise. However, in order to guide a managerial decision, we may get away substantially cheaper.

The usual method of supporting a decision when there is little hard data, is to acquire a reasonable amount of "expert" judgment. In many cases, expert judgment is all we can hope for, when, for example, the data we need depends on the future outcome of certain events.

Expert judgment is not a substitute for hard data. The experts involved have already "preaveraged" important distinctions in their mind in ways which might be destructive to our application. The experts also carry prejudices around with them. When these prejudices can be averaged out over experts, more reasonable results are likely to be obtained. The most dangerous case is when the experts are uniformly biased, as for example when the decision to be made based on their judgment intimately affects them.

Nevertheless, as a result of our data gathering, we found no complete hard data adequate for our purposes. We found no records relating a MCCRES-evaluated unit with the number of exercises it performed, complete with expenditures, and complete with the changes of personnel within the unit. Therefore, it was necessary to acquire subjective data from qualified Marine Corps personnel. This subjective data was gathered in the form of extensive questionnaires. These questionnaires asked for both qualitative and quantitative information. They asked questions both directly and indirectly and asked them in several ways in order to double check the responses and to eliminate biases. Each questionnaire response was then processed in such a way that it could be regarded as a substitute for three pieces of hard data gathered from MCCRES-evaluated units.

As hard data becomes available in the future, the subjective information can be replaced by such data. It can be replaced completely, or it can be mixed with the hard data. When mixed, and when enough hard data is available, the preponderance of that data will necessarily swamp the original subjective estimates. The decision-making portion of the

methodology will thus improve from its original subjective base to an empirical base.

5. Structuring the Modeling

a. General

This paragraph describes how we organize and apply the data needed to support a decision concerning the ammunition required to train. The organization and collection of data is the scientific aspect of this study. It supports, but is distinct from, the decision guidance aspect of this study. We use mathematical models to organize the data and to tell us the kind of data we need to support the decisions we wish to make.

When there is a large amount of coherent data available, the data can well "speak for themselves". We need no preconceived curve or shape or theoretical construct to aid us in interpreting the data. The data will fall as they may and construct their own "curve". They may not lead to any "understanding" in the scientific sense, but it is sufficient to support a managerial decision.

For example, suppose we knew from measurements that every battery training 30 times per year with 65 rounds of live fire would test out at 82 percent proficiency on MCCRES. And suppose we have similar measurements for a large range of annual exercises with various numbers of consumed rounds per exercise. Then we need no theoretical construct to relate proficiency to ammunition expenditures per year. Rather, we have complete data. We pick a proficiency we like, and train according to our evaluation of the best of the alternative ways to get there.

On the other hand, when the data available are sparse and incomplete (the usual case), then it behooves us to have some theoretical idea of how the data holds together and relates to itself and to our decision variables. We need some theoretical construct, based on past scientific study and/or operational procedures, and representative of the best current thought, to help us use a small amount of perhaps inconsistent and confusing data. That is, we need to fill in the rationale which will lead from sparse and uncertain data to a decent managerial decision.

To provide this rationale, we have constructed two mathematical models. One of the models relates the proficiency of a battery to the proficiencies of its elements (the forward observer function, the fire direction function, and the howitzer aiming and loading function) evaluated with respect the the MCCRES standards. The other model applies the past half-century's developments in quantitative learning theory to the problem of how much training it takes to attain and maintain the proficiency of each element's crew. Together, they relate different amounts of training to the proficiency of the battery overall.

Over a period of time, as hard data are collected from training experience, and appropriate records are kept, the parameters of these models can be updated from the parameters provided by this study. The updated parameters will reflect the most recent training experience. The models will then change from a means of "extrapolating" from small amounts of data, to a means of "interpolating" between measured results. As data is collected further, at some point, we would hope that they would "speak for selves". Until that time, we propose that the Marine Corps use the modeling and parameters this study provides.

b. Relating Battery Proficiency to Elements' Proficiencies

The overall proficiency of the battery is a complicated combination of the proficiencies of each of the elements (FO, FDC, and GC) and the "coordination proficiency" between elements. The first model this study provides is one which describes this relationship in a quantitative fashion. This model, called the Battery Proficiency Model, outputs the battery proficiency associated with specified input element proficiencies.

The ability of an element's crew to perform those subtasks endemic to its function with accuracy and timeliness is fundamental to the performance success of the battery. Relating the amount of accuracy and timeliness at the element level to the accuracy and timeliness at the battery level, requires that we formalize the interactions among elements. We do this in consideration of the different missions a battery must be able to perform.

Different missions make different demands on each element's crew. Different missions require the elements to interact differently among themselves. Thus, battery performance cannot be evaluated by simply homogenizing the performance of the elements. Rather, it is necessary to analyze the element's interactions at the mission level, and then assemble the likely performances of several selected missions into a measure of the battery performance overall.

In order to produce an analytically tractable model, suitable for this study's decision purposes, we need a way to place a value on an element's performance of a subtask within any mission. To do this, we choose to apply the elements specified proficiency to characterize it's ability to meet the MCCRES standards for each subtask under consideration. We do this in a way which provides a probability distribution on the amount of time it would take the element to achieve the MCCRES accuracy standard. We describe this in more detail later in the next subsection.

Within each mission there are MCCRES standards for the subtasks demanded of each element. However, there are no such standards governing the accuracy and timeliness of the communication or the coordination between individual elements. Thus, in our modeling, we allowed a model parameter to characterize the goodness of these interactions, and allowed that parameter to be fit to data. With this parameter in place, elements' performance and interactions within mission can be strung together, burdened with their probability distributions, so that the probability of completing the entire mission within MCCRES standards results.

Finally, individual mission proficiencies, based on element proficiencies and the coordination parameter, can be combined to produce an overall estimate of battery proficiency. We do this by taking a weighted average of selected mission. We discuss this in more detail in the next subsection. As an exercise of this Battery Proficiency Model, we can investigate the sensitivity of battery proficiency to the element proficiencies. This is useful for evaluating which element, when given extra training, would most benefit the performance of the battery. Figure III-28 summarizes our method.

- For a specified mission, couple the element proficiencies to relevant MCCRES standards to generate a statistical characterization of element performance in each subtask of the mission.

- Piece these representations together to obtain a statistical representation of battery performance in the mission.

- Interpret the resulting quantification in light of the battery-level MCCRES standards for the mission and obtain a battery proficiency for this mission.

- Average the mission-dependent proficiencies over relevant missions, using appropriate weights for each mission, and thus establish an overall battery proficiency.

Figure III-28. Summary of the Battery Proficiency Model Method

c. Mission Analysis

In order to quantify the time and accuracy constraints of the MCCRES standards on the joint performance of the elements, we need a functional analysis of each battery mission. In this way we can assess how the proficiency demands on each element's crew affects the overall performance and how the communication flows between elements. This subsection gives an example of the procedure we use in this study.

We have selected three mission types to characterize the demands on the battery elements' crews: Fire-for-Effect, Adjust-Fire, and Coordinated-Illumination. We have selected these missions because, among them, they embody virtually all the important subtasks each battery element must perform. That is, if a battery can perform these missions with accuracy and timeliness, then it is likely that it can perform all battery functions with accuracy and timeliness.

Among these three mission types, the Fire-for-Effect mission is the simplest. Figure III-29 displays the time sequence of events which characterizes the mission. Figure III-30 displays the applicable MCCRES standards for the conduct of this mission. Built into box 3 of Figure III-23 is a communication time T_3 between the FDC and the GC for which there is no specified standard. This time, T_3, is our coordination parameter.

Other missions are substantially more complicated than this one. For example, the Adjust-Fire mission requires loops of repeated event sequences in order to characterize the time of accomplishment of the entire mission. The necessary number of loops is a matter of chance, and this makes our analysis substantially more difficult. Nevertheless, we are able to handle these difficulties in a mathematically tractable way.

The way we do this is in the way we interpret an element's proficiency. We take an element proficiency of 80 percent to mean that it can perform its function 80 percent of the time within the time specified by the MCCRES standard. The actual time it takes to perform its function is governed by chance. However, among all the chance performance times, we

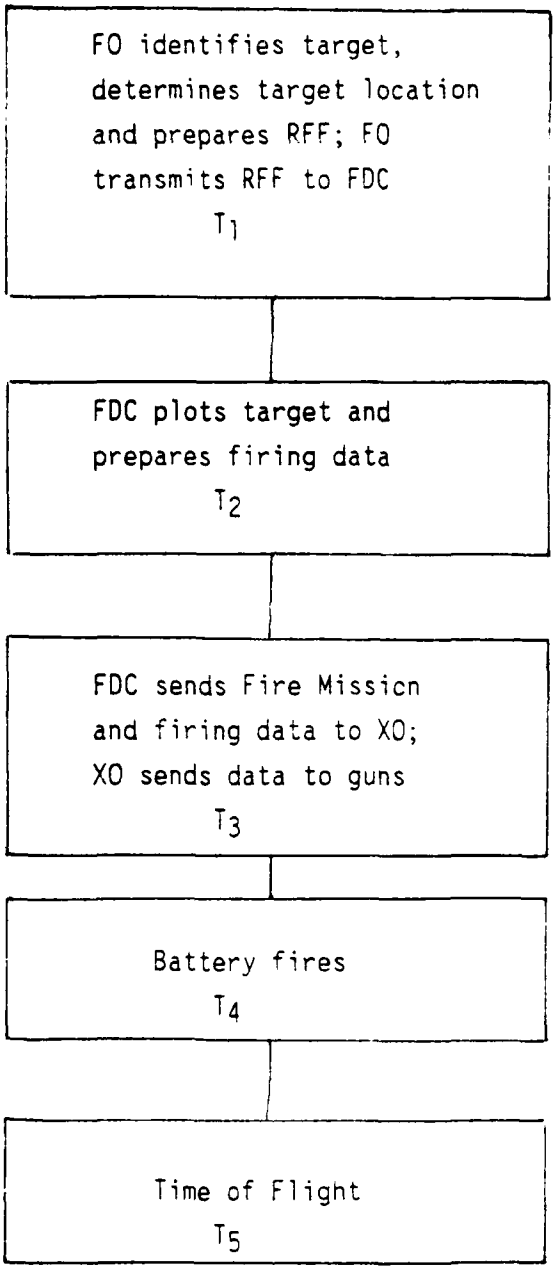


Figure III-29. Time Sequence of Events in the Fire-For-Effect Mission

Time Standards	Accuracy Standards
• Standard for FO performance time T_1 is 60 seconds	• FO will locate target position to within 200 meters
• Standard for FDC performance time T_2 is 45 seconds	• FDC will plot target position by determining DF and QE settings to within $\pm$3 mils; this translates into a radial error of 50 meters
• No explicit standard for time T_3; estimated minimum time is 19 seconds	
• Standard for GC performance time T_4 is 45 seconds	• GC will implement DF and QE settings, again to within $\pm$ 3 mils. This is equivalent to an (additional) allowable radial error of 50 meters
• Time of flight T_5 for charge (?) and range 15,000 meters is 35 seconds	
• Standard for Battery performance time T is 170 seconds (2.83 minutes)	• Standard for Battery performance is - At least 1 round of 8 fired within 50 meters of target* - At least 6 rounds of 8 fired within 200 meters of target

* In this and other missions, we assume an 8-gun battery.

Figure III-30. MCCRES Standards for Conduct of Fire-For-Effect Mission

say that 80 percent of them will be less than or equal to the MCCRES standard.

We then string together these probabilities from element-function-performance time to element-function-performance time. This allows us to construct a probability that the total mission time will be within MCCRES standards. We interpret this probability as the proficiency of the battery in that mission.

d. The Element Proficiency Model

In order to feed element proficiencies into the Battery Proficiency Model, we need some way to estimate the proficiency of each element. To do this we use the same simple training model applied to each element. This training model applies to the training of crews performing procedural tasks. It takes into account the amount of training the crew has received and the amount of personnel turnover the crew has experienced. We call this model the Element Proficiency Model.

From the previous subsection we see that the element proficiencies insinuate themselves in multiple ways into the evaluation of battery proficiency. Thus, those element proficiencies become the key drivers of the battery proficiency. Consequently, we have taken some care to prepare the Element Proficiency Model so that it is simple to use, yet founded on the best knowledge available from the psychology of learning.

The two major factors governing the proficiency of an element's crew are: 1) the number of exercise days in which it has participated, and 2) the amount of personnel replaced in that crew over the period of training. Also, we must take into account the forgetting which occurs between "training events" among the stable crew members. The Element Proficiency Model is a crew training model which embodies these considerations.

