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Interim Report

SUSTAINING TEAM PERFORMANCE: A SYSTEMS MODEL

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This report examines the factors that influence the maintenance of team performance. It presents a review of literature concerning variables that maintain or degrade military team skills, including skills of the individuals who are members of the team. The review organized around a systems (input-process-output) model and focuses on team performance variables pertaining to the maintenance of system (e.g., weapons system) output over time. Input variables include three categories: organizational and environmental, individual, and team specific. (continued)			

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PREFACE

This report documents research conducted by Litton Mellonics for the Defense Advanced Research Projects Agency under Contract MDA903-79-C-0209. The work was performed in Litton's Washington Scientific Support Office.

The project was designed to identify factors affecting skill retention and skill loss, to determine programs of initial and refresher training which will maintain technical proficiency, and to develop predictive models for programming cost-effective training and retraining programs. This report presents the literature review organized around a preliminary model. The model covers organizational and collective (i.e., crew, group, team, and unit) factors as well as individual factors influencing skill retention. Objectives of subsequent phases of the research are testing and refinement of the model, and development of a methodology for improving research that will result in more cost-effective collective training. Important to this will be any assessment of the costs of training and the cost implications of skill loss.

The present research was greatly assisted by the advice and support of many individuals and organizations outside Litton Mellonics. Most importantly, the authors recognize the invaluable assistance provided by Dr. J. Dexter Fletcher, DARPA, and LTC William Valen, TRADOC. The authors also extend their special appreciation to COL Ronald J. Rabin and his staff at U.S. Army Training and Doctrine Command Systems Analysis Activity (TRASANA), who supplied the REDEYE data and descriptive materials contained in Chapter 3 and Annex D.

Within Litton Mellonics, Dr. John Chiorini provided valuable assistance in all aspects of the research; Dr. Thomas Wyatt contributed substantially to the information concerning sociological processes; and Miss Sue Tepper served as Administrative Assistant for the research group.

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SUMMARY

Objective

The purposes of this research were, first, to examine factors that influence the individual, organizational and collective skill retention within the military system, and, second, to design a model of variables that influence team performance changes over time.

General Methods Employed

Literature concerning variables that maintain or degrade military team skills, including skills of individuals who are members of a team, was reviewed and organized around a systems (input-process-output) model. This review focuses on team performance variables pertaining to the maintenance of system (e.g., weapons system) output over time. Variables that do not pertain to changes in performance over time are not emphasized.

Results and Conclusions

Input variables fall into three categories: organizational and environmental, individual, and team-specific. The organization in which the team performs supplies to the team its individual members, and usually determines their number, selection and training. It also assigns the team's mission or task, and defines the job of each team member. The environment determines working conditions -- including the level of emergent or unpredictable situations.

The second input category includes variables that affect individual skill retention or decay, such as the extent of the individual's original learning, the length of the interval between learning and use, the amount of practice during this "retention" interval, the type of task to be performed, as well as the quality of recall or transfer of information that is required.

The individual skill retention of the team members represents the reservoir of skill within the team. Conclusions based on the individual skill retention literature are:

1. Training to a high level of initial performance enhances skill retention. Minimal initial training (e.g., training until the first time the trainee can demonstrate the skill) is inadequate to sustain proficiency.
2. Skill on procedural tasks decays more rapidly than on continuous control tasks. Therefore, procedural tasks need more training and more frequent refresher training.
3. Since skill performance aids (e.g., technical manuals and other job aids) reduce reliance on memory they enhance performance maintenance.

The last input category contains team-specific variables. The team's task and composition (number and ability of members), for instance, influence the level

of team productivity. Furthermore, team processes such as communication, orientation, organization, adaptation, and motivation mediate effects of input variables on team output. In fact, communication and coordination requirements have been shown to degrade team performance to the point that total productivity is less than the potential sum of the products of individual members' efforts.

The system output, therefore, has both task-related and team process-related components. The focus of the present report, however, is on performance that is task-related.

Hypotheses derived from the team performance and team training literature are:

1. In operational military units, practice and other mission-related experience maintains or improves skills, even if it does not provide high fidelity training for individuals or for teams.
2. Task type and team size interact with team processes in their effects on team productivity.
3. Increasing team size degrades performance if it increases communication and coordination requirements; decreasing requirements for interactive processes enhances team performance.
4. Tasks performed in emergent situations benefit from team training, and tasks that are communication-oriented benefit from team training.
5. Team member ability strongly influences team productivity regardless of task type, team size, and other team performance variables.

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CHAPTER I INTRODUCTION

A critical issue in planning military training programs is how to estimate requirements for refresher training following initial learning. Certain tasks, for instance, which are performed infrequently, show considerable post-training memory loss, so that periodic retraining is required. The required frequency of retraining is dependent on the rate of forgetting, cost considerations, and the minimum level of proficiency below which mission-degrading performance will occur. Thus, the initial objective of this research is to identify relationships between varieties of technical tasks, the types and amounts of initial training received for these tasks, and resulting post-training forgetting curves that are indicative of memory retention. From these relationships, the goal is to develop a predictive model to use in programming refresher training.

Early in the project it became apparent that a great deal has already been written and summarized about human memory, and consequently, about the retention and decay of skills at the individual level. What is needed is more knowledge of team, crew or group-skill retention, and about the organizational structure in which the groups function.

Purpose

The purpose of this report, therefore, is to review and analyze literature in order to focus on factors that maintain or degrade military team skills and to design a preliminary model of variables that influence team performance changes over periods of time.

Collective performance, i.e., the task-oriented activities of crews, teams, and military units, is the essence of military system output. The military system responds to a threat (enemy force); the success of the system opposing the threat depends on enemy weapons and personnel destroyed and other components of mission accomplishment. Missions are accomplished through the concerted efforts of teams, whether they are infantry squads, tank crews, indirect fire support teams (FIST), tactical operations center (TOC) staffs, or higher level command and control groups. "Since the team is the most obvious feature of the multiman system, one cannot understand that system without considering the team" (Meister, 1976, p. 231). The system must, therefore, enhance collective performance.

Most performance enhancement research and development pertains to individuals rather than teams for three reasons: rejection of the "group mind" hypothesis, early group productivity results, and the complexity of team research problems (Davis, 1969). For most of this century, the scientific community has rejected the notion of "group mind" as a remnant of nineteenth century explanations of mob behavior. Objections to team research still contain elements of resistance to the "group mind" concept, so it is important to clarify that the present research assumes no "group mind" or other supernatural phenomena.

The second stumbling block to team research has been the product of early group study demonstrating that collective productivity is not necessarily greater than the sum of individual contributions and often is less than that sum.

The third and most serious reason that researchers avoided study of team performance is the complexity of the problems involved. Interaction within and

between teams is very complicated. Variables and measures associated with interactions are numerous and difficult to define concretely. While some of these variables have been isolated and explored in laboratory experiments, they do not account adequately for variance in performance scores when applied to field research.

Because of all of these difficulties, scientists have turned their attention to the improvement of individual, rather than team productivity. Individual research is important because individual performance accounts for approximately 50% of the variance in team performance scores (Meister, 1976). Some scientists even feel that the contribution of individual performance is so great that it is not necessary to study teams (Hall and Rizzo, 1975). While individual performance is a major factor in the model designed for the present research, team factors are also considered.

Since military tasks are multi-person in nature, it behooves the military research community to determine the conditions under which team performance declines, to search for solutions, and to make recommendations for improving performance-system output. Unlike individual training, especially the individual training conducted in military institutions, collective training is embedded in the operations of military units (Defense Science Board Task Force on Training Technology, 1976). During force operations, some personnel learn while others do not because operations differ in mission relevance. To the extent that relevant practice does occur, the retention interval is not comparable to that between initial learning and final testing under research conditions; therefore, the amount of practice is difficult to assess.

The Defense Science Board Task Force on Training Technology (1976) gave new impetus to military team training and team performance research. The Task Force recommended systematic team training research and the establishment of developmental test beds. They recommended several substantive areas for investigation: the development of a team taxonomy; an analysis of cost-effective team training; creation of a methodology to coordinate personnel, training and hardware systems; development of simulators and instructional technology for application to teams; and study of the interface between individual and team training. The need for systematic research was reiterated during the Training and Personnel Technology Conference (1978).

Team Definitions

Reviews of team performance literature emphasize the difficulty of defining "team" (see Table 1-1). Briggs and Naylor (1965) define a team as a group of two or more operators working in a structured and task-oriented environment. Klaus and Glaser (1968) cite three main characteristics of teams: rigid structure, organization, and communication network; well-defined assignments; and the most distinguishing feature, a necessity for cooperation and coordination.

Boguslaw and Porter (1962) state that the term "team" is used to describe a collection of people who work together to achieve a common goal, but that it connotes more than a relationship among people. They use it "to describe a relationship in which people generate and use work procedures to make possible their interactions with machines, machine procedures, and other people in the pursuit of system objectives" (Boguslaw and Porter, 1962, p. 388). Their expansion of the definition is important because it emphasizes team procedures as well as team interaction with the system environment, which is particularly important in a military setting.

While all military actions are performed by individuals who are part of some designated unit, the term "team" is not necessarily synonymous with the term "unit." Teams of interest in this study are those formed by individuals actually carrying out a cooperative and interactive effort to accomplish a specific mission. In this sense then, a unit may also be a team, but it is more likely that formal unit (e.g., squad) combat operations will involve the actions of a number of different teams. Some, such as crews, are established while others are transient and evolve only through coordinated efforts of unit members.