The Element Proficiency Model is relatively frugal in its demand for data to support the selection of its parameters. It uses three parameters: a learning rate per "training events", a forgetting rate applicable between "training events," and a turbulence rate applicable when a member of the crew leaves and is replaced by an individually skilled, but

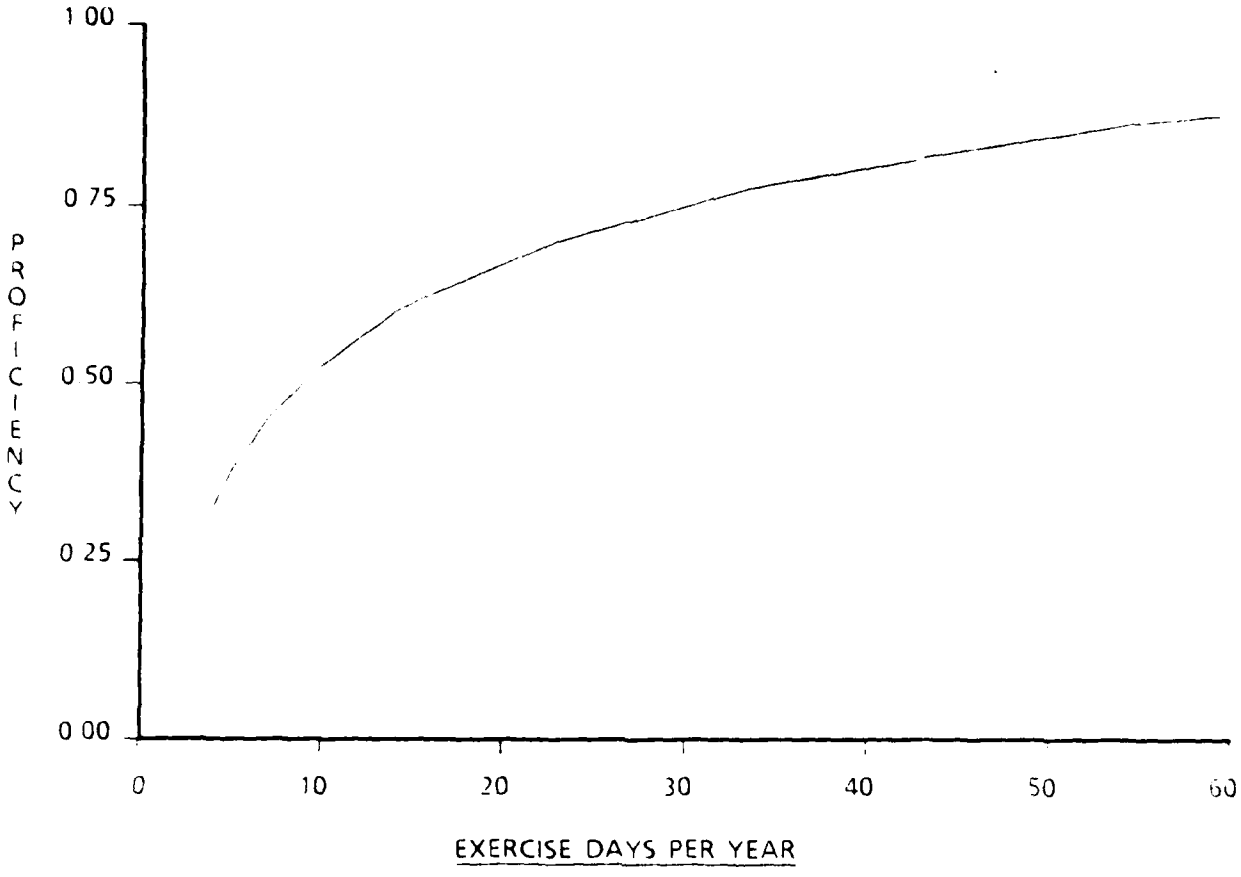
new to the other crew members. These parameters need not be evaluated directly, but they can be estimated by fitting the model either to measured training data, or to subjective estimates of such measurable training data.

The Element Proficiency Model has two basic applications. It can be used to assess the maintainable proficiency of a mature crew as that crew trains and changes. It can be used to measure the gain in proficiency of a new crew as that crew trains together and matures. Secondarily, the model can also predict how long it would take to increase the proficiency of a crew by some specified amount, under intense training, i.e., prior to deployment. It can also be used to evaluate the degradation of proficiency as a crew is unable to train, i.e., when deployed at sea.

The Element Proficiency Model is based on the current best thought in the mathematical theory of learning as it applies to individuals. We have extended those concepts to the training of crews based on the little extant work on team training, and on the little extant work concerning the learning of procedural tasks.

In order to achieve a tractable mathematical form, we assume that the occurrence of "training events" and the occurrence of personnel turnover are independent from week to week. The apparent weakness of this theoretical assumption is counter-balanced operationally by one of the first lessons in statistics: in independent trials, it is common to observe strings of like events followed by strings of the non-occurrence of the same events. When you are away training, you will keep training; when you are back home, you may not train so regularly.

As a sample of the type of result available from the Element Proficiency Model, Figure III-31 displays a curve representative of "maintenance training". This curve relates the number of exercise days per year to the average proficiency which would be displayed by crews training at that rate. As expected, the more you train, the better your proficiency. The simple formula given in Figure III-31 generates the curve. The purpose of gathering data is to support an accurate value of the formula parameter C.



For training at the average rate of n exercise days per year, the average maintainable proficiency will be of the form:

$$P(n) = \frac{n}{n+c}$$

for some value of C depending on the model parameters and the turbulence rate.

Figure III-31. Maintenance Proficiency

Figure III-32 displays a curve representative of attainment training. Although the shape of this curve is similar to that of Figure III-31, the underlying formula is quite different. Take special note of the label on the x-axis. It is different from the label for the maintenance curve. Attainment of proficiency is characterized by a continuous improvement in proficiency as weeks go by.

However, there is a limit to the proficiency that a crew can attain. The largest that a crew's proficiency can become is the maintainable proficiency associated with the rate of training (in terms of exercise day per year) it is experiencing. This upper limit is available from the maintenance curve of Figure III-31, when the same turnover rate (embedded into the value of C) which applies to maintenance training also applies to attainment training.

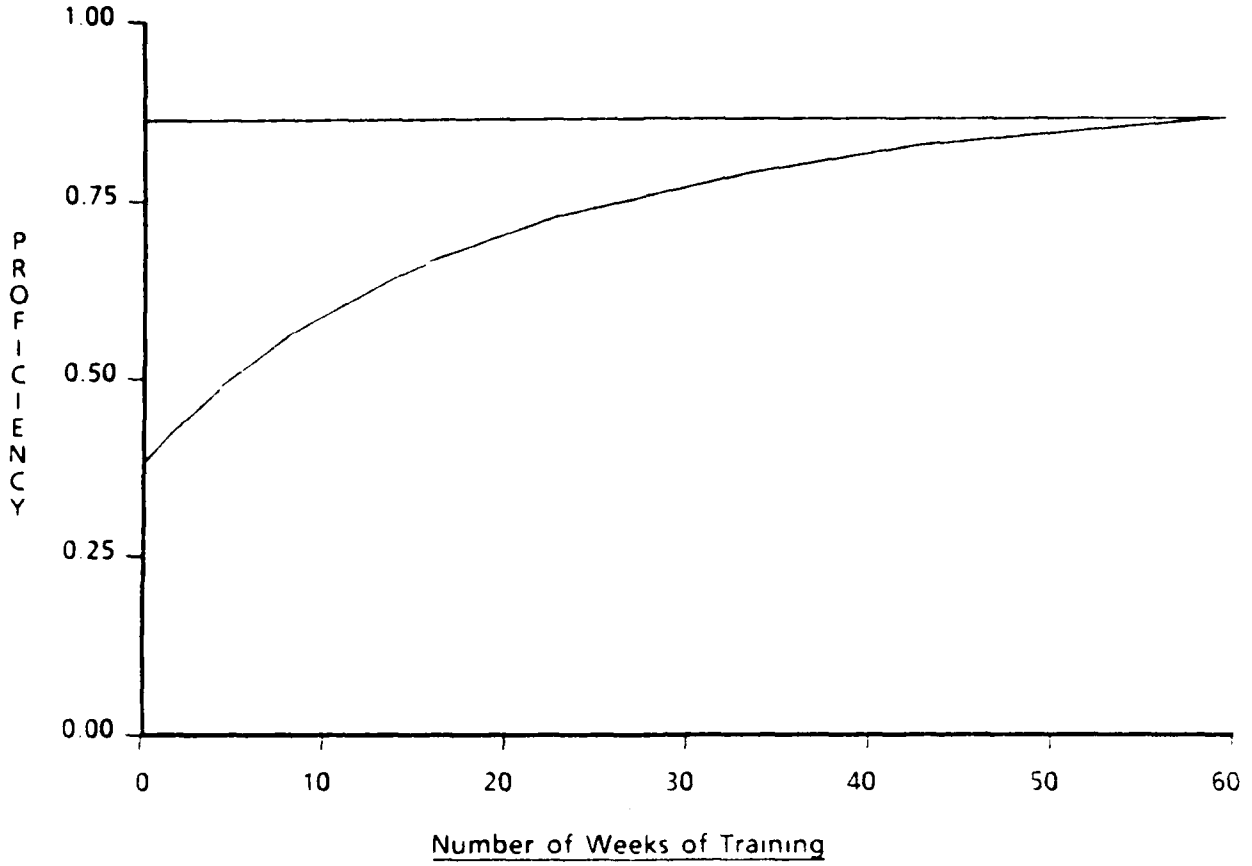
At this point, we need to know how data can be gathered to support the parameters we need in the formulas. The next paragraph addresses this problem.

6. Developing Inputs to the Methodology - The Questionnaire

a. Results of Liaison with US Army

At the outset of this study effort, members of the study group made two visits to Fort Eustis to confer with the Army Group which was also involved in studying the relationship between proficiency in training and expenditures of ammunition in exercises. In addition to conducting an extensive literature search on the subject matter of this study, the members conferred at length with each of the Army counterparts, each representing an Army major weapons category, i.e., Artillery, Tanks, Infantry, etc.

The Army study had been on-going for some period prior to the initiation of this study effort. The Army group, having encountered the same difficulty in obtaining "hard data" on the subject matter of the effects of live firing on crew weapon proficiency, elected to conduct a questionnaire survey which was widely distributed at various facilities. These questionnaires were available to the study group and were reviewed.



For a new crew starting at proficiency P[o] and training at the average rate of n exercise days per year (maximum attainable proficiency is then P[n] in Figure III-31)the new crew's attained proficiency after N weeks of training will be of the form:

$$AP[N] = P[n] + r^N (P[o]-P[n]),$$

where r is of the form $r = 1-[n + C]C^1$ (see Figure III-31)is less than 1, and C' depends on the learning rate parameter, AP[N] approaches P[n] as $N \rightarrow \infty$. In the sample curve n = 55, C = 10,

Figure III-32. Attainment Proficiency

In general, the questionnaires did provide various types of useful information, but they did not attempt to quantify any relationships between changes in proficiency and live firing.

The Army Group elected to establish this relationshp by conducting a series of live fire training exercises with selected trained units. For these units, the Army Group proposed to systematically decrease the quantity of ammunition used per live firing, and measure the reduced proficiency obtained by the reduced firing. This decrease was to be concentrated at values of 1/3 and 2/3 of standard allowance. Figure III-33 illustrates the expected results of this approach. If a trained unit was evaluated to be 90 percent proficient by whatever method of measurement (Point A), then by reducing the quantity of ammunition expended in live firing and/or by substituting training devices, one should measure the change in proficiency (Point B). The difficulty with this approach is that, in order to reach a conclusion from the data so developed, one must assume that the unit being evaluated was "at the knee of the curve" on the 90 percent proficiency line, and not at any other point such as A^1, A^2, A^3 on the 90 percent proficiency line.

We did not feel this assumption concerning the knee of the curve could be validated from the Army Group's stepped allowance. If, for example, the 90 percent proficient unit was at point A^3 on the 90 percent proficient curve, and that unit's ammunition expenditures were reduced, it is probable that the unit performance would show relatively little decrease, since it is moving laterally a good way on the 90 percent curve before it traces any downward path. In any case, this would not help us determine the number of live-fire exercises as it effects proficiency. And there is no theoretical model to assist in assessing the impact of reductions in expenditures per training event, as there is in assessing the impact of reductions in the number of training events as discussed in Paragraph C5.

b. USMC Study Approach

The study group, facing the lack of "hard data" on the subject matter, decided on a different approach for indirect fire. The

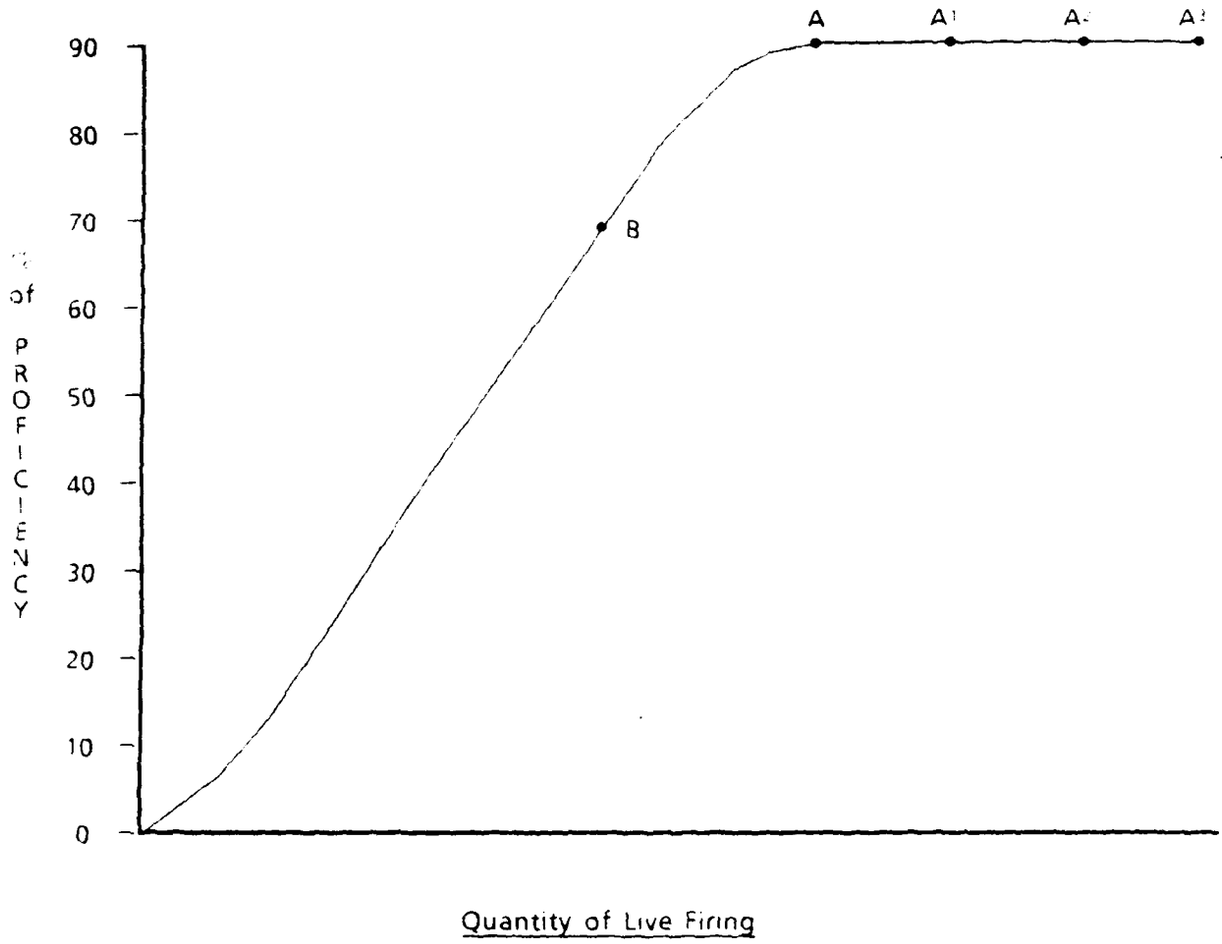


Figure III-33. Expected Impact of Ammunition Reduction

approach was to develop inputs to the methodology through the vehicle of a series of indirect fire weapons questionnaires. The questionnaires were formulated to address the artillery and mortar weapon organizations at various levels in the organization structure.

For example, the artillery questionnaires addressed both the section level and the battery level. Separate questionnaires were formulated for the following categories of functional billets:

(1) Command and Staff:
    (a) Artillery Battalion Commander
    (b) Artillery Battalion S-3
    (c) Artillery Battery Commander
(2) Battery Executive Officer/Gunnery Sergeant,
(3) Battery Forward Observer,
(4) Battery Fire Direction Officer, and
(5) Howitzer Section Chief.

The Forward Observer and Fire Direction officer questionnaires addressed the FO and FDC functions respectively; the howitzer Section Chief questionnaire provided the view of the howitzer crew activities from the view of the Section Chief; the Battery Executive Officer/Gunnery Sergeant provided the view of the howitzer section activities from the aspect of the firing battery level; the Command and Staff questionnaire provided the broad view of the coordinated section activities at the battery level.

The questionnaires were formulated to address the common and unique aspects of each functional activity. Each functional set of questionnaires was administered to nine (9) experts. With the exception of the Command and Staff questionnaire, all questionnaires were administered to members of the 10th Marine Regiment at Camp Lejeune in late November/early December 1982. Respondents were selected by the parent commands based upon the respondent's experience and knowledge. The Command and Staff questionaire was administered through the mail individually to officers selected by Headquarters, Marine Corps, based upon the experience and knowledge and reputation of the officers.

Each questionnaire provides a background of the purpose of the questionnaire, that is, to obtain the respondents judgement on such issues as the contribution of live firing to section and battery proficiency, the contribution of simulators and training devices to section and battery proficiency, the frequency at which training should be conducted, and the effects of personnel turnover and crew skill degradation on section and battery proficiency. Further, the instructions, provided by the questionnaire to the respondents, specifically define the term "proficiency" and relate that measurement to the MCCRES standards. This is done in order that there is a common basis of reference between the questionnaire and the respondent regarding the standards of proficiency and the measurement of changes in proficiency. The instructions provide an illustration of how proficiency is measured for purposes of the study and its relationship to the MCCRES standards. Finally, the MCCRES time and accuracy standards of proficiency relating to the functional area of the questionnaire are summarized for the respondent as a source of review and immediate reference.

c. Questionnaire Outline

Although each questionnaire is unique to its particular functional area, the common theme of the questionnaire is outlined as follows:

(1) Qualifications/experience of the respondent;

(2) The number of days of live firing per quarter and the number of rounds per firing day expended by the respondent's unit;

(3) The determination of the rate at which personnel attain proficiency in their artillery tasks as a function of live firing;

(4) Given the attainment of a desired proficiency level, what frequency of live firing is required to maintain that level, assuming no personnel turnover?

(5) At what rate does proficiency degrade, due to inactive intervals between live firing exercises: Once proficiency has degraded, how rapidly can it be regained as a function of live firing exercises and frequency of live firing?

(6) The effect of personnel turnover on section proficiency;

(7) The effects of simulators and training device on proficiency levels; and

(8) The difficulty of "learning" the skills needed to effectively participate in a variety of distinctly different type missions. At the command and staff level, the line of questioning additionally addressed the difficulty in "coordinating" the various types of missions.

In addition, the questionnaire explored not only the quantitative aspect of each functional area, but also attempted to determine the "What and Why" aspects. For example, what kinds of problems inhibit section acquisition of desired proficiency levels? When skill degradation takes place, does the principal degradation occur in forgetting procedures, making errors in procedure, the timely application of procedures, or in coordinated team effort? What is the value and availability of training devices? How effective are current training devices in increasing the section proficiency? Which sections benefit most?

The nature of any questionnaire is admittedly subjective. The responses are subjective judgments based on the best cumulative experience available. There is no alternative "hard data" source to answer the questions posed by this study. A "hard data" source could be created as a follow on effort to validate the findings of the study, but it did not exist at the initiation of the study and does not now exist. The questionnaire was the best effort of the study group toward obtaining the most useful inputs to the methodology, notwithstanding the subjective character of the data.

Nevertheless, the combination of subjective data (or more precisely subjective estimates of the likely findings from hard data) and modeling have produced substantial results from this study. The next paragraph discusses the nature of these results, and a sample application of the developed methodology to artillery.

7. Results of Analysis

a. Introduction

The purpose of this paragraph is to present the results of our analyses. The basic results we have to offer concern the relationship of battery proficiency to the number of "exercise days" the battery participates in per year. We get this proficiency by:

(1) Evaluating the proficiency of each battery element (FC, FDC, and GC) in relation to the number of exercise days per year through use of the Element Proficiency Model, and

(2) Evaluating the proficiency of the battery by using the Battery Proficiency Model applied to the element proficiencies.

An average number of live rounds is associated with each live-fire exercise day. Thus, we can relate battery proficiency to the number of live rounds fired annually. We begin with two discussions concerning how the two proficiency models (presented in Annex B) were calibrated for use in this study. Figure III-34 summarizes some of the collected questionnaire data.

b. Fitting the Element Proficiency Model

The Element Proficiency Model required three parameters. These three parameters have to do with:

(1) The skill increase during a training event - the learning parameter,

(2) The skill decrease between training events - the forgetting parameters, and

(3) The skill decrease when an existing crew member is replaced by an individually skilled, but new to the crew, - the turbulence parameter.

To evaluate the model parameters of any one element, we rely on the responses to the questionnaires (in Tab B-1 to Annex B) which concern that element. We focus on certain responses to the questions in the applicable questionnaire(s), and extract the quantitative data (identified in Exhibit B2-1 in Tab B2) for each respondent. We then use the "smoothing" technique in Tab B2 to select those model parameters which are most consistent with the individual respondent's answers. We then compile

Questionnaire	Proficiency	Exercise days per year	Turnover #/ 6 months	Rounds per Exercise day
Section Chiefs[1]				
1	85	56	6	200
2	85	80	4	75
3	75	20	2	200
4	65	80	2	155
5	75	80	3	90
6	70	100	3	200
7	95	84	6	120
8	75	32	8	80
9	75	92	6	80
10	85	40	3	5
median	75	80	3	105
mean	78	66	4.3	121
XQ				
1	75	28	3	50
2	85	76	1	65
3	65	30	4	30
4	85	20	2	90
5	85	12	2	40
6	75	36	2	60
7	85	40	5	100
8	85	48	3	100
9	75	12	2	40
median	85	30	2	60
mean	79	34	2.7	64

Notes:

1. In comparison to the response to the other Questionnaires, the Section Chiefs have reported about double the number of exercise days per year and double the rounds consumed per exercise.

Figure III-34. Summarized Basic Data from the Questionnaires

Questionnaire	Proficiency	Exercise days per year	Turnover #/ 6 months	Rounds per Exercise day
Fire Direction Center				
1	60	32	4	80
2	90	32	2	100
3	70	24	3	60
4	80	60	5	50
5	80	32	3	25
6	70	32	2	50
7	80	60	3	50
8	80	60	5	50
9	80	40	3	40
median	80	32	3	50
mean	77	41	3.3	56
Forward Observer				
1	85	60	0	60
2	83	60	3	50
3	85	36	3	50
4	81	48	1	60
5	81	24	2	180
6	87	24	3	60
7	75	60	4	40
8	91	60	3	50
median	84	54	3	55
mean	84	47	2.4	69
Command and Staff				
1	85	20		60
2	75	36		30
3	75	40		60
4	85	76		43
5	85	40		40
6	65	96		70
7	75	72		100
8	75	40		100
median	75	40		60
mean	78	53		63

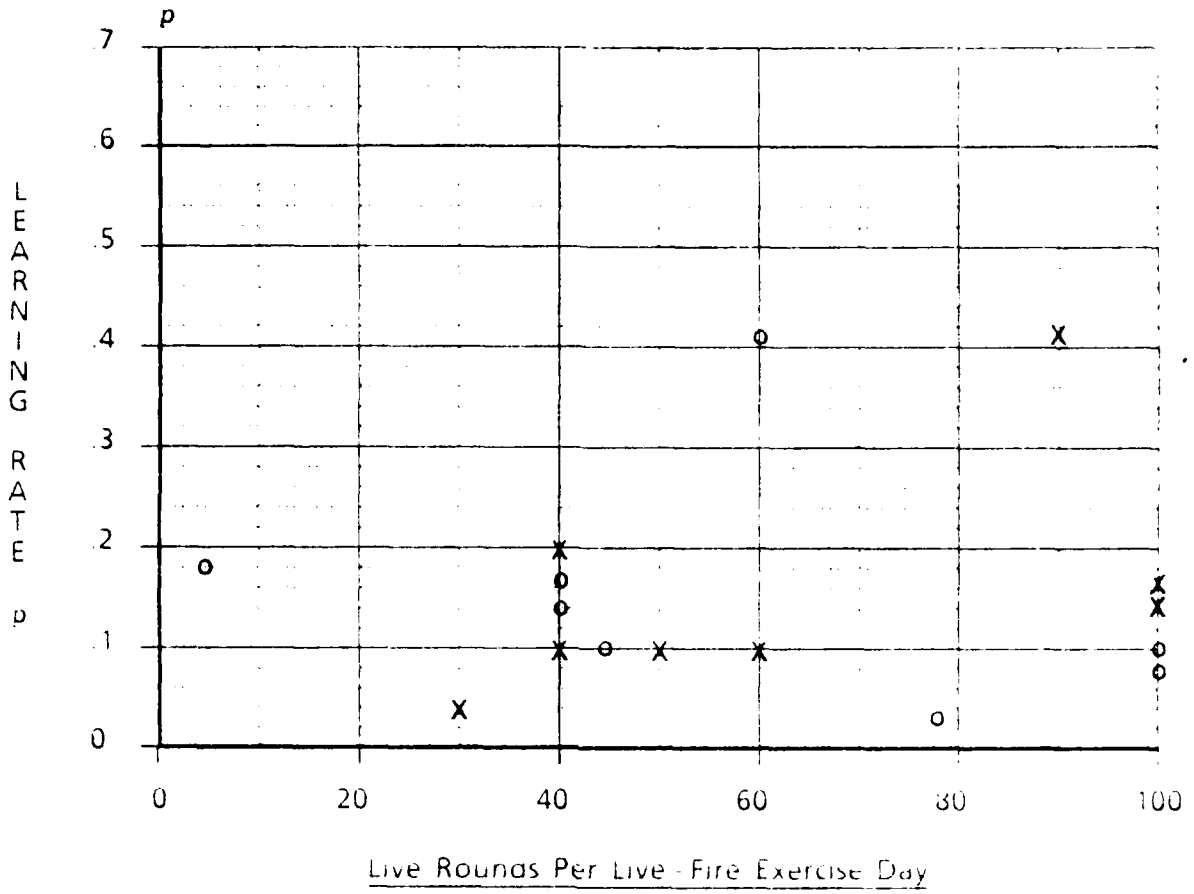
Figure III-34. Summarized Basic Data from the Questionnaires (Continued)

the "smoothed" parameters of each respondent and analyze them statistically in order to achieve a consensus on the value of each of the three parameters. The value of these parameters for each element can be found in Figure B-2 of Annex B. (There are two values for the learning parameter - one for live-fire training and one for non-live-fire training.)

There are three notable results in our analyses of questionnaire data. First, we could find no functional relationship between the number of live rounds fired in an exercise and the learning parameter. Intuitively, we might expect that the larger the number of rounds fired, the greater the increase in skill acquisition. However, from the subjective data extracted from the questionnaires (indirectly), we could find no such relationship. Figure III-35 is typical of what we did find. This again leads us to believe that the Army Group Study will not find the "knee" of the curve in Figure III-33, if indeed there is one.