TABLE 1-1
TEAM DEFINITION

Definition/Characteristics of a Team	Author(s)
"A group of two or more operators working in a structured and task oriented environment."	Briggs & Naylor (1965)
The term "team" is used "to describe a relationship in which people generate and use work procedures to make possible their interactions with machines, machine procedures, and other people in the pursuit of system objectives."	Boguslaw & Porter (1962)
"It is considered to be relatively rigid in structure and organization with a well defined number of tasks, roles, and communication links."	Klaus & Glaser (1968)
"A group of individuals who are working together toward a common goal."	Blum & Naylor (1968)
Two or more individuals whose interaction is required to perform a complex task or series of tasks. (paraphrased)	Trussell, Watts, Potter & Dieterly (1977)
"A distinguishable set of individuals who function together to accomplish a specific objective."	Dieterly (1978)
"... two or more interdependent individuals performing coordinated tasks toward the achievement of specific task goals. This definition of teams has two major components:	Nieva, Fleischman & Rieck (1978)
1) a task orientation shared by all team members, and	
2) a condition of task interdependence among team members."	

Models of Team Performance

All too often team performance literature has become mired in definitional semantics. Models of team performance have been designed, however, that clarify and elaborate on the definition of "team" by synthesizing a host of team performance variables into logical categories and by explaining relationships among these categories. Systems models, or "input-process-output" models (Figure 1-1) organize the variables in a manner highly useful for military research (Collins 1977; Hackman and Morris, 1975; McGrath, 1964; Meister, 1976). Input variables fall into three categories: organizational and environmental, individual, and team-specific. The organization in which the team performs supplies to the team its individual members and usually determines the number of participants and their training. The organization also assigns the team its mission or task and defines the job of each team member. The environment determines working conditions, physical constraints, and uncertainty levels (e.g., weather, terrain, and enemy force activities).

Individual variables form the second input category. The present research is concerned with maintaining proficiency over time; therefore, variables that produce individual skill retention or decay are of interest. In general terms, these variables are the extent of the individual's original learning, the nature of the retention interval, the type task to be performed, and the quality of recall or transfer requirements necessary to do the job.

The last input category contains team-specific variables. As noted earlier, the team's task and composition (individual member resources) are shown by the literature to influence the level of team productivity.

The team structure, or configuration, is a compound of the input (positions of team members are designated by the organization) and team processes -- the latter described in team performance models by Dieterly (1978) and by Nieva, Fleishman, and Rieck (1978). In Dieterly's model "team" processes are communications, control, and decision processes. Nieva et.al. developed a taxonomy of interactive team functions "that enable the team to work together as a unit, over and above individual member performance of specific behaviors" (Nieva et.al., 1978, p. 59). They identified four major categories of interactive functions (team orientation, organization, adaptation, and motivation) and several performance dimensions within those categories. Team processes appear from the literature to mediate the effects of input variables on outputs. Poor communication, for instance, is cited as a major reason that team productivity does not equal the sum of the efforts of individual team members.

System output is affected by both task-related and team interaction components. Most models, including the one designed to organize the present report (Figure 1-1) consider both. The focus of the present report, however, is on task-related performance.

Report Organization

The following chapters describe each category of variables shown in Figure 1-1, using the model as an organizational guide and emphasizing problems of maintaining team performance over periods of time. Chapter 2 discusses the impact of the military personnel system (particularly personnel selection, training, and turnover), and the working environment. Chapter 3 reviews literature on individual skill retention. Chapter 4 presents team performance factors that

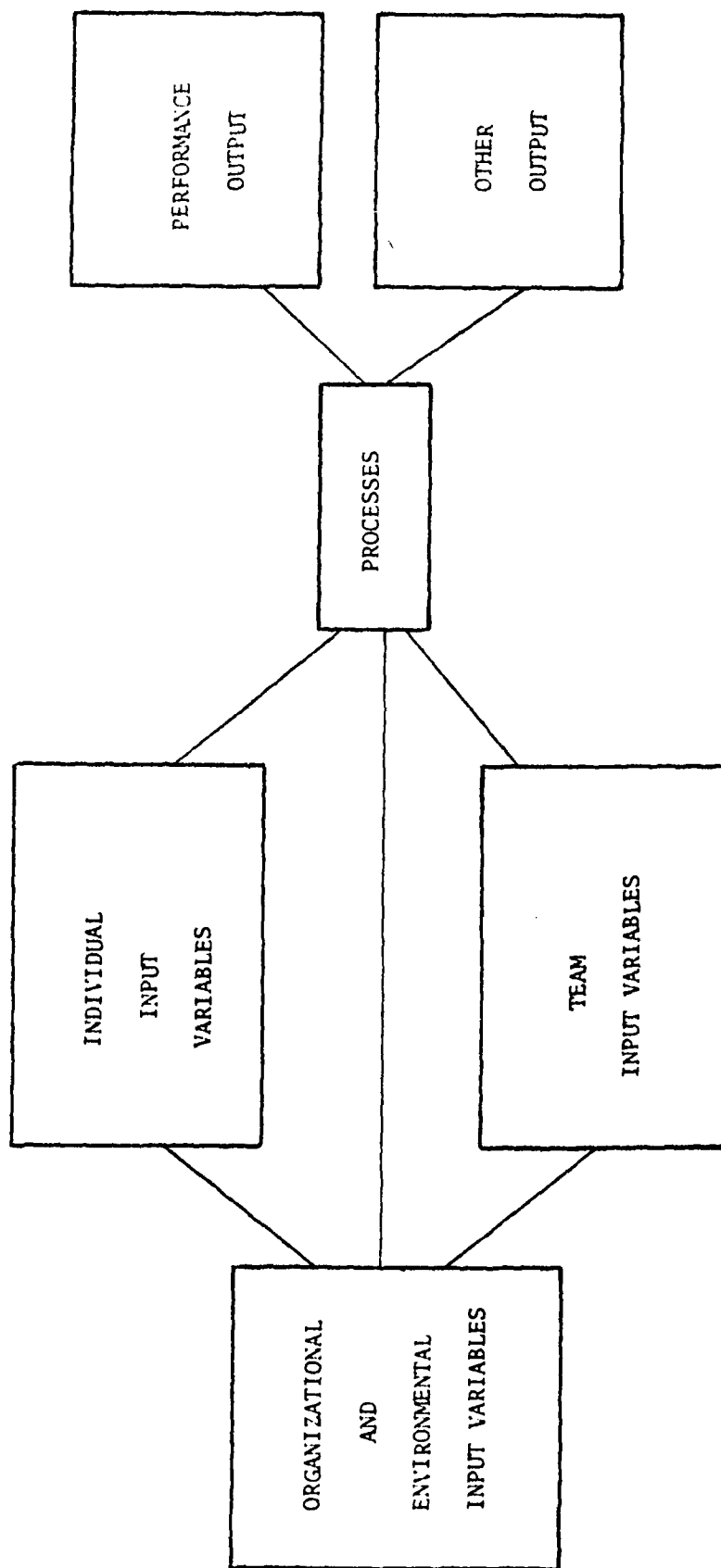


FIGURE 1-1. Systems Model of Team Performance

appear from the literature to change team productivity over time. Chapter 5 discusses the nature of team structure and team processes, including the taxonomy of team interactive functions designed by Nieva et al. Chapter 6 summarizes the impact of input and process variables on the team's pool of skills, and Chapter 7 reviews conclusions and recommendations.

Three annexes have been appended to the document. They are Annex A, Glossary; Annex B, Bibliography; and Annex C, Literature Abstracts. Annex C, Literature Abstracts, contains substantial summaries of the major recent reviews of individual skill retention and team performance research.

CHAPTER II

ORGANIZATIONAL AND ENVIRONMENTAL FACTORS

Many organizational and environmental variables have been examined in research contexts ranging from naturalistic perceptual experiments (Brunswik, 1955) to sociological (Homans, 1950) and man-machine systems (Meister, 1976). The various disciplines agree that the organization external to the team, group, or individual imposes constraints and other antecedent conditions. Fortunately, review of the research concerning team performance eliminates all but the few organizational and environmental variables shown to influence changes in team performance. Critical organizational inputs appear to be: first, the characteristics of individuals assigned to the team; second, the mission and tasks assigned to the team; and third, the processes for the team to use to achieve its mission. Military teams must achieve their missions under unpredictable and dangerous conditions. Some environmental influences are discussed following organizational variables. The place of the organizational and environmental variables in the system model is shown in Figure 2-1.

Personnel System: Selection, Classification, and Training

The military personnel system supplies to teams their individual members. Through the personnel system, enlistees are selected, classified as to job (military occupational specialty: MOS), given initial training, assigned to units, and periodically tested, retrained, and reassigned. Enlistees who have low aptitude test scores tend to obtain lower training test scores. They require longer to train and need to benefit from special training techniques. Even so, they learn less during their initial training. The level of initial training has a major influence on the extent of skill retention: trainees who learn less in the first place retain less over time. Thus, skill retention factors begin with the selection and classification testing process.

Military job proficiency is tested and job tasks are trained periodically. The Army, for example, administers Skill Qualification Tests to ascertain the soldier's level of job performance and Army Training and Evaluation Program (ARTEP) tests to assess unit performance. Prior to the administration of tests, there is a surge of preparatory training. Teams and larger units, for instance, have annual training seasons to prepare for their ARTEP tests. Between training seasons, skill is believed to decay. Proficiency cycles that result from intermittent training have been depicted as shown in Figure 2-2 (U.S. Army Training and Doctrine Command, 1976, p. II-6). The military's goal is to sustain proficiency over time and lessen the skill decay between training cycles.

Technological advances in materiel and procedures, such as integration of computers into battlefield information systems, however, compound problems of training and maintaining proficiency. Advances in technology may even outstrip the soldier's capability to learn to use materiel and perform procedures.