Second, individual responses do not support any distinction between the initial learning of a skill, and the relearning of a skill which has been forgotten. Intuitively, if there were a distinction between an "unlearned" state of mind and a "forgotten" state of mind, with respect to these procedural skills, one would expect the learning parameter representative of relearning from a "forgotten" state to be greater than that of initial learning from an "unlearned" state. There is no evidence of this. Furthermore, the learning parameter representative of recovery from personnel turnover might reasonably be between that of relearning and initial learning. This is because in such situations, the old crew members will be recovering from "forgetting" while the new crew members will be initially learning. Neither is there evidence of this.

Third, the responses to the effectiveness of non-live-fire training seemed erratic. Nevertheless, there seems to be one noticeable trend. Namely, that when mixing live-fire training with non-live-fire training, it seems better to mix live-fire with non-live-fire exercises within the same "training event" than it is to mix training events devoted purely to either live-fire or non-live-fire exercises. Unfortunately, the Element Proficiency Model is designed to address separate "training event



Notes 1. X marks XO response
O marks Section Chief Response
(applies to double the rounds stated)

Figure III-35. Howitzer Crew Learning Rate as a Function of Rounds Expended

types in terms of how many events are needed to attain and maintain proficiency. It is not designed to address how to do the "training event" itself. This point will be important when we make our recommendations.

c. Fitting the Battery Proficiency Model

The purpose of the battery proficiency model is to link the proficiencies of the battery elements together in order to assess how well the battery performs overall. The "missing link" in this connection is the "coordination proficiency" within the battery. That is, no matter how individually proficient each battery element is in it's own right, the battery itself will likely perform poorly if the communication and the coordination are poor. In the course of this study, we found this coordination concept difficult to model and even more difficult to evaluate from the questionnaire data we had. Thus, we chose to operate the Battery Proficiency Model with the coordination parameter held constant. As indicated in Annex B, this parameter is a single inter-element coordination time, and we found a suitable value of this coordination time by fitting the Model to information in the Command and Staff Questionnaire.

This Command and Staff Questionnaire information pertains to specific subjective evaluations of joint FO, FDC, GC, and battery proficiencies after certain amounts of attainment training. We use a linear regression on the logarithm to relate element to battery proficiency, and we fit this simple model to the data (see Tab B-3). This simple model says that for the element proficiencies all at 80 percent, a corresponding battery proficiency in the mid to low 70's is consistent with the data from the Command and Staff Questionnaire. Thus we compelled the Battery Proficiency Model to approximate this result. Originally, we had estimated that the coordination time was between 19 seconds and 45 seconds. We found that a coordination time of 29 seconds was reasonable. Thus, a coordination time of 29 seconds was fixed in the Battery Proficiency Model for all further applications.

As a test of the Battery Proficiency Model, we set element proficiencies at the median Marine Corps values specified by the questionnaire answers. These were 84 percent for FO, 80 percent for FDC, and

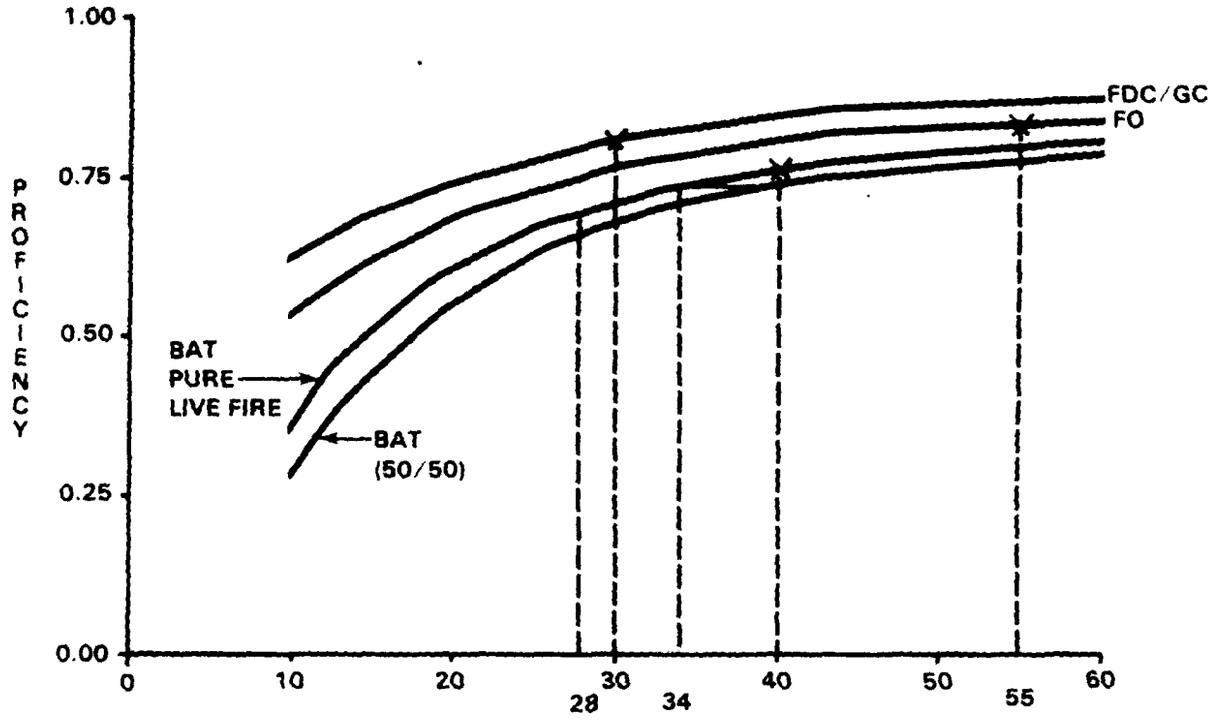
80 percent for GC (see Figure III-28). The battery proficiency then calculates to 75 percent. The median reported battery proficiency was also 75 percent, which is right on the computed value. Thus, we seem to have some consistency among the questionnaire responses, at least on the average, when it comes to estimating current Marine Corps battery and element proficiencies, and the relationship among those proficiencies.

d. The Maintenance of Proficiency

We can summarize the relationship of training to proficiency as follows. The greater the number of exercise days per year, the higher the average maintainable proficiency for a mature crew (and the more quickly attainable that proficiency for a new crew) - all other things being equal. The purpose of this section is to quantify how many exercise days per year are associated with what proficiency level, and what has to be equal. We begin with the maintenance curve. Figure III-31 is our guide.

Figure III-36 is a consolidated display of the maintenance proficiencies as they depend on the number of exercise days per year. We include the curves for FO, FDC, GC, and Battery overall. (The battery curve assumes that the elements train together). The element sample proficiency curves come from the Element Proficiency Model (equation (18) of Annex B) and they all assume a median personnel turnover rate of 3 individuals per 6 months (=3/26) in the FDC, in the GC, and among the FOs. The sample battery proficiency curve comes from the Battery Proficiency Model using input element proficiencies associated with the common number of exercise days per year. Battery proficiency is expressed in both pure live-fire and 50/50 live-fire/non-live-fire (non-live-fire element proficiencies can be found in Annex B).

Figure III-36 contains other information. Notice that the FDC and GC occupy the same sample proficiency curve. This is because at the personnel turnover of 6 individuals per year per crew, the "C" value for the formula in Note 2 of Figure III-36 (following equation (18) of Annex B) is about the same for both crews. (It cannot be distinguished on the scale of Figure III-36.) Furthermore, the median number of reported



NOTES: 1. EACH LIVE-FIRE EXERCISE DAY CONSUMES ABOUT 60 ROUNDS.

2. ELEMENT CURVES FOLLOW THE FORMULA:

$$P[n] = n/(n + C)$$

WHERE n IS THE NUMBER OF LIVE-FIRE EXERCISE DAYS PER YEAR AND P[n] THE MAINTAINABLE AVERAGE PROFICIENCY. THE VALUES FOR C ARE: FO-C = 8.91, FDC-C = 6.35, GC-C = 6.05.

3. X ON CURVES MARKS THE MEDIAN QUESTIONNAIRE RESPONSE FOR EXERCISE DAYS PER YEAR.

Figure III-36. Element and Battery Maintenance

exercise days per year is about the same for both FDC and GC at about 30 exercises per year. At 30 exercises per year, the FDC/GC curve is just slightly higher than the median reported FDC/GC proficiencies of 80 percent.

For the FO, the median reported exercise days per year is 55 (almost double the FDC and GC) in Figure III-36. At this value, the FO curve is just slightly above the median reported proficiency of 84 percent. With the median proficiencies of FO at 84 percent and FDC and GC at 80 percent, the Battery Proficiency Models predict a battery proficiency of 75 percent, right on the median reported value of the battery proficiencies. Coincidently, the median reported battery exercise days of 40 per year corresponds on the sample battery proficiency curve to just above 75 percent. (At 40 exercises per year, the FO proficiency would be about 82 percent, the FDC about 86 percent, and GC about 87 percent as calculated by P(n) in Note 2 of Figure III-36).

If Marine Corps wishes to operate its artillery batteries at lower proficiencies, then it can reduce the number of live-fire exercise days by the appropriate amount. This will reduce the live ammunition consumption. For example, according to Figure III-36, 76 percent proficiency can be maintained at 40 exercises per year at 60 rounds per exercise, a total of 2400 rounds per battery per year. To operate at 70 percent proficiency, reduce the number of exercise days to 28 per year and consume 1680 rounds.

If this reduced allowance (1680) were to be spread over the same number of exercises (40), reducing the rounds per exercise (to 42), then we would expect the proficiency loss to be less than that under the reduced number of exercises. This is the observation from Figure III-36. However, we are unable to quantify this proficiency in the absence of testing under reduced allowances.

Also plotted in Figure III-36 is the battery proficiency curve for a 50/50 mix of non-live-fire and live-fire training. This is

assembled from similar element proficiencies (different C's in Figure III-36.) The information concerning the relationship between proficiency and non-live-fire training is weak because there seems to be only limited experience with non-live-fire training.

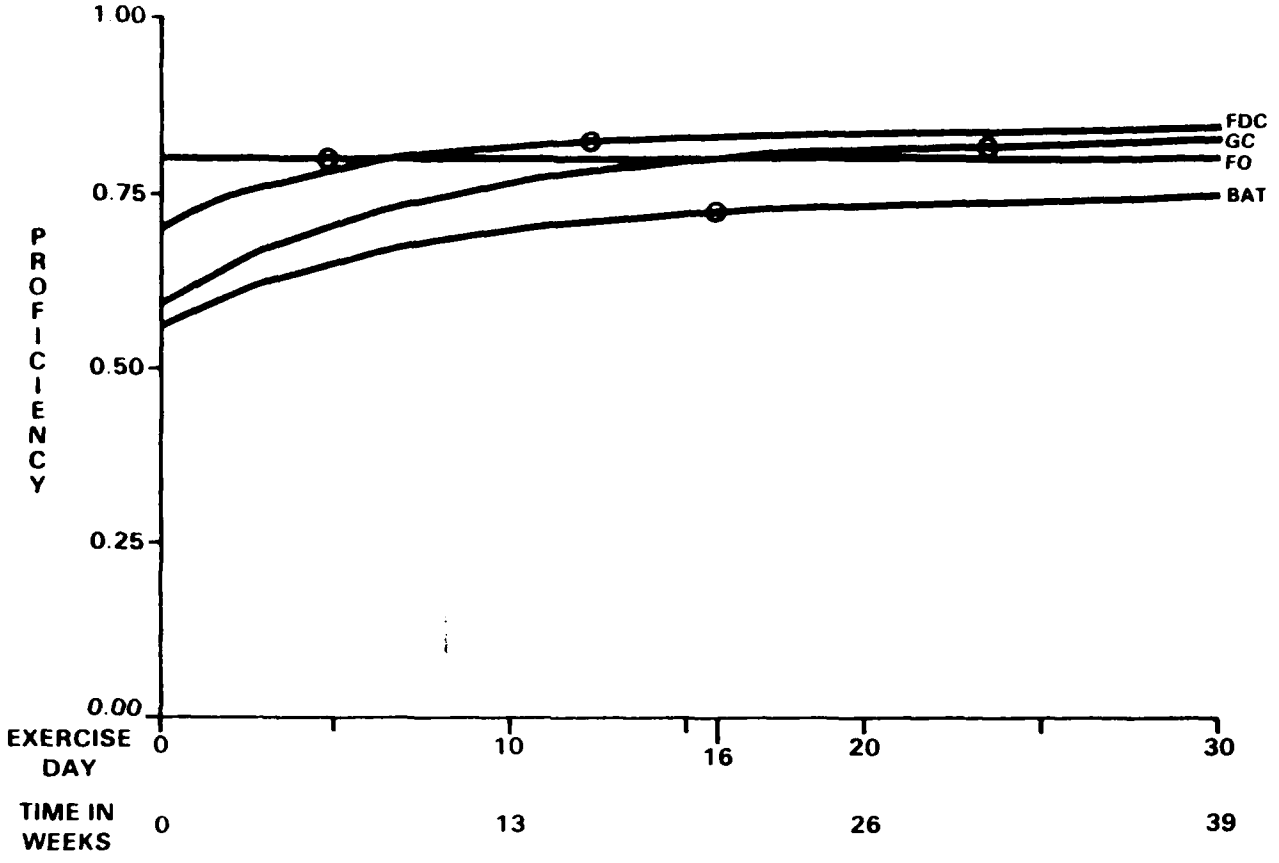
The 50/50 curve in Figure III-36 is our best estimate of the maintainable proficiency using a 50/50 mix of live-fire/non-live-fire exercises. But the two battery curves in Figure III-36 are not as close as they look. To maintain 74 percent proficiency takes 34 pure live-fire exercises per year but about 40 mixed exercises per year - almost a 20 percent increase.

Note that we present the 50/50 mix curve in terms of mixing pure live-fire exercises with pure non-live-fire exercises. This is required by our modeling since our data is gathered in terms of pure exercises on one form or the other. However, the questionnaire responses do indicate that a better procedure may be to mix live-fire with non-live-fire within the same exercise (but not necessarily during the same day). Again, we are unable to quantify this. This requires testing, for it concerns how to train and not how much to train.

e. The Attainment of Proficiency and Applications

When a new crew comes together, their proficiency is apt to be low. As they train together, their proficiency will increase. This subsection displays results concerning how quickly proficiency can be attained. Figure III-32 is our guide. The major decision variable here is the rate of training. It could be intense, or it could be at the normal rate for maintenance training. We display both applications in this sub section. We also display how fast proficiency decreases when training fails to take place. Let's begin with attainment at an average maintenance training rate.

Figure III-37 displays the increase in proficiency of each element and of the battery as a whole as the elements train together. The circles on each curve indicate when the curve reaches the proficiency value



NOTES:
1. EACH EXERCISE DAY IS ASSOCIATED WITH 60 LIVE ROUNDS.
2. ELEMENT CURVES FOLLOW THE FORMULA:

$$r^N (Po - P[n]) + P[n]$$

WHERE N IS IN WEEKS. WE ASSUME 40 LIVE-FIRE EXERCISE DAYS PER YEAR AND P[n] IS THE MAINTAINABLE PROFICIENCY AT n = 40 (SEE FIGURE III-36). AT $\alpha = 0$, THE VALUES FOR C ARE: FO-C = 7.24, FDC-C = 4.34, GC-C = 5.42. ALSO, $r = 1 - (n + C)C^1$ AND C^1 IS: FO-C^1 = .00138, FDC-C^1 = .00230, GC-C^1 = .00184. SO r IS: FO-r = .935, FDC-r = .898, GC-r = .916.

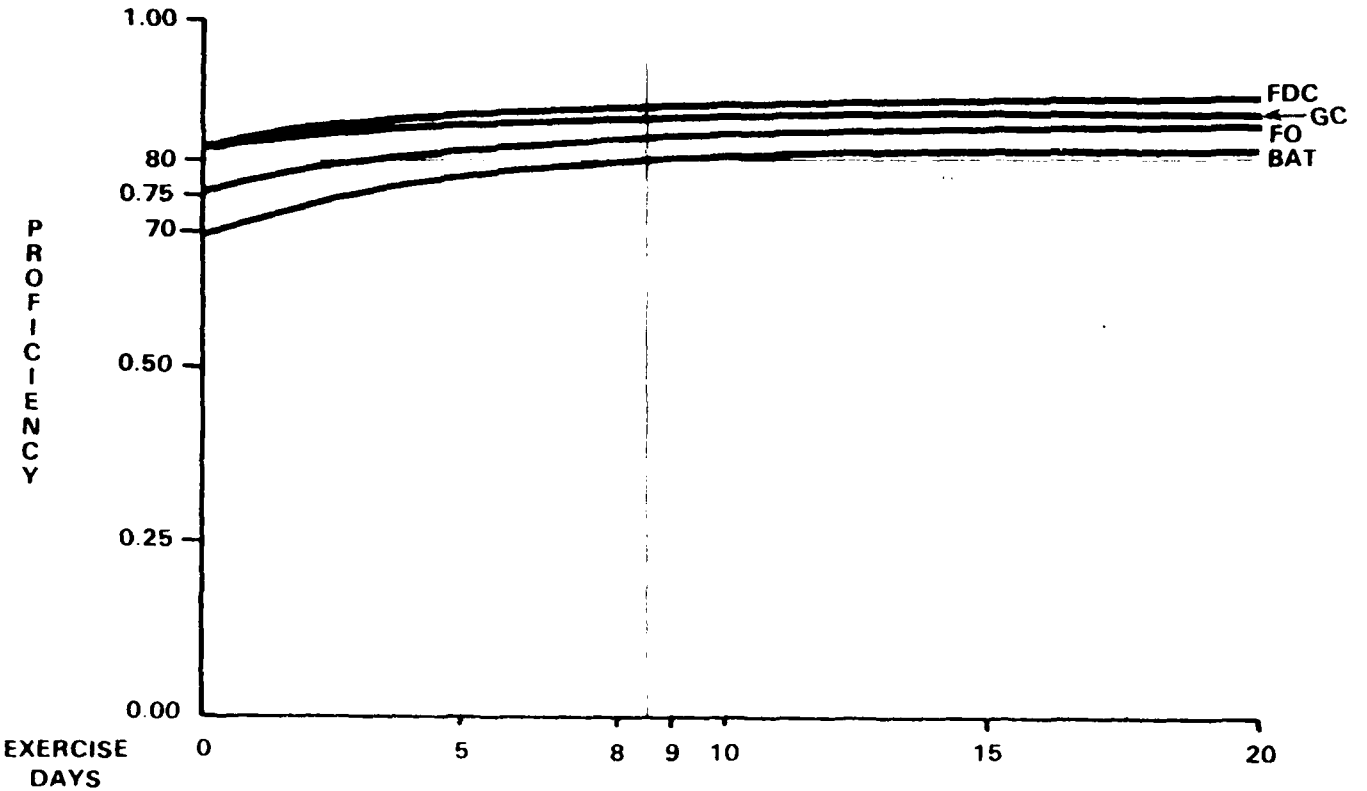
3. CIRCLES MARK THE MAINTAINABLE PROFICIENCY WITH MEDIUM TURBULENCE RATE.

Figure III-37. Element and Battery Attainment

maintainable at the median turbulence rate (=3/26). The initial proficiencies were taken from the questionnaire responses concerning the proficiency level of the respective crews after one live-fire exercise together. We took this as our P. The battery achieves a "steady-state" proficiency after five months of training together. This equates to 16 live-fire exercise days, or about 8 two-day shoots (960) rounds). With this analytic "machinery" in place, we can perform other applications: Subsection 7b stated that, at this point in our knowledge, there is no discernable distinction between an "unlearned" state of crew skill, and a forgotten state of crew skill. As far as we can tell, if a crew is x percent proficient, no matter how it got there, it will still require the same amount of training to increase its proficiency to x+1 percent. And no matter how it got to x+1 percent, it will take the same amount of time to reduce to x percent with no training when there is no turnover.

One application of this principle is the following pre-deployment strategy: Rather than maintain a relatively high proficiency, one might maintain a relatively lower proficiency (at perhaps some considerable saving), and, prior to deployment, boost that lower proficiency with intense exercise. This strategy may have particular application when the battery is deployed at sea, and unable to train with live-fire. In that situation, the decrease in proficiency due to lack of training, which is inevitable, occurs at the expense of the cost of the intense training period, rather than at the expense of the larger cost of the incremental maintenance training applied y[illegible] long.

Figure III-38 displays an example. We assume no turnover during pre-deployment. It takes between 8 and 9 exercise days to get the battery from 70 percent to 80 percent. This consumes about 510 rounds. According to Figure III-36, to maintain a battery at 80 percent takes about 52 to 53 exercise days per year - for an average consumption of 3150 rounds, while to maintain a battery at 70 percent takes 33 to 34 exercise days per year - for an average consumption of 2010 rounds. This is a difference of 1140 live rounds per battery, which might be made up for, when needed, by 510 rounds used in intense training. Figure III-39



NOTES: 1. EACH EXERCISE DAY IS ASSOCIATED WITH 60 LIVE-FIRE ROUNDS.

2. ELEMENT CURVES FOLLOW THE FORMULA:

$$R^{D}(P_{o} - P(n)) + P(n)$$

WHERE D IS IN EXERCISE DAYS AT 1.67 EXERCISE DAYS PER WEEK FOR A VALUE OF n OF 86.84. HERE WE USE THE VALUES OF C AND C' FROM FIGURE III-37 AND SET $R = r^{1.67}$. SO FOR FO-R = .894, FDC-R = .836, GC-R = .864.