Personnel Turbulence

Threats to maintenance of proficiency such as long intervals without training, technologically advanced equipment, and limited trainee aptitudes are exacerbated by turnover among unit members. Turnover, or personnel turbulence, results from limited durations of assignments and of enlistments and the need to fill

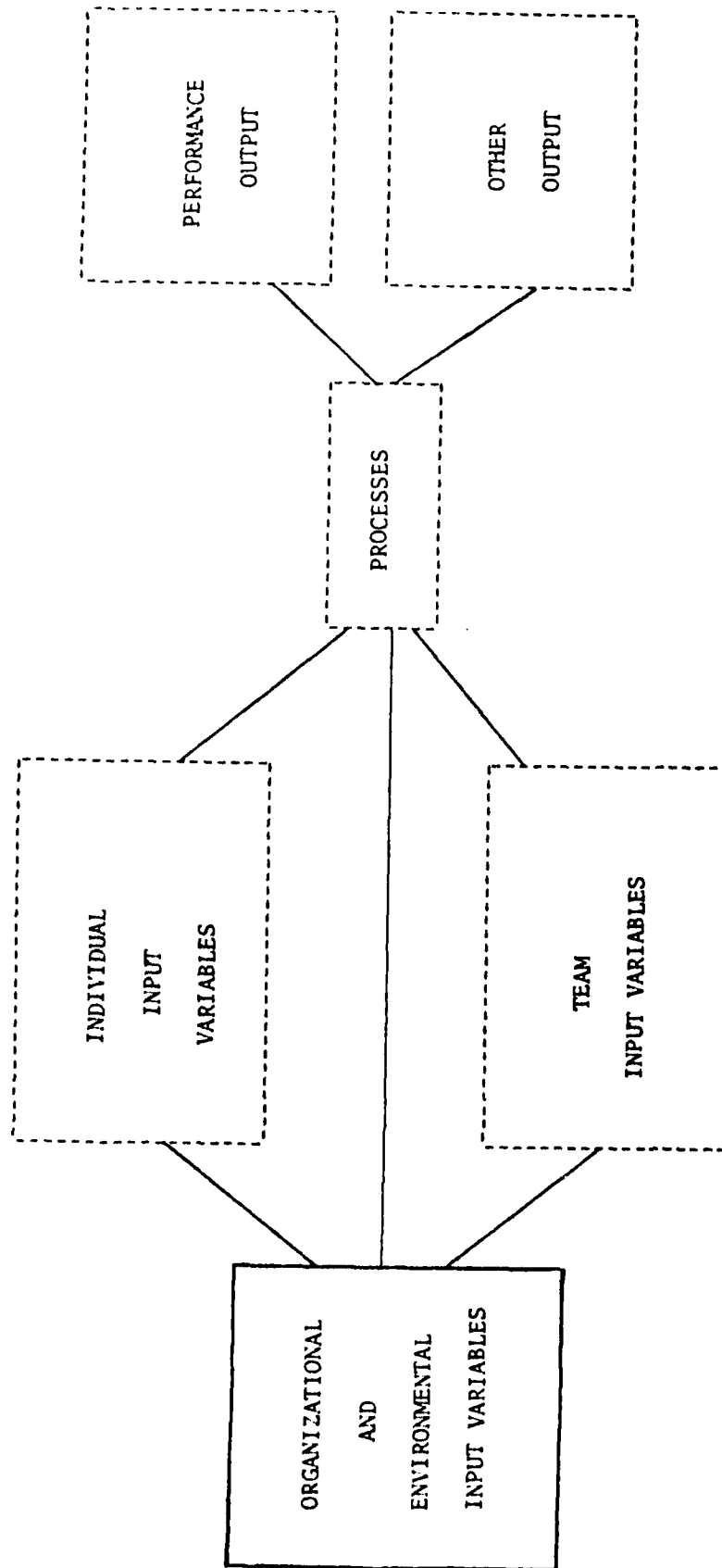
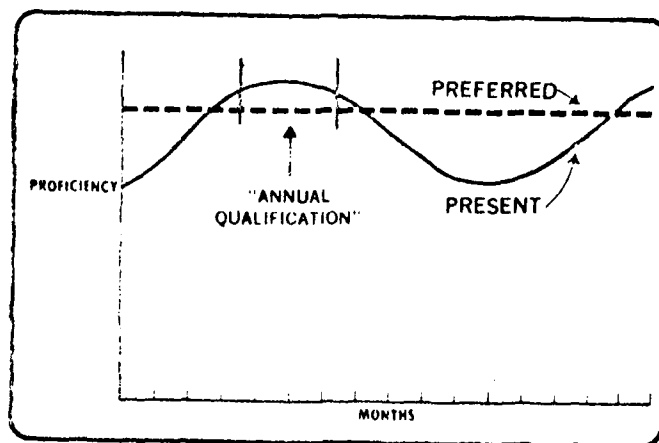


FIGURE 2-1. Organizational and Environmental Input Variables in the Systems Model

personnel positions. As a permanent characteristic of military personnel systems, turbulence must, therefore, be reckoned with in research and in proposed solutions to training and performance problems.



(From U.S. Army Training and Doctrine Command, Analyzing Training Effectiveness, TRADOC PAM 71-8, 10 Feb 1976)

Figure 2-2. Proficiency Cycles

Research on the amount of personnel turbulence in the Army consistently shows substantial turnover, although amounts differ with the definition of turbulence employed. Bialek (1977) observed ten infantry squads for four months, and noted that 12-15% of the personnel changed squads monthly. Similar amounts of turbulence have been reported for tank crew members. The Defense Science Board Task Force on Training Technology (1976) noted 40% turnover in tank crew members every 90 days. A later survey of armor battalions disclosed high amounts of change in duty position and tank crew assignment: in 4-6 months the turnover rate for tank commanders was 0-20%, and for gunners, loaders, and drivers it was 33-88% (Larson, Earl, and Henson, 1976). When changes in positions in specific crews were considered, the rate was 53-95%; some crews had almost complete turnover of members in half a year.

Eaton and Neff (1978) in their tank crew research considered movement to a different duty position to be turbulence. The duty position change was either to a different tank crew or was a change between tank commander, gunner, loader, and driver positions. In an examination of five battalions, they found the following durations:

<u>Positions Held</u>	<u>Duration (in months)</u>
Complete crew together	1-2
Tank commander, gunner together	1-3
Tank commander	12-42
Gunner maintaining same position	5-12
Driver maintaining same position	5-9
Loader maintaining same position	2-6

Tank commanders, who hold the top position in the tank crew, have the most stability while loaders, who are the lowest in rank in the crew, have the most turbulence.

Eaton and Neff (1978) experimentally tested the effects of personnel turbulence in tank crews in a battalion that had just completed its annual gunnery qualification training and testing. After qualification activities, tank crews were assigned to one of four research groups and repeated one of the primary qualification tests ("Table VIII"). The experimental groups and their descriptions were:

<u>Experimental Group</u>	<u>Description</u>
1. Control	Complete crews that trained and tested together.
2. Unfamiliar crews	Crew members maintained their usual duty positions but crews were scrambled so that they worked with people other than their regular teammates.
3. Unfamiliar crews and positions	Tank commanders were excused and replaced by gunners; gunners were replaced by loaders. Drivers and loaders were assigned who had not trained with the crew.
4. Non-armor replacements	Tank commanders and drivers who had served together were given non-armor personnel (e.g., cooks and clerks) as gunners and loaders, and an intensive three-day training program.

Groups 1, 2, and 4 had similar scores, while group 3 performed significantly worse. Unfortunately, loss of the tank commander, a key person in the crew, is highly likely during combat and the loss seriously degrades crew performance.

Personnel turnover or turbulence is generally hypothesized to degrade team performance. In the extreme case, teams have to function for some time without a replacement for the lost member, thus performing without their full complement of resources. New team members may have less individual experience especially given the large influx of new recruits and trainees. In addition, teams with new members who have not performed together and have not learned compensatory behavior are at a disadvantage.

Review of research concerning the effects of turbulence indicate that when it is moderate and does not involve critical personnel, the effect on team performance is not significant (Meister, 1976). But if Eaton and Neff's (1978) discovery of almost complete tank crew turnover in six months is accurate, then turnover is massive and may be having a negative effect on performance.

Task Assignment

Military teams are required to perform a large number of different types of tasks. Indirect fire support teams, for instance, plan indirect fire support

with maneuver unit personnel. To do this, they must allocate resources to provide the support, perform procedures to request fire and assess results, operate radios and vehicles, and carry out a host of other types of tasks. As another example, the mechanized infantry and tank task force Army Training and Evaluation Program (ARTEP) requires rifle squads to conduct reconnaissance patrol, move to contact the enemy, engage in antiarmor ambush, and other missions. Each mission entails a number of different kinds of squad and individual tasks.

The term "task," as it is used in team performance literature, is usually wider in scope than the use of the same term in individual performance literature, and may be more aptly termed "goal" or "mission." Such a "mission" may include a large number of tasks for individuals. For example, the goal of a weapon system crew may require that each crew member perform a particular set of tasks.

Both individual and crew skill retention depend in part upon the type of work to be performed. For example, individuals remember continuous control tasks (e.g., bicycle balance) better than they retain procedural ones. Since military jobs do not require just one type of activity, but rather a complex combination of activities, frequent retraining or more thorough initial training may be necessary. Classification of tasks by extent of skill retention or skill fragility will therefore aid in training decisions.

Task characteristics and demands to a large extent determine team activities. Technical tasks specify procedures, work content, standards, and objectives. Tasks may or may not be assigned to a particular position in the team (Dieterly, 1978). In a tank crew, for example, the tank commander, driver, gunner, and loader have assigned tasks. The tank driver cannot perform other duties while serving as driver, but it is possible for the tank commander and gunner tasks to be performed by a single crew member although the double duty probably degrades crew performance. Additional characteristics are discussed in Chapter 5, under Team Tasks.

Environmental Conditions

Military working conditions are often harsh, demanding, and unpredictable. Boguslaw and Porter (1962) distinguish emergent (unpredictable) situations like those encountered in combat from established routine environments. Established situations can be forecast as to conditions, activities, and consequences while emergent situations cannot be predicted or easily submitted to analytic solution because of their constantly changing nature.