3. P_o TAKEN FROM FIGURE III-30 AT n = 28 HOLDING THE AVERAGE BATTERY PROFICIENCY AT 70%, FO AT 76%, AND FDC/GC AT 82%.

Figure III-38. Pre-Deployment Intense Training

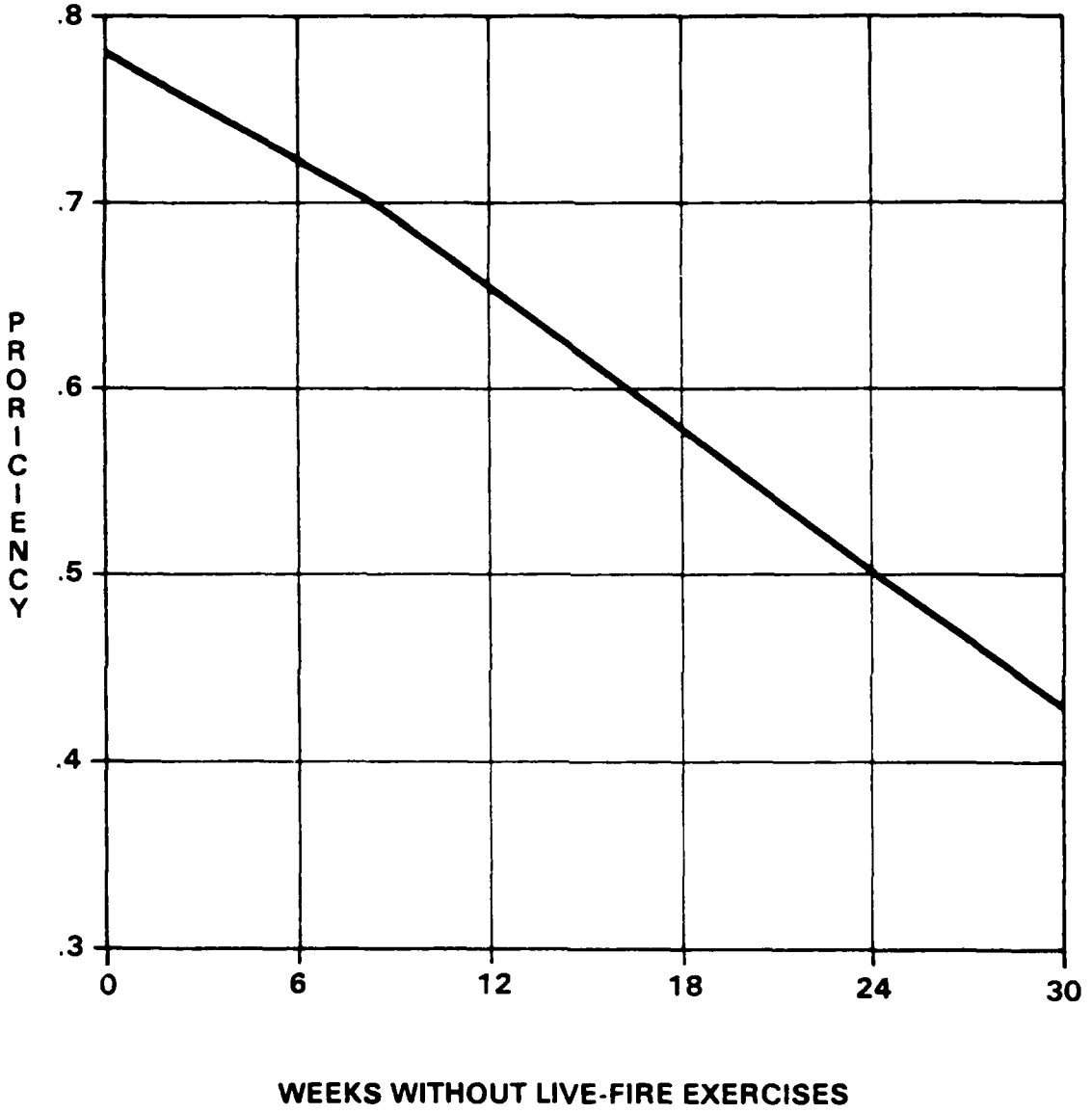


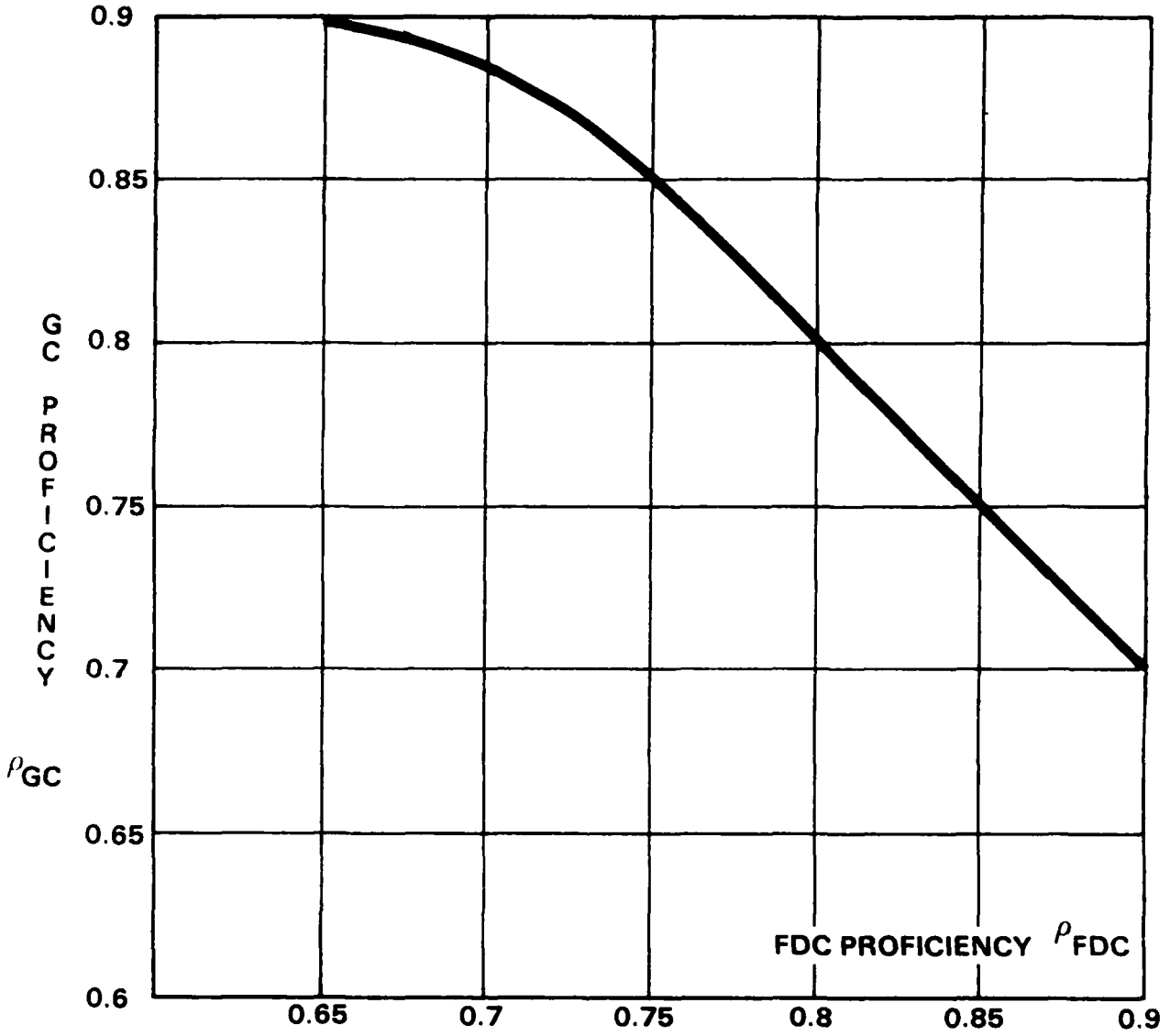
Figure III-39. Battery Proficiency Decay

displays a sample decrease in proficiency for a battery unable to train. This Figure is identical to the Battery Proficiency Decay Exhibit in Annex B. We simply wish to demonstrate that the decay is very sharp. This rate of skill decay dictates that regular training is most necessary.

We should also comment that it is possible to adjust the model for the turnover of different crew members having different impact on professions. The average turnover rate can be adjusted by equating a specific crew member's impact to the impact of some number of "average" crew members. For example, the loss of a Section Chief might be equated to the loss of 2 gunners. The average "gunner" turnover can then be increased to account for the turnover of the Chief.

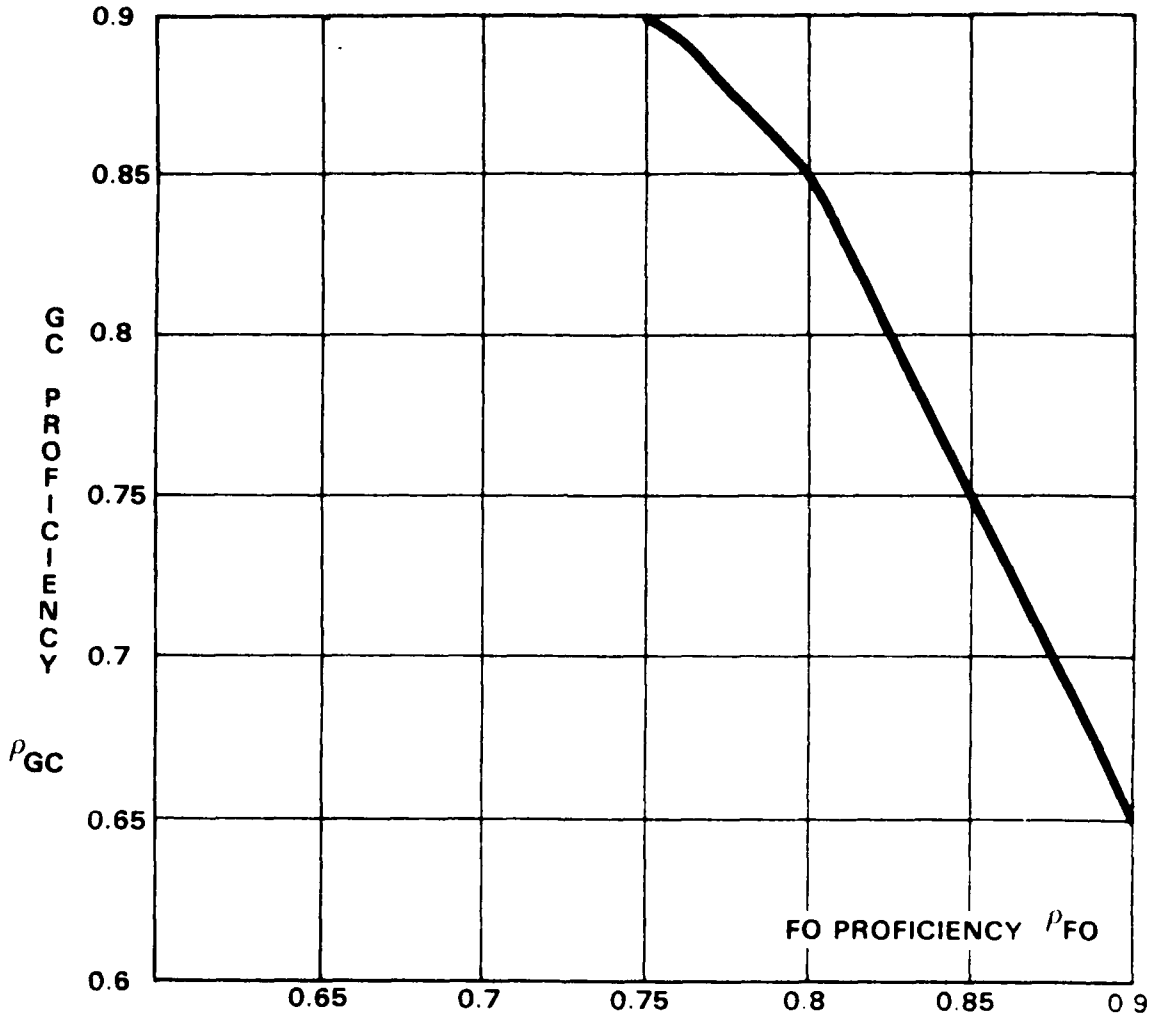
f. Sensitivity of the Battery Proficiency Model

Which element is the most critical to battery performance? If we can quantify this, we might suggest a training strategy in which the element with the most battery proficiency impact would be given some over-training. This would be a less expensive way to maintain overall battery proficiency. The Battery Proficiency Model allows us to do this. We can determine which element has the greatest impact on battery proficiency and by how much. We do this by testing the sensitivity of the battery proficiency output of the model to the input proficiencies of the elements. Figures III-40a, b, and c display these results. The idea in these figures is to hold the battery proficiency at the current median of 75 percent, and fix one element's proficiency at 85 percent. Then, see what relationship is forced on the proficiencies of the other two elements in order to maintain the 75 percent battery proficiency. For example, Figure III-40a holds the FO proficiency at 85 percent. Then, an 80 percent proficiency for the GC and FDC yields a 75 percent battery proficiency. As the FDC proficiency decreases to 75 percent, the GC proficiency must increase to 85 percent to keep the battery at 75 percent. In the area of FD and GC at 80 percent, every percent decrerase in FDC must be counter balanced by a percent increase in GC, and vice versa. At the top of the curve in Figure III-40a, a one percent decrease in FDC proficiency can be balanced



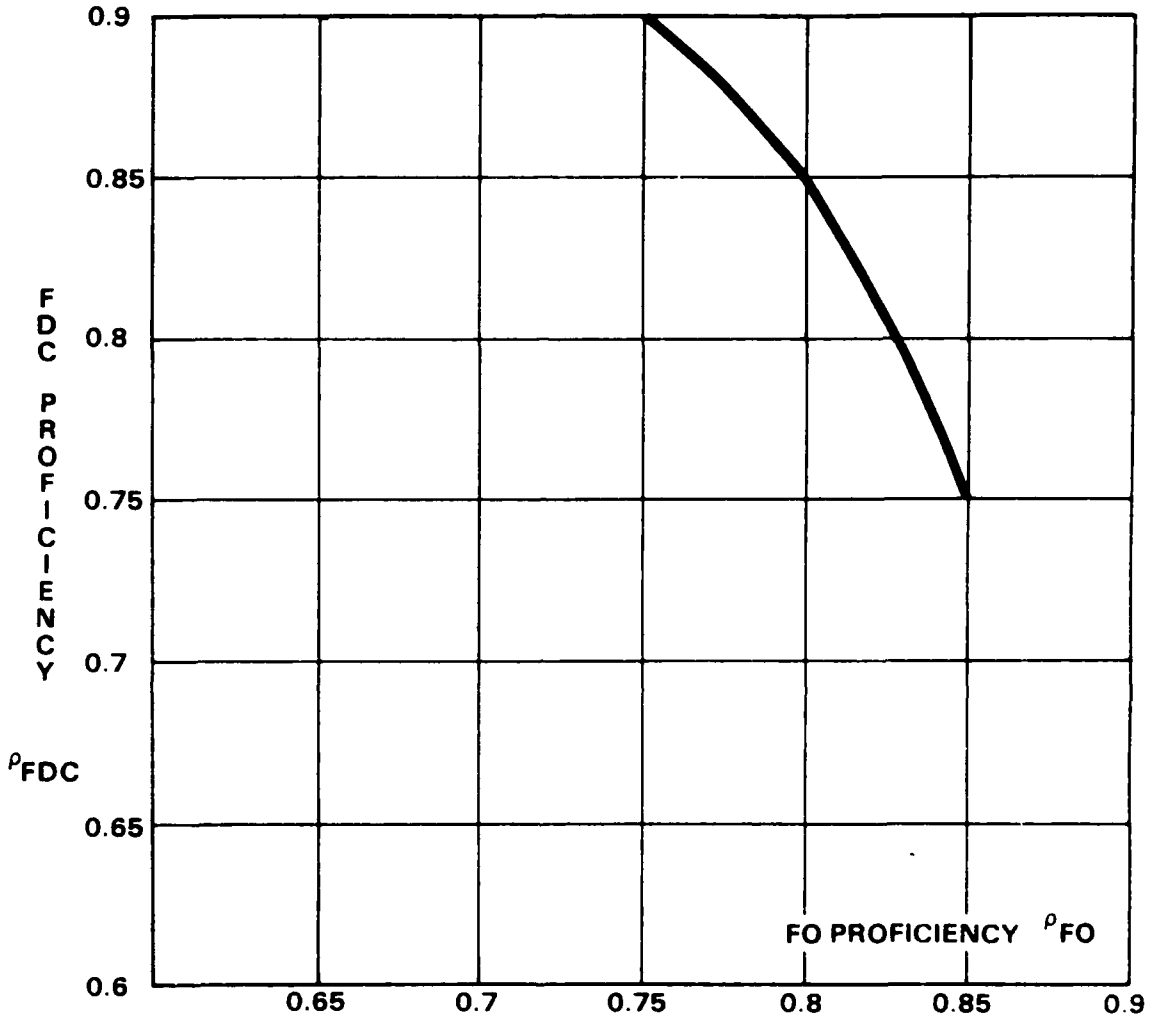
NOTES: 1. BATTERY PROFICIENCY FIXED AT 0.75.
2. FO PROFICIENCY FIXED AT 0.85.
3. PLOT OF THE RELATION $\Psi(0.85, \rho_{FDC}, \rho_{GC}) = 0.75$.

Figure III-40a. Level Curve for GC and FDC Proficiency: Given Fixed Battery and FO Proficiencies



NOTES: 1. BATTERY PROFICIENCY FIXED AT 0.75.
2. FDC PROFICIENCY FIXED AT 0.85.
3. PLOT OF THE RELATION $\Psi(\rho_{FO}, 0.85, \rho_{GC}) = 0.75$

Figure III-40b. Level Curve for GC, and FO Proficiency: Given Fixed Battery and FDC Proficiencies



NOTES: 1. BATTERY PROFICIENCY FIXED AT 0.75.
2. GC PROFICIENCY FIXED AT 0.85.
3. PLOT OF THE RELATION $\Psi(\rho_{FO}, \rho_{FDC}, 0.85) = 0.75$

Figure III-40c. Level Curve for FDC and FO Proficiency; Given Fixed Battery and GC Proficiencies

by a one-half percent increase in GC proficiency. However, one-half percent increase about the 90 percent level is expensive to obtain.

Figure III-40b displays the reciprocal relationship between FO and GC proficiencies. Through the .8 to .9 range, the curve indicates that every one percent decrease in FO proficiency must be counterbalanced by a two percent increase in GC proficiency. Figure III-40c shows a similar tradeoff about the FO proficiency of 85 percent. About FO = 80 percent the tradeoff is one FO point for 1 1/2 FDC points.

Figures III-40a, b, and c suggest that it is a reasonable strategy to overtrain FOs. In fact, according to Figure III-34, Marine Corps seems to be doing this, since the FOs report more live-fire participation and a higher overall proficiency than the other elements.

g. Mortars

A survey questionnaire was designed and administered as part of the study (see Annex B) however, results were not obtained in time to be included in the analysis of indirect fire. Accordingly, the modeling of mortar missions using the MCCRES standards has not been accomplished as was done for the artillery missions. However, because of the comparability of most aspects of artillery and mortar indirect fire, the same methodology applies.

h. Proposed Artillery Training Allowance

Table III-3 is a proposed Artillery Allowance in MCO P8011 format for the 155mm Howitzer, M-198. This proposed allowance could be used as a basis for validation testing. Further, the allowance is exclusively focused on battery proficiency. It does not include allowances for demonstration, combined arms training and exercises, etc.

TABLE III-3. PROPOSED ARTILLERY ALLOWANCES IN MCO P8011 FORMAT

m. 155 mm Howitzer, M198 (2)

DODIC	ITEM	CURRENT ALLOWANCE/BASIS	*RECOMMENDED ALLOWANCE 1 BASIS (1)	APPLICABLE UNITS
D544	Prop, HE	306/Wpn	a. 2,800/8 Tube Btry b. 2,200/8 Tube Btry	a. One Btry Per Bn b. Two Btry Per Bn
D550	Smoke, WP	40/Wpn	a. 48/8 Tube Btry b. 40/8 Tube Btry	a. Two Btry Per Bn b. Two Btry Per Bn
D505	Proj. Illum	30/Wpn	a. 96/8 Tube btry b. 56/8 Tube Btry	a. One Btry Per Bn b. Two Btry Per Bn
D562	HE (ICM)	1/Wpn	1/Btry or None	All Btry

NOTES:

*(1) Recommended allowances are derived from the analysis of 6 tube batteries with conversion factors designed to maintain one 8 tube battery per Bn near 80% proficiency and the other two above 70% proficiency.

(2) Proposed allowances to be used as a basis for validation testing and are exclusively focused on battery proficiency; they do not include special allowances for other purposes such as combined arms exercises, demonstrations, etc.

D. OTHER CREW SERVED WEAPONS

Analysis of allowances for other crew served weapons was primarily based on annual consumption data related to the basis of the current allowance and costing considerations. The following subparagraphs discuss those crew served weapons identified in the study guidance.

1. TOW and Dragon

The current allowances for TOW and Dragon are:

TOW

- PA66, GM TOW BGM-71A; one perlauncher
- PA67, GM TOW Practice BTM-71A; one per launcher
- VX94, TOW Blast Simulator; 180 per launcher

DRAGON

- PL22, GM Dragon Practice M223; one per tracker
- PL23, GM Dragon M222; one per tracker
- G839, CTG Rifle Grenade 7.62mm, M64 (for use in M54 Dragon trainer; 840 per gunner and assistant gunner

It is understood that the current total inventory of practice and primary missiles for both TOW and DRAGON are such that replacement of training consumption is not required or anticipated over the next few years. However, the number of TOWs and DRAGONS in the FMF will concurrently increase significantly in conjunction with the force structure evolution and eventually generate a requirement for procurement/replacement of improved TOW and DRAGON missiles. The current item replacement costs for TOW and DRAGON missiles are estimated at $9,950 and $8,000 respectively. Although current allowances appear minimal, item costs seen in conjunction with an increasing inventory and potential use of the MILES XM62 and XM64 training devices appear to warrant reconsideration of the basis of these allowances. Specifically, experimentation with variable

organizational allowances similar to those discussed for tanks and artillery would provide a means of determining if a more cost effective allowance basis was feasible.

2. Air Defense (HAWK and STINGER)

The annual allowances of VX80, GM HAWK MIM-23B are three missiles per battery in the active force structure and two per battery in the SMCR. The unit cost of the missile is $244,000. It is noted that the high cost of the missile is directly related to the battery vice launcher basis of the allowances. While the allowances can be considered minimal, the high unit cost appears to warrant additional experimentation with variable organizational allowances both at and below current allowances. In this regard, due consideration should be given to:

(1) Mount-out/deployment factors and constraints,

(2) Annual availability and location of live fire ranges, and

(3) Annual personnel turnover or turbulence.

The current annual allowance of VX81, GM REDEYE M41A2 is one per Gunner. It is understood that this allowance was possible due to a very large inventory as related to only 60 gunners in the active force structure. However, the active force structure has been increased to two full batteries each containing 150 Gunners. In light of the increased structure and high cost of the STINGER missile, the Marine Corps has developed a STINGER Launch Simulator which will be used to qualify all FMF gunners on an annual basis. Therefore, there are no plans to institute an annual FMF training allowance of the STINGER missile.

3. Machine Guns (M60 and .50 Caliber)

The current high density allowances for the M60 and .50 caliber machine guns are:

M60

- A131, Ctg 7.62 Linked 4 and 1; 4,800 per weapon

.50 Cal

- A576 Ctg Cal .50, Linked 4 and 1 (M2); 1,500 per weapon
- A589, Ctg Cal .50 Linked 4 and 1; 1,870 per weapon

The annual consumption history of the high density .50 caliber ammunition is shown in Figures III-41 and III-42 together with related unit replacement costs. The data clearly show wide variations in annual consumption which tend to validate a need for a management system providing more control over training allowances. This need is not exclusive to .50 caliber consumption but extends to all infantry crew served weapons. Perhaps the best example of the need is the introduction of the M249 Squad Automatic Weapon. It is understood that the procurement will total 10,284 weapons which has the potential of generating an annual consumption of 40-50 million rounds. As the focal weapon of the Marine Fire Team, field requirements or "demand" for high or liberal allowances can be anticipated. Assistant gunners as well as gunners need to be qualified. In addition, the fire team and squad leaders will need to be fully trained in directing and coordinating the fire of the M249 in a variety of tactical situations. Concurrently, the Marine Corps needs a cost effective approach in determining reasonable training allowances that will be predictably stable over a number of years. It is believed this example points toward transition to an organizational training allowance system as the C series infantry battalion is introduced into the force structure.

E. VARIABLE ORGANIZATIONAL ALLOWANCE CONCEPTS

The methodologies defined above leads to the predictable premise that differing hard data curves will evolve through testing. Due to the many variables included in the methodology, it seems highly improbable that any two battalion level organizations will produce matching curves. One could attempt to normalize these curves to derive standard allowances for all FMF units. However, such an approach would not take advantage of the data gathered nor the magnitude of differences in force posture, mission tasking, personnel turnover, and range location/availability that are existent in the FMF. The study group believes it is entirely feasible to set different (or variable) FY84 allowances through judgmental analysis of

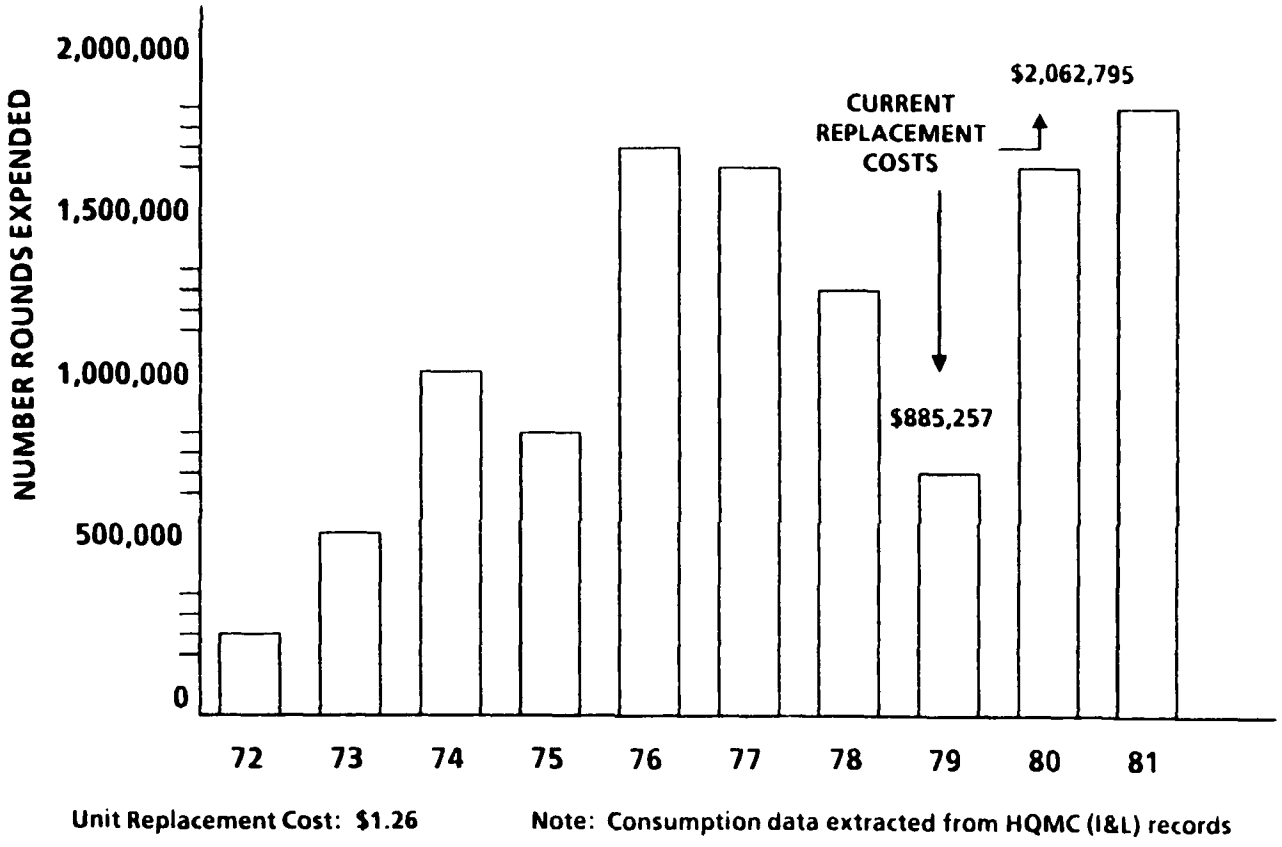


Figure III-41. .50 cal Consumption (Unit Replacement Cost: $1.26)

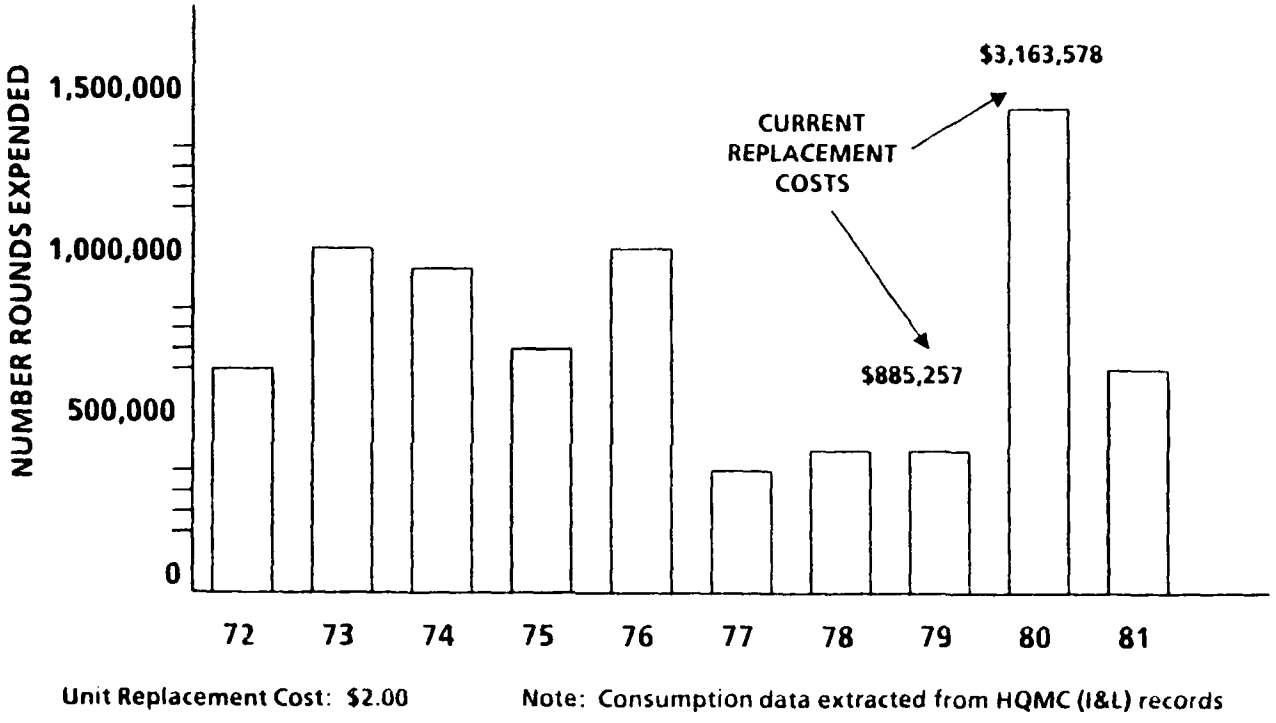


Figure III-42. .50 cal Consumption (Unit Replacement Cost: $2.00)

the current curves and an evaluation of organizational location, mission tasking, personnel turbulence and live-fire range constraints.

Using the tank structure as the first basic example, the 2nd Tank Battalion is organized with four tank companies and located at Camp Lejuene, NC. It continually provides one platoon to the MED BLT, supports other deployments and exercises at a high tempo including special cold weather exercises. The Bn (-) exercises extensively at Camp Picket, VA. Tank Crew turnover may be expressed as CT_1; Range location/availability may be expressed as R_1.