Another environmental parameter is response situation (stimulus-response versus organismic) as differentiated by Alexander and Cooperband (1965). The distinguishing characteristic is the amount of latitude the individual has in deciding how to respond to a given stimulus. In the stimulus-response environment, tasks, activities, and procedures can be closely specified. Stimuli can be anticipated, and the appropriate response can be prescribed. The organismic environment is one in which there is greater proportion of emergent situations. Individuals have roles, functions, and task assignments; however, they also have a considerable amount of discretion as to how to respond to specific stimuli. Team members in an organismic environment need to be more creative to find solutions to combat problems.

The emergent, organismic nature of the operational setting increases demands for coordination, communication, and cooperation within the team. These demands tend to complicate team functions and degrade team performance for reasons explained in Chapter 5.

CHAPTER III INDIVIDUAL SKILL RETENTION

Introduction

Proficiency of individual team members who are supplied by the personnel system is the key to effective team performance; therefore individual training and skill maintenance require emphasis. The position of individual input variables in the system model of team performance is shown in Figure 3-1.

Historical Overview

Human memory was among the first psychological phenomena scientifically investigated. Hermann Ebbinghaus' classic treatise On Memory (1885) was the pioneer experimental study in the field of learning, retention, and remembering (Woodworth and Schlosberg, 1965). It was followed by thousands of publications on the topic of verbal learning and memory.

Remembering, or forgetting, refers to the phenomenon that occurs in the interval between learning and subsequent application of the learned behavior. Remembering is demonstrated by such behaviors as recognizing something that has been seen before, repeating a performance, or relearning something that has been forgotten. The earliest explanation of forgetting was passive decay through disuse during the time of the retention interval. Theories of interference, however, have largely replaced passive decay to explain forgetting. Interference postulates that either previous learning (proactive) or new learning during the retention interval (retroactive) interferes with memory. Empirical research supports both proactive and retroactive interference (Hilgard and Bower, 1966). Other explanations of forgetting are based on motivation, including repression (memories become inaccessible because they pertain to personal problems) and systematic distortion of memory (Glaser, 1968).

Ebbinghaus described a curve of retention of nonsense syllables that has been shown to describe various tasks (Woodworth and Schlosberg, 1965). Motor skills are among some of the various tasks that are shown to adhere to this retention curve (Schendel, Shields, and Katz, 1978). The curve is characterized by a rapid fall immediately after initial learning, followed by gradual flattening during the retention interval.

Woodward and Schlosberg (1965, p. 726) present data from an experiment by Strong in 1913. The data are depicted both as percent correct graphed against time and percent correct graphed against the logarithm of time. The regular graph shows the same function as the traditional one described by Ebbinghaus. The plot of the scores against the logarithm of time produces a straight line, which implies that retention decreases in step with the logarithm of time. The simplest logarithmic equation between retention (R) and the time interval (t) is:

$$R = A - B \log t$$

The parameter A is the amount retained at a particular time. Parameter B is computed by measuring retention at the end of an interval. B is the loss in retention between the two times and t is the amount of time lapsed (see Figure 3-2).

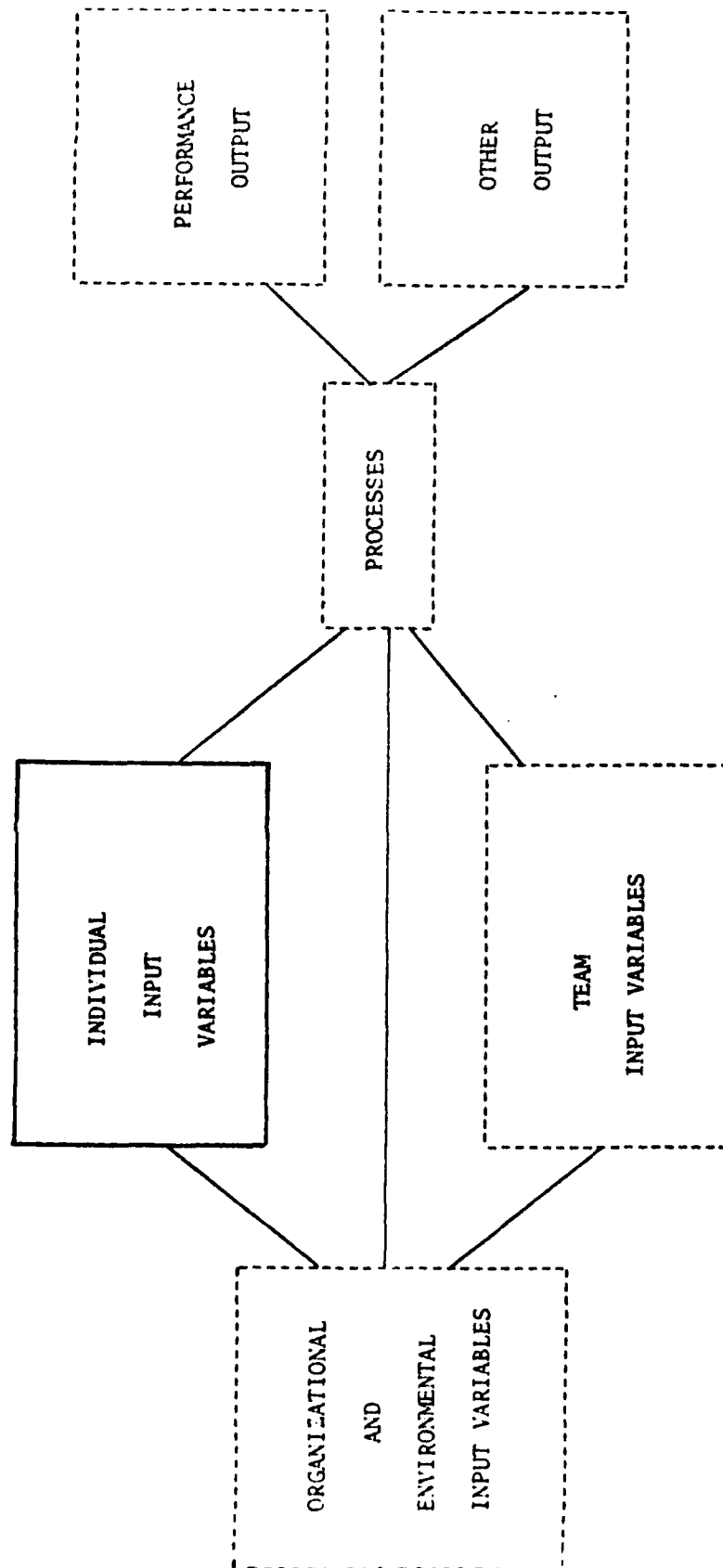


FIGURE 3-1. Individual Input Variables in the Systems Model

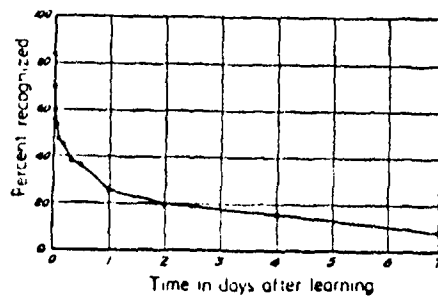


Figure 3-2a. Retention Curve

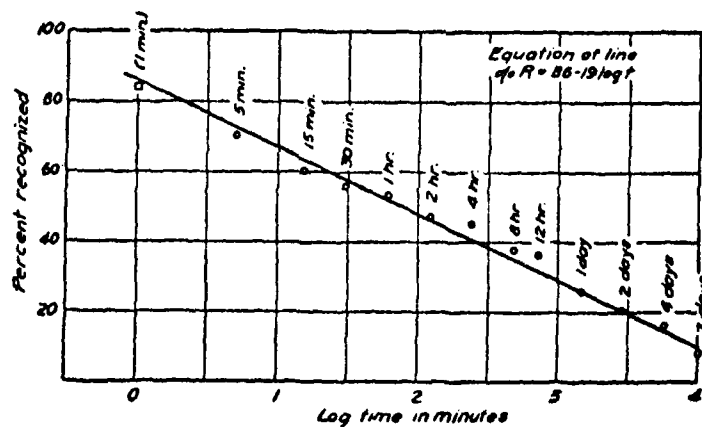


Figure 3-2b. Same data as Figure 3-2a with scores plotted against the logarithm of time.

(from Woodworth and Schlosberg, 1965)

NOTE: Both graphs depict data from Strong, 1913.

Figure 3-2. Curves of Retention, Woodworth and Schlosberg

Recent Military Research

An empirical example of the classic retention curve is provided by Strasel, Holmgren, Bercos, Shafer, and Eakins (1977) who tested learning and retention of Army job-specific skills. The skills were on tasks from infantry, armor, field artillery, and air defense artillery branches. Approximately 300 enlisted men were divided by branch that contained their military occupational specialty (MOS). They were further divided into five experimental groups. Two experimental groups were trained using an audiovisual program called TEC for Training Extension Course. TEC lessons are accompanied by performance-oriented tests for each lesson. The first experimental group used the lesson tests in conjunction with the TEC training. The second group used the TEC lessons without the tests. Two other groups were trained using conventional Army techniques rather than TEC. In one of the conventionally trained groups, the lesson tests associated with the TEC lessons were administered. The other conventionally trained group did not have the lesson tests. The fifth experimental group received no instruction during the research interval; their scores were used to correct for the reactive effects of testing and are not of further interest in the present discussion.

The subjects were retested eight to nine weeks after the initial training and testing. The initial retest scores for four experimental groups, averaged over the technical topics: means and sample sizes are presented in Table 3-1.

Table 3-1. Skill Retention Following Different Initial Training Techniques

	Scores		
	Initial	Retest	N
TEC and Lesson Test (TL)	58.2	55.6	59
TEC without Lesson Test (TO)	53.9	51.4	71
Conventional with Lesson Test (CL)	48.6	44.8	79
Conventional without Lesson Test (CO)	47.8	47.1	73

The two data points for each group demonstrate a universal forgetting phenomenon: those who achieve higher original levels of proficiency still are ahead at the end of the retention interval. The functions are approximately parallel (see Figure 3-3).

Strasel et.al. assumed that the curve describing retention is an exponential function similar to the classic forgetting curve. The retention curves extrapolated for each experimental groups are shown extending beyond the empirical data points (used as estimate of A and B in the logarithmic function) in Figure 3-3.

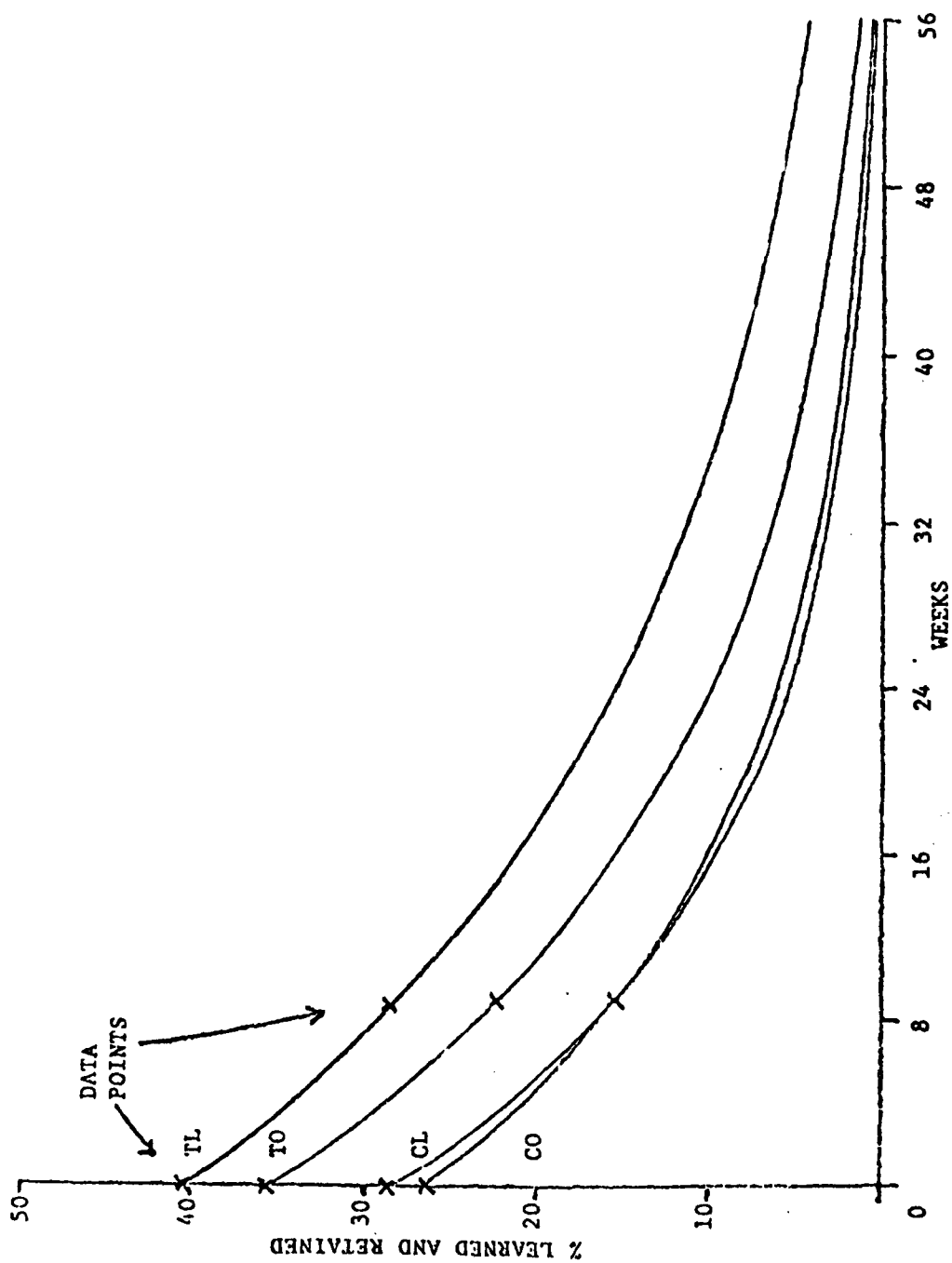


FIGURE 3-3. Retention Curves for Groups With Different Amounts and Types of Original Learning

Strasel et al., 1977

Literature Review

The research by Strasel et.al. is one example of a large number of publications concerning human memory. This body of literature has been integrated recently in several excellent literature reviews. The reviews differ with respect to the publication time frame covered; type of behavior examined (e.g., verbal or psychomotor); perspective (cognitive or task performance); setting (academic or military); and special interest such as transfer of training or the relation of cognitive style to skill retention. Precise of the major reviews are included as Annex C.

The principal variables and hypothesized effects are summarized in Table 3-2. Reviewers (Wheaton et.al., 1976a; Prophet, 1976a; Schendel et.al., 1978) who examined individual differences and refresher training also concluded that:

- o Individual ability and experience interact with level of original learning and thus affect retention.
- o Refresher training is usually rapid (less than one half the original training time).
- o Training devices and simulators are effective for refresher training.

A brief summary of current retention and loss theory is presented in the following paragraphs. The variables considered are organized according to the previously cited Table 3-2. An example is cited for each variable covered.

A representative sampling of military and industrial research documentation dealing with substantive variables that affect skill retention is in Annex C, Tables C-3 and C-4. Table C-3 lists variables indexed by relevant documents. The documents are denoted by their numbers as listed in Table C-4. Table C-4 lists documents indexed by variables numbered as in Table C-3. Complete bibliographic citations for referenced documents are in Annex B, Bibliography.

Individual Skill Retention Factors

Original Learning

As noted earlier in this report, there is unanimous agreement among researchers that the level of initial learning is the single most important factor in determining the level of performance after periods of non-practice.

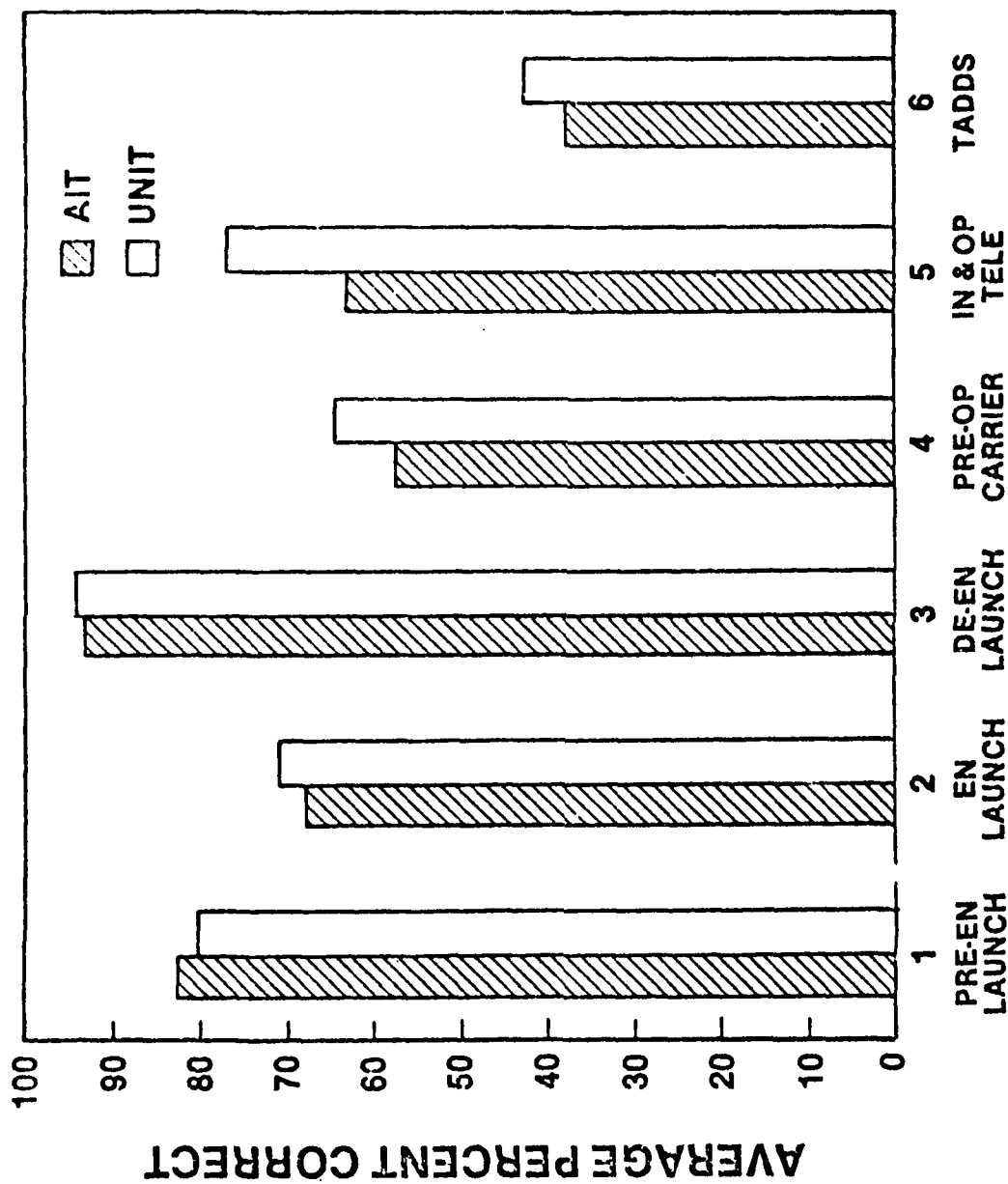
This effect also is demonstrated in research conducted by Strasel et.al. (1977) discussed earlier in this chapter (pg. III-4). The experimental groups with the greatest amount of initial learning (TL and T0) retained the most absolute learning although each group lost similar amounts at approximately the same rate (Figure 3-3). Although not designed for this purpose, the data show this phenomenon quite clearly. Average initial and retention test scores for 272 subjects are as shown in Table 3-1 (p. III-4).

That a high level of initial learning has favorable impact on skill retention is shown by Shields, Joyce, and VanWert (1978). Investigating Chaparral (an Air Defense Missile System), they found virtually no forgetting in the

Table 3-2. Individual Skill Retention Effects

<u>Variable</u>	<u>Hypothesized Effects</u>
<u>Original Learning</u>	1. The higher the original learning, the higher the retention. 2. The absolute loss in performance is not affected by amount of original learning; decay functions for different levels of original learning are parallel.
<u>Retention Interval</u>	1. Retention decreases with time. 2. Interference (habits, activities, both before or after original learning) decreases retention. 3. Practice or rehearsal increases retention.
<u>Task Variables</u>	1. Continuous control tasks show superior retention (months/years) to discrete procedural tasks (days/weeks). 2. Degree of task organization increases original learning.
<u>Recall Variables and Transfer</u>	1. Increased similarity between the transfer task and the original task increases retention. 2. Similarity of task trained to the job increases amount of original learning.

interval between AIT and performance in the unit. Shields et.al. tested 79 Chaparral gunners (MOS 16P) at the completion of AIT and again after they reported to their units in Europe. At AIT, as part of the experimental design, soldiers were trained to 100% criterion as required by the 16P MOS Technical Manual. They were retested again when they arrived at their unit assignments in Europe. Soldiers with overseas assignments were chosen to minimize exposure to the tested skills during the no-practice interval. The mean interval was 50 days with a standard deviation of 15.6 days. Subjects were trained and tested on six different tasks. Performance did not decline significantly between testing at AIT and testing on arrival in unit. Some tasks, possibly "refreshed" by the test situation, showed higher scores (also not a significant difference). A graphic representation is shown in Figure 3-4.



TASK TESTS

FIGURE 3-4. Comparison of Scores, Six Chaparral Task Tested After No-Practice Interval
Shields et al., 1978

Shields et.al.'s research design was more comprehensive than this initial portion. Their other findings as related to retention variables are discussed in subsequent sections.

Shields et.al.'s (1978) results contrast sharply with studies that demonstrate substantial skill loss over time. In some cases, apparent skill loss follows inadequate initial training. In some cases, apparent skill loss follows adequate initial training. An example of this is Hagman's (in press) study of typing skills as taught in Army schools. Performance decreased 27% ($p < .05$) between AIT and unit duty (14-38 days), a significant drop. The soldiers ($n=38$) had only been trained to 3.3 words per minute above the minimum standard. No additional decrements were found between intervals of 14 and 38 days.

Level of experience at the task and general ability have effects similar to the intensity of original learning in affecting skill retention. Smith and Matheny (1976) demonstrated that the amount of flying experience prior to a prolonged non-flying interval was highly related to skill retention. They tested two groups of pilots who had been prisoners of war in Southeast Asia. Their criterion measure was time required for retraining. The two groups had mean non-flying episodes of 19 months and 34 months, respectively. Retraining of the first group ($n=21$) averaged 38.4 flying hours while that of the second group ($n=39$) averaged 45.4 hours. The pilots were grouped on the basis of flight time prior to being prisoners (low=300-1000 hours, mid=1001-2000 hours, and high=2001-7250 hours). Statistically significant differences were found in retraining time between the low-time group and the other two groups. Mean retraining times were 48.5, 35.3, and 41.6 for the low, mid, and high flight time groups, respectively. Pilots who had less flying experience prior to the no-flying interval required more retraining time to regain proficiency.

Differences in Individual Ability

Individual differences in aptitude, or ability to master new material, account for some of the differences shown in the amount of initial learning. When possible, examples have been drawn from the Air Defense missile training effectiveness research data presented in the REDEYE Weapon System Training Effectiveness Analysis (WSTEAE), 1977, and REDEYE Training System Effectiveness Analysis (TSEA), 1978. A REDEYE TSEA was conducted by the TRADOC Systems Analysis Activity (TRASANA) in 1978 at the request of the Army Air Defense School. The stated objective of the study was the assessment of the impact of training effectiveness on combat readiness, specifically relating the number of aircraft destroyed by REDEYE to training proficiency. In addition, training in both units and institutions was examined in order to make recommendations to improve its quality. This TSEA incorporated data and information acquired in a similar WSTEAE conducted in 1977 that assessed REDEYE training programs in order to improve quality of instruction. Two important skills were emphasized: tracking a target using the moving target simulator (MTS) and recognizing aircraft using the range ring profile (RRP). Test subjects were AIT trainees and trained members of other units. (The number and description of subjects for each test vary and will be presented with the appropriate example.) The REDEYE trainees coming into the training cycle represent a wide range of aptitude based on Armed Forces Qualification Tests (AFQT) -- tests used to select enlisted personnel. Eighty percent of the AIT students tested during TSEA (1978) were high school graduates or above at the time of enlistment -- significantly higher than the 65 percent of the WSTEAE (1977) test subjects. A comparison of the mean AFQT scores and

Armed Service Vocational Aptitude Battery Scores on two subjects, Operations and Food (OF) and General Technical (GT), was made as a possible explanation for this change.

Table 3-3. Comparison, AFQT Scores with ASVAB Scores, Two Subjects

	AFQT	MEAN SCORES	
		OF	GT
WSTEА	46.9	104.7	99.5
TSEA	<u>37.3</u>	<u>100.1</u>	<u>94.1</u>
Change	-9.6	-4.6	-5.4

This comparison showed there was a significant drop in two critical REDEYE Skills: Moving Target Simulator (MTS) tracking and use of the range ring profile (RRP). Overall, persons who had lower selection and classification test scores (TSEA), had lower REDEYE skill scores than persons with higher test scores (WSTEА). It is possible, however, that other differences between the samples account for the drop in scores.

Levels of performance or proficiency in the RRP and in the MTS were then determined for each of the AFQT mental categories. Categories range from I (highest mental category) to V (lowest). Category V recruits are not inducted.

Scores decreased for each of the major lower mental categories. The Category IV performance was unacceptable in all areas of the RRP test, but within the acceptable range in the MTS. The determination of range ring coverage is the most difficult task for all mental categories according to questionnaire response data and it is acutely difficult for Category IV.

The RRP and MTS scores by AFQT category of the gunners tested is shown in Table 3-4.

TABLE 3-4. RRP AND MTS SCORES BY AFQT CATEGORY

AFQT CATEGORY	RRP	MTS P _h (n)
I (1)	0.444 (1)	1.0 (1)
II (8)	0.535 (8)	0.81 (8)
IIIA (13)	0.427 (13)	0.71 (13)
IIIB (61)	0.248 (61)	0.79 (57)
IVA (18)	0.133 (18)	0.74 (18)
IVB (16)	0.035 (16)	0.66 (17)

NOTE: The number of gunners who were tested in the RRP differed slightly from the number tested in the MTS, and so the sample size (n) is shown for each.

The ability of high aptitude individuals to require less training time was also demonstrated in research conducted by Bialek, Taylor and Hawke, 1973. The objective was to determine the most appropriate instructional strategies for training high (CAT I) and low (CAT IV) aptitude soldiers. In an elaborate series of tests (training methods not identical for the two groups but training was on the same tasks) a high proportion (>90% for most tasks) of CAT I trainees passed after one trial in contrast to about 30% for CAT IV. The high ability CAT I trainees were found to learn many tasks by themselves, given only a minimum of required information, directions and standards. Consistent with other research, Bialek et al. found that differences were greatest in tasks making cognitive demands (e.g., phonetic alphabet) and least in tasks using manipulative motor tasks (e.g., field wire splicing).

Learning theory, research, and practice are unanimous in concluding that knowledge of the results of one's performance is a necessary condition of learning. Knowledge of results, also called feedback, has both informational and motivational components. Specific information reinforces correct behavior and cues the individual as to the type, extent, and direction of his errors. Either specific or general feedback motivates the individual and helps him set goals to guide his future behavior (Locke, Cartledge, Knerr, and Bryan, 1969).

Johnson (1978) in research for the Air Force, investigated a procedural task that had to be performed in a sequence without hesitation or the use of a checklist. He found that requiring the trainee to provide his own feedback from memory increased retention of these procedural skills. As part of his research on interaction of training strategies and cognitive style, he used three training strategies. In two strategies, conventional and reproduction (simulated) the trainee generated his own feedback. As a result of previous actions and the subsequent cueing of the next action, the trainee received "hard copy" representation of the effect of his previous efforts. The "blind" or third strategy did not provide this feedback. Mean performance time measures and the importance of the results are shown in Tables 3-5 and 3-6. Significantly longer initial training times (as well as retraining and transfer times) are shown for the strategy that required no feedback.

Feedback, individual ability, and level of experience, however, are only a few of the variables that affect the extent of original learning although others appear to be less important. Since the less important variables are reviewed elsewhere, they are not discussed here.

Rate of Decay

One factor not related to the level of initial learning is the rate of skill decay. Figure 3-3, depicting Straszel et al.'s data, is a good example of this phenomenon. Initial levels of performance differ, but functions are parallel. As a result, those who start higher also have higher proficiency at the end of the retention interval.

The REDEYE research demonstrates this phenomenon. Both the WSTE and the TSEA (1977, 1978) measured moving target simulator (MTS) proficiency of a representative sample at the end of advanced individual training (AIT). After a period of several months, the subjects, now in their assigned units, were retested. The objective of this effort was to quantify the loss of proficiency in terms of a "forgetting curve." Three cases were tested and retested under four different research schedules. A description of the test cases follows.

Table 3-5. Means and Standard Deviations of Performance Time Measures and Their Transforms (in Minutes)

MEASURES	STRATEGY					
	CONVENTIONAL		REPRODUCTION		BLIND	
	MEAN	SD	MEAN	SD	MEAN	SD
INITIAL TRAINING						
TIME ON FIRST TRIAL	17.14	4.69	19.37	6.40	22.25	7.14
TIME ON LAST TRIAL	6.96	1.36	6.90	2.20	8.58	1.74
TOTAL TRAINING TIME	71.86	26.64	84.80	37.48	106.71	48.32
(TRANSFORMED)	8.36	1.51	9.02	1.91	10.12	2.12
RETRAINING						
TOTAL TRAINING TIME	27.00	12.73	29.37	7.67	31.54	19.67
TRANSFER						
TOTAL TRAINING TIME	29.39	10.01	31.08	18.98	42.81	22.64
(TRANSFORMED)	8.36	0.91	6.37	1.56	8.33	1.67

Table 3-6. Significance Table for Performance Time Measures and Their Transforms

MEASURES	F	df	p < .05	.05 < p < .10	MEANS* COMPARISON
TRAINING					
TIME ON FIRST TRIAL	3.78	2,56	0.030		C,B
TIME ON LAST TRIAL	3.57	2,56	0.036		C,R,B
TOTAL TRAINEE TIME (TRANSFORMED)	4.15	2,56	0.021		C,R,B
RETRAINING					
TOTAL TRAINING TIME	< 1	2,50			
TRANSFER					
TOTAL TRAINING TIME (TRANSFORMED)	2.74	2,50		0.074	

* C,R,B INDICATES THAT $\bar{x}_C$ AND $\bar{x}_R$ ARE STATISTICALLY DIFFERENT FROM $\bar{x}_B$ BUT NOT DIFFERENT FROM EACH OTHER AS DETERMINED BY NEUMAN KUELS TESTS (C - CONVENTIONAL, R - REPRODUCTION, AND B - BLIND).

In Case 1, seventy-two WSTEAs AIT gunners were retested twice. Thirteen were tested about 3.4 months following completion of AIT, and again 10 months later. These are shown as Case 1 in Table 3-7. Gunner proficiency dropped significantly in the MTS and slightly for the RRP between completion of AIT and the start of unit training. Since less than half of those retested for the WSTEAs had received any REDEYE training in their units, this drop was considered to represent a forgetting curve for the weapon handling skill. The slight change in RRP proficiency was attributed to the trainees never having acquired an acceptable level of proficiency in the first place. At the time of the second retest, this group had regained forgotten skills in the MTS, but had not made any improvement in the RRP.

The second group, Case 2, was composed of gunners from the five AIT classes who were retested in their respective units under TSEA. Approximately 34% of the 125 trainees were tested 5.9 months after AIT and proficiency in both the MTS and RRP had dropped. It was concluded that in the period between 3 months and 6 months after AIT, gunners are fully integrated into the unit training cycle but have not recovered from the loss of proficiency due to forgetting.

The third group, Case 3, is also from the WSTEAs. Twenty-eight percent of the 72 gunners from AIT were retested. As stated for Case 1, less than half had received any REDEYE training in their units in the 3.4 months since AIT, and overall performance had dropped significantly.

The MTS results are shown in Table 3-7 and a graphic representation of the MTS retention over time is shown in Figure 3-5.

TABLE 3-7. MTS PROFICIENCY RETENTION OVER NO-PRACTICE INTERVAL

CASE	NUMBER OF GUNNERS	MTS* P_h AIT	MTS P_h UNIT	AV. TIME SINCE AIT (months)
1	13	.78	0.63	3.4
2	43	.78	0.68	5.9
3	25	.77	0.58	3.4

* P_h = Probability of hit

The gunners in Case 1 were found to have achieved hit probabilities (P_h) of 0.80 on the second retest conducted after 10 months of unit training. This improvement, almost to desired $P_h=0.85$ level, is also shown in Figure 3-5.

Another group of approximately 130 gunners were tested in their units during the WSTEAs, but the time interval after AIT was not reported. They were retested a year later during the TSEA and showed a significant increase in proficiency in the MTS (from a mean of .72 to .86). This increase is similar to results of testing in the units during the WSTEAs when the mean for Case 1 ($n=13$) rose from

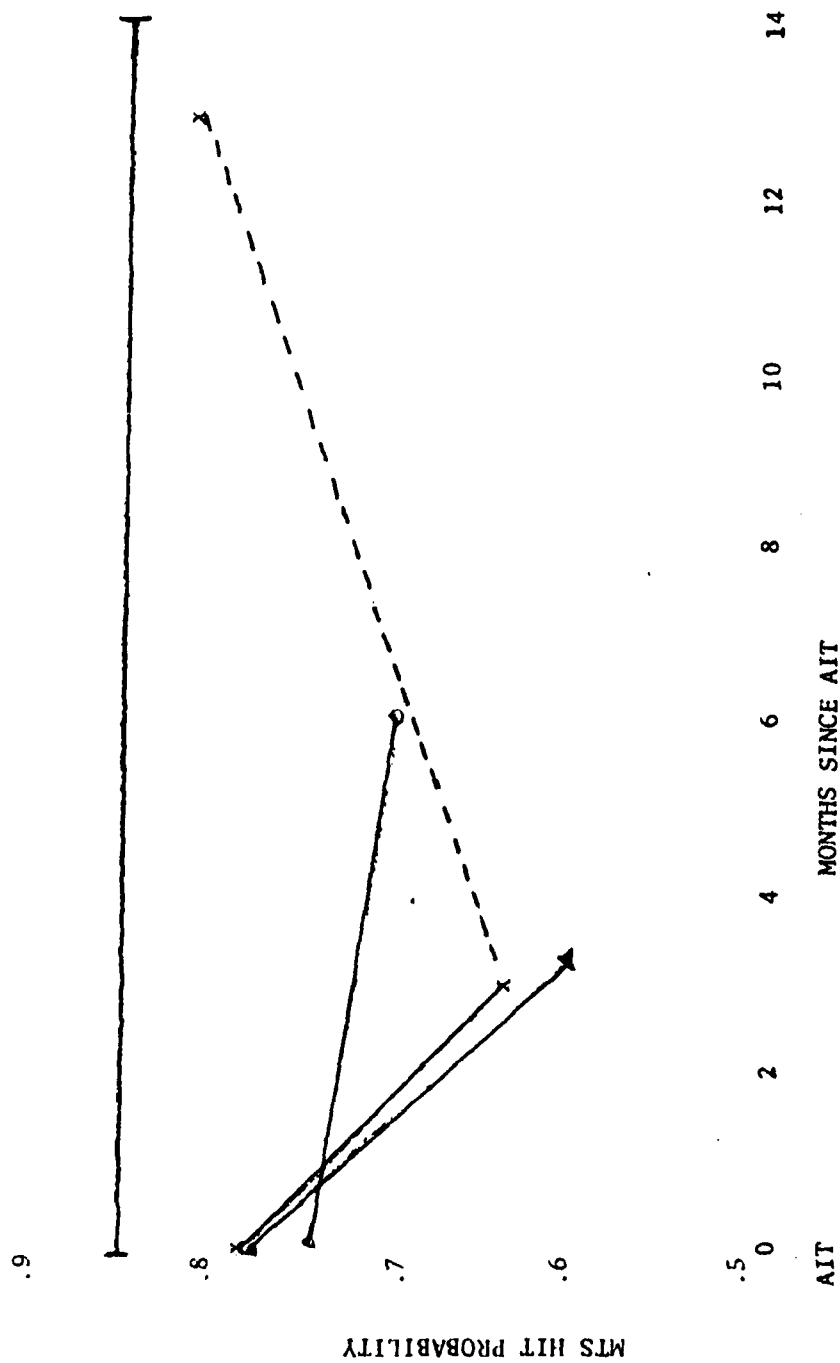


Figure 3-5 MTS Proficiency as a Function of Time Since AIT

x = Case 1, n = 13

o = Case 3, n = 43

Δ = Case 4, n = 25

— = Doctrinal P_h

- - - - - Represents Unit Training Time

.63 to .80 over a year. In general, skills of gunners who have entered unit training programs appear to improve rather than decay. Data points are not available to show fluctuation in P_h due to unit yearly training cycle.

Another real-world military example of the classical forgetting curve is found in the weapon system training effectiveness analysis (WSTEa) of the forward observer (FO) position conducted by the U.S. Field Artillery School at Fort Sill, Oklahoma (1977). One skill evaluated was the ability to locate the target. The measure of effectiveness chosen was the distance the target was missed, measured in feet. Initial ability was computed for 1281 officer students using institutional data. A total of 2803 score cards were analyzed for target location error. This established a baseline of target location accuracy that FO were capable of achieving at the end of formal training. To establish the rate of skill decay, 45 lieutenants serving as FO in field units were tested. All were graduates of the FY 76 Basic Course Classes (selected from the population noted earlier). They were field tested 6, 12, and 15 months following graduation. The FO WSTEa retention curve is shown in Figure 3-6.

INSTITUTIONAL DATA BASIC COURSE SHOOT NUMBER

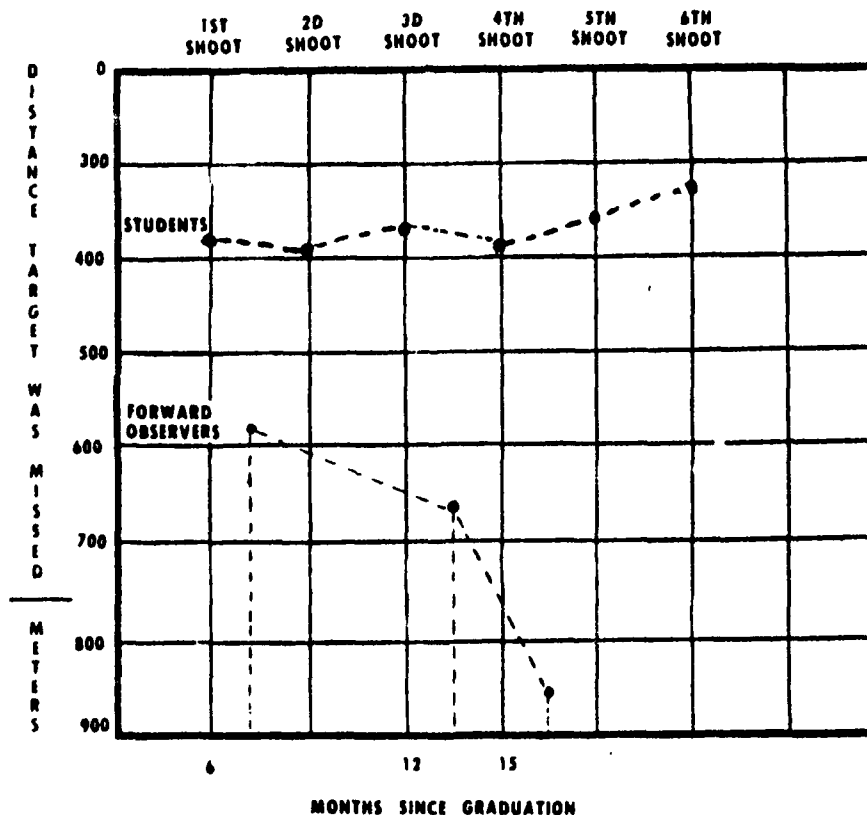


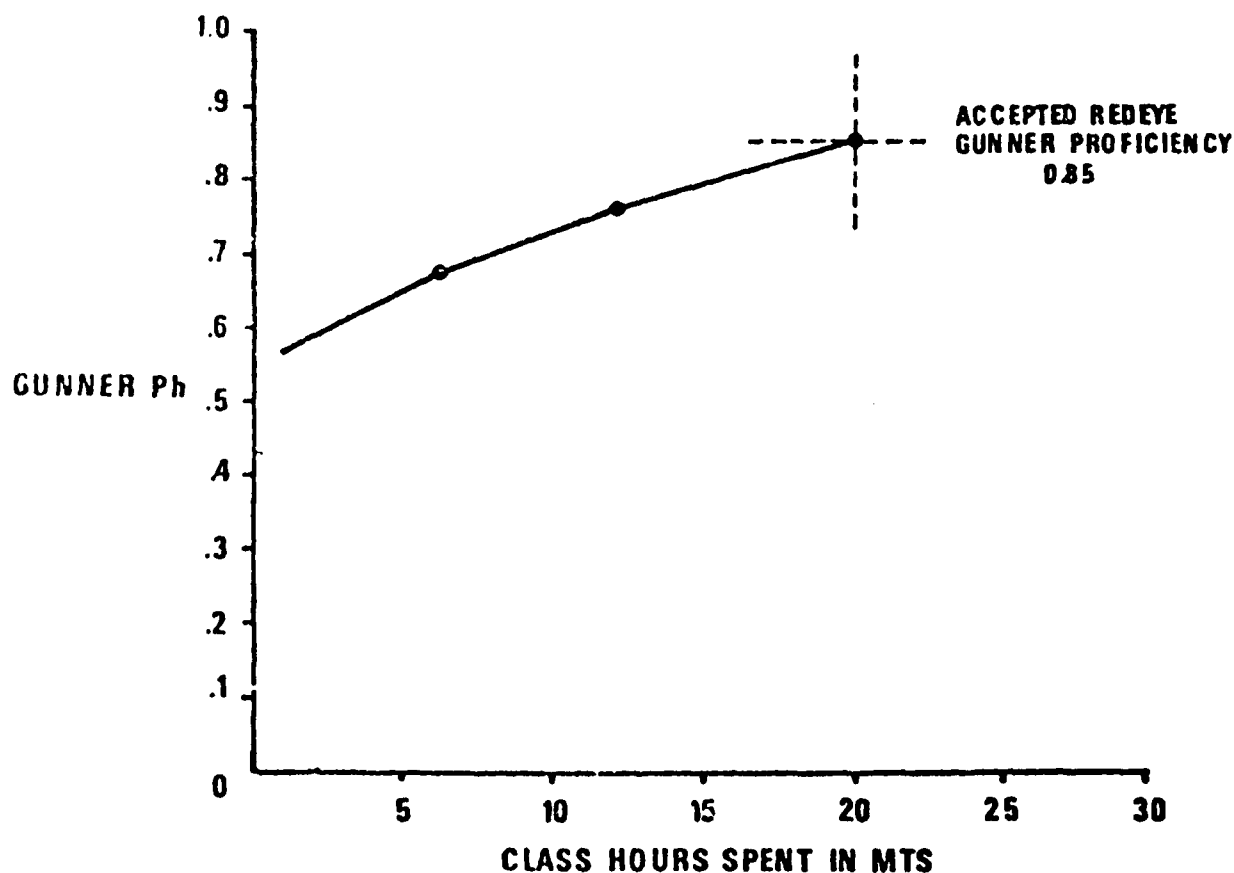
FIGURE 3-6. Institutional and Field Test Results -- Target Location Error

FO WSTEa, 1977 (page 6)

This comparison shows that the Basic Course student is able to locate the target with mean accuracy of 300-400 feet. Six months later, a graduate "is worse than the Basic Course student at his very first shoot (612 meters vs 382 meters)" (FO, WSTEА, 1977, page 6). This skill has decayed far below the acceptable Army Training and Evaluation Program standard of 'within 250 meters.' The study group recommends improved initial training and continued unit testing and training (practice and/or refresher) to alleviate this condition.

Increased Initial Training

The REDEYE WSTEА/TSEA concluded that to achieve the doctrinal goal of $P_h = .85$, each student should receive increased initial training time. To assess the amount of additional time, 16 gunners from one class were given additional training in the MTS. They were tested at the 1-hour, 7-hour, and 12-hour points during the normal AIT-MTS cycle. They were then given MTS training for eight additional hours and retested. The P_h growth to the desired value of 0.85 was attained (Figure 3-7).



WSTEА, 1977

FIGURE 3-7. MTS Proficiency (P_h) Growth Rate

Schendel et al. note that mastery training (to a high level of proficiency) may be more cost effective than training to a minimally acceptable level (proficiency training). The application of cost/effectiveness analytical techniques to the retention and decay of skill over time has not been fully explored. On the one hand a soldier's everyday peacetime skill will probably be exercised for only three years because of the low rate of first term reenlistments. Expensive mastery training might not be cost effective if the soldier's skill is high enough to meet combat readiness criteria. However, each enlistee incurs a total service obligation of six years. In the face of shortages due to failure to meet enlistment quotas, absence of a draft, and declining birthrates, some Department of Defense planners have proposed increasing the service obligation to eight or nine years. This, it is hoped, would provide a large group of trained personnel for rapid mobilization. No studies have addressed retention of skill during the three years of Individual Ready Reserve status following release from active duty. Cost/effectiveness analyses that explore mastery training, refresher training, and skill retention after a long no-practice period remain areas for future study.

The Army training policy implications are also recognized by Schendel et al. who point out that the Army presently relies on combinations of proficiency training. They note the high personnel, time, and equipment costs required by refresher training. A suggested alternative is increased initial training. Schendel et al. propose future research to determine if retention following mastery training equals or exceeds retention following an equal amount of proficiency training plus refresher training. Data derived from such research could be used to dictate training doctrine.

Although the majority of researchers and reviewers conclude that the amount of proficiency retained declines over time and varies directly with what was originally learned, there is some dissent. Annett's (1977) review of skill loss literature includes reports of research with contrary results. He notes reports of significant amounts of retention after periods of no-practice of up to fifty years and lists many examples of good retention after a year. Annett (p. 42) presents as one of his major findings:

There is no generally valid curve of retention, that is to say a single function relating degree of retention to the duration of the retention interval. Retention curves are necessarily composite since the act of measuring retention provides an opportunity for rehearsal. The shape of the retention curve probably depends on the nature of the task and is strongly influenced by the measure of retention employed. Different measures of retention do not necessarily correlate perfectly.

Retention Interval

A large body of research (1858-1976) indicates that basic perceptual-motor skills decline over a period of non-use, although retained moderately well for extended periods. Retention of military skills acquired in basic combat training (BCT) after a period of non-use was studied by McDonald (1967) who collected performance data on three motor skills learned in BCT (rifle marksmanship, physical combat fitness, end-of-cycle tests). Using separate groups (n=60) soldiers were tested during BCT, AIT, combat support training and in their units (6-12

months of service). Results in all three areas showed a decrement over the one-year period. Percentage decrement from BCT levels were so small, however, that McDonald found that the practical significance of the loss was open to question.

Moreover, the loss of this skill is easily reinstated. Illustrating this was Smith and Matheny's (1976) research on the retraining of prisoners of war pilots in Southeast Asia. Pilots who averaged 34 months without flying usually required only about 45.4 hours to regain proficiency.

The pilots involved in this investigation had more than a no-practice interval. While they were POWs, their memory was subjected to the effects of "interference" caused by a drastically different environment. It is impressive that they retained their skills despite lack of practice and a large amount of interference. The study of the POWs provided an unusual opportunity for researchers.

Under even normal circumstances, events and activities that take place during the retention interval complicate relationships that exist between level of training, passage of time and retention. Adam's (1967), pages 305-306, Human Memory is quoted as follows:

For all its problems, it [the interference theory] is the best theory of forgetting that we have, and the evidence is almost solely derived from verbal behavior and recall. The significance of interference theory for nonverbal response classes and for recognition is mostly untested and vague. This is a grievous deficit because an overriding issue for memory is whether one set of lawful principles, or more than one, is required to explain forgetting. No strong resolution of this issue will take place until the laws of forgetting are tried in a multitude of situations and for a variety of response classes.

The REDEYE (1977, 1978) WSTEa and TSEa present some data demonstrating the presence of considerable amounts of unrelated activity during the work week. In fact, Army REDEYE gunners responding to the WSTEa and TSEa questionnaires indicate that little of their total working time is devoted to REDEYE training. The constant activity using other skills on unrelated tasks may therefore interfere with retention of REDEYE skills between tests or training periods. Estimated number of hours per month spent in RRP practice and MTS tracking are shown in Table 3-8.

TABLE 3-8. Estimated Time Spent