The 3rd Tank Battalion (-) with three tank companies is located at 29 Palms, CA; has NIPS tasking, MCATF testing, but no unit deployments. Personnel and range variables may be expressed as CT_2 and R_2. The 1st Tank Battalion (-) is located at Camp Pendleton, CA; does not have NTPS tasking nor MCATF testing and no unit deployments. Personnel and range variables may be expressed as CT_3 and R_3. The tank company in the 1st Marine Brigade stands in stark contrast to all other tank units in the FMF -- continuous support of the deployed 31st MAU drives all facets of its training program. Again in Japan, the tank company constitutes a unique tasking, personnel turnover, and range availability variable. In summary, a variable organizational annual allowance tailored to mission tasking and other basic factors should form the basis of a more cost effective allowance management system.

This same premise can be applied to FY84 artillery allowances. It is understood that the FY83 allowances for M198 direct support weapons was based on 155mm allowances, e.g., 306 rounds of DODIC D544 vice 400 rounds of C445 allowed for the 105mm Howitzer direct support weapon. It is further understood that the increased cost of the 155mm ammo ($170.34 per round of D544) was a basic factor in setting the FY83 allowance. However, it should be clear that setting the D544 allowance at 306 rounds per weapon does not reduce costs or hold them even. The M198 direct support batteries are being formed with 8 vice 6 weapons per battery. Assuming a direct support 105mm battery fired its total allowance of C445, the replacement cost

would be $340,080. Assuming an 8 tube M198 battery fired its "reduced" total allowance of D544, the replacement cost would be $416,992.

The study group believes that it is not only feasible but highly desirable to set different FY84 organizational artillery allowances again through judgmental analysis of the artillery curves in conjunction with artillery organizational tasking, location and other basic factors.

It is further believed that the basic premise can be used in FY84 in conjunction with the formation of C series infantry battalions and their variable unit rotation cycles.

F. CHANGES IN FORCES, WEAPONS AND DOCTRINE AND BUDGET LEVELS - IMPACT ON TRAINING AMMUNITION ALLOWANCES

1. General - Acquisition Process

Military forces are in a continuing state of evolutionary change. New weapons and equipment are constantly being integrated into the military forces inventory. This, in most cases, requires changes in doctrine and training procedures. The overall policy governing the acquisition of major systems is set forth by Department of Defense in DOD Directives 5000.1 "Major Systems Acquisition", DOD 5000.2 "Major System Acquisition Process" and DOD Directive 5000.3 "Test and Evaluation". The developmental process of a weapon systems is all inclusive, and includes the development of the doctrine of employment, the training and support packages to field and maintain the item, and the personnel skill requirements to operate and sustain the system under field conditions.

The Marine Corps relies primarily on the other services, principally the Army and Navy, to develop its weapon systems. However, full coordination is maintained by the USMC with the developing service during the acquisition process.

2. Development of Training Support Packages

The overall acquisition process for new materiel is divided by DOD into four (4) major phases which include:

(1) Conceptual,

(2) Validation,

(3) Full Scale Development, and

(4) Production and Development.

The training concepts and requirements are studied, tested and/or evaluated during each phase in development process. At the major decision points at the termination of each phase, impact on training is a pertinent decision-making factor to be considered prior to proceeding to the next phase.

In the conceptual phase, a materiel concept in the form of a breadboard and experimental model is presented for developmental decision. Formal testing is not accomplished in this phase. Usually, the concept is demonstrated to indicate potential military value. The impact on training is visualized and forms the basis for training requirements enunciated in the Letter of Agreement (LOA). This is a jointly prepared and authenticated document in which the user and developer outline basic agreements for the further investigation of the potential of the materiel system. Training is covered only in broad, general terms.

During the Validation Phase, an advance development prototype is produced. It is given both technical and operational tests to form the basis of an evaluation of the future military potential of the system and the readiness of system for transition to the full scale development phase. Critical technical and operational issues are addressed during the testing in this phase. Aggressive force development tests and evaluations are accomplished by the user to develop employment concepts, operational feasibility, estimated/potential military advantage and also the burdens of the system. The decision to transition a system to full scale development is the major acquisition decision in the validation phase. This decision establishes the requirement, initiates the expenditure of large sums of R&D money, and indicates the extent of the procurement dollars to be committed. Very seldom is a system cancelled after it transitions to the system development phase. Supposedly, at this decision point, critical issues concerning training have been addressed and answered satisfactorily. However, details concerning training, such as resources required, have only been addressed in a cursory manner. Generally, they have been estimated in a parametric manner by comparison with previous similar systems.

During the Systems Development Phase, DOD policy requires considerable emphasis on the development of doctrine for employment, organizational structure, maintenance allocations and procedures, and training programs and associated training aids. This is referred to as the integrated logistic support (ILS) package. Most of these support items are covered in draft field and technical manuals. The training ammunition requirements are an essential part of the training package. Generally, it is formulated parametrically based upon requirements of previous like systems. If it is a completely new system, engineering judgments are made to provide an initial requirement which is integrated with the remainder of the training package.

3. Test and Evaluation of Support Packages

At the culmination of the development phase, the engineering development prototype to include the training support package is supposed to be thoroughly tested and evaluated to determine whether the system meets the requirements and should transition into production. However, there is a tendency in the development process, due to budgetary constraints and project urgency, for the development of the ILS items, including the training package, to fall behind the development of the prototypes. This lag in ILS development and the resulting testing has a tendency to be carried through to the deployment phase. Therefore, systems are frequently deployed with the training package incomplete, and not thoroughly tested. This impacts on training ammunition requirements which are developed late and hurriedly with in ufficient and inadequate testing. It is extremely difficult under the circumstances, to provide adequate and timely justification for budgetary purposes for training ammunition which is being produced concurrently with the system to meet deployment schedules.

4. More Emphasis on Timely Training Development in the Overall Acquisition Process

Greater emphasis must be placed in assuring that doctrine, organizations, tactics, personnel skill requirements and, above all, the total training package are progressively and concurrently developed with the

materiel system. Training must be a major consideration in each phase of development. Further, the total training package must be:

(1) Thoroughly tested and evaluated at the conclusion of the engineering development phase, and

(2) Verified with production items in the production phase.

In regard to training ammunition requirements, the evaluation should answer critical issues pertaining to the development of the optimum operational proficiency of individual and unit skill levels in the most economic manner. To develop these requirements, troop unit tests, which determine acceptable proficiency versus the optimum combination of live and sub-caliber fire and simulation, should be conducted. The methodology developed in this study for tank gunnery and artillery battery training should provide a valuable evaluation tool in this test process.

5. Impact of Materiel Product Improvements, New Training Aids, and Procedures on Training Ammunition Allocations

All military materiel systems are ever changing. Systems undergo a number of product improvements over their useful life. Also, training processes and procedures are evolutionary - constantly in a state of change. Consequently, the training ammunition allocation should be under close scrutiny to assure that it dovetails with the training procedure. Data on ammunition usage and proficiency attained must be gathered on a consistent or periodic basis as determined necessary. Thus, data utilizing the methodology developed in this study will provide a justification for the live-fire ammunition requirement related to readiness proficiency.

6. Impact of the Budgetary Issue

The military is constantly faced with budgetary constraints that impact on the amount of training ammunition available for troop use. Major caliber ammunition, i.e., artillery, tank and mortar, form a majority of training ammunition budgetary requirements. Hence, there is pressure by DOD and Congress to reduce the requirement for the high cost ammunition items. Emphasis is placed on substituting sub-caliber firings and various other training devices in lieu of live firings using the major caliber weapon ammunition.

Currently, training techniques using new technology is undergoing dynamic development. There are indications brought out in this study that an increase in crew proficiency is not proportional to ammunition expended. Hence, to meet the continuing budget pressure, efforts must continue to seek more cost effective means of achieving weapons crew proficiency. It is essential that we seek new non-live fire training techniques which, coupled with required live-firing, will meet the individual and crew proficiency requirements. Only in this manner can budget constraints be successfully overcome.

The methods proposed will provide ammunition allocation as a function of proficiency and budget constraints. When new weapons or tactics are introduced, the same general methods will apply. New data will will be needed, beginning with operational tests of the weapons and tactics and new equations might be required. The latter decision will be determined by the data obtained from tests, and the understanding gained from the methods developed from the models presented in this report.

G. FINDINGS

The following summarizes the study findings resulting from the research, survey and analysis:

1. General

Annual missions and deployments of USMC units are a major factor which should determine individual MAF element training programs, and ammunition requirements and allocations.

Hard data on tank gunnery and indirect fire battery performance are virtually non-existent. This lack of hard data resulted in the need to use subjective questionnaires as a survey tool in this study.

The judgments of personnel surveyed showed considerable variance in absolute values of expected results. For example, estimates of the crews qualifying in one case varied from 40 to 85 percent. However, there is consistency in trends as reflected in the direction and slope of curves.

Training ammunition expenditures for tank gunnery and artillery live firings are not available on a battery/tank platoon basis. Hence, no correlation between performance and expenditures could be made.

2. Tank Gunnery

The evident lack of consistency identifies data collection needs. Data should be collected on the following for each tank crew and platoon:

(1) Qualified or not on first MCCRES test,

(2) Number of retests to qualify,

(3) Amount of full caliber ammo expended by test table,

(4) Amount of subcaliber ammo expended by table,

(5) Proportion of simulation used in pre-table training (crews only),

(6) Crew longevity to reflect turbulence, and

(7) Platoon longevity to reflect turbulence.

The following concepts can be tested to determine the effects of changes in ammunition allowances, both full and subcaliber:

(1) Reduce the ammunition allowance for selected crews and platoons. Set aside the unused portion of each crew's and platoon's normal allowance. Design the test so that crews or platoons not qualifying have access to the set-aside ammunition, either until they qualify or until they have exhausted their normal allocation.

(2) Test the substitution of subcaliber for full caliber, repeating tests until the crews/platoons involved in the test qualify.

(3) Vary pre-table use of simulation.

After the collection of hard data over a one-year period, the methodology presented in Chapter III will permit more precise definition of training ammunition requirements.

3. Indirect Fire Weapon Systems

Analysis of the questionnaires revealed:

(1) A great variation in judgmental MCCRES performance in relation to days of live-fire/simulator training and rounds fired per day, and

(2) Occasional judgmental contradictions within the same respondents questionnaire.

The effect of changes in training ammunition allowances is highly uncertain.

The basis for structuring hard data collection is found in our proposed methodology. The indirect-fire methodology developed in this study requires as input (for each battery element and for the battery overall):

(1) The MCCRES scoring, and for the prior year,

(2) The number of days of training,

(3) The rounds expended per day (live-fire and subcaliber), and

(4) The personnel turnover.

The analysis provides a basis for testing to determine the effects of ammunition use on proficiency. Since battery proficiency depends a great deal upon the coordination of elements, testing must be devised to elicit some measure of the effect of training the battery together versus training the elements separately.

The updated procedures proposed in the methodology can be used to determine ammunition allowances needed to achieve a specified average battery proficiency, once testing has provided a relationship among:

(1) "Rate of learning" and rounds expended per day (both live-fire and subcaliber) at the element level,

(2) The effects of turnover at the element level, and

(3) A measure of the increase in "coordination" (e.g., coordination times) between elements as a function of mutual training.

4. Other Crew Served Weapons

High cost missile systems training ammunition expenditures are very tightly controlled; hence these offer little opportunity for savings. A pontential saving might be made by reducing the HAWK missile annual training allocation per battery from 3 to 2.

Machine gun training ammunition, which has a low unit cost but has a high expenditure rate, is not tightly controlled and its allocation rate varies widely on a year to year basis. There appears to be no valid justification for this fluctuation in allocations.

5. Impact on Ammunition Training Allowances of Changes in Weapons, Tactics, Doctrine and Budget Constraints

Emphasis must be placed on the concurrent development of systems and their training procedures to include training ammunition allowance beginning at the latest in the full scale development phase of the acquisition.

As weapon systems develop and mature, the training procedure should be under constant review with the goal of optimizing crew performance and training costs.

CHAPTER IV
CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS:

(1) The methodologies developed in this study provide a valid basis for determining tank and artillery ammunition training allowances. (Chapter III, Section B.4 and C.5 & 7)

(2) Specific changes in ammunition training allowances should commence on an experimental basis in FY84. (Chapter III, Section B.4.C and C.7.h)

(3) There is a need to collect hard data on both direct and indirect fire weapons systems; the basis for structuring this collection effort is identified in Chapter III. (Section B.4 and C.7)

(4) There is a need to introduce and refine a more definite and responsive ammunition allowance management system. (Chapter III, Section B.1, B.3 and C.3)

(5) Variable organizational allowance concepts should be tested through the FMF in FY84 to determine the effects of changes in ammunition allowances, both full and subcaliber. This should be instituted in conjunction with directed increased use of other training devices. (Chapter III, Section E)

(6) Logical alternative to the current annual allowance system is an organizational basis of allowance vice a per weapon basis. Further, annual organizational allowances could be developed in conjunction with a quarterly allocation and expenditure reporting system (Chapter III, Section E)

(7) Transition to an organizational basis of allowance in conjunction with adoption of the methodology presented in Chapter III would provide a management system responsive to changes in weapons, tactics, doctrine, force structure, and budget constraints. (Chapter III, Section F)

B. RECOMMENDATIONS:

(1) That current allowances be sustained during FY83. (Chapter III, B.4.b, and C.7.h)

(2) That, commencing with FY84, a system to collect hard data be instituted as defined in Chapter III. (Chapter III, B.4.c and C.7)

(3) That, commencing with FY84, variable organizational allowance concepts be tested throughout the FMF. Proposed FY84 allowances for tank and M-198 artillery units are depicted in Chapter III, Sections B and C, respectively.

(4) That the Marine Corps consider transition to an organizational basis of allowance system for all FMF weapons systems. It is further recommended that early transition to an organizational allowance system be considered for M-198 artillery battalions and C Series infantry battalions. (Chapter III, Section E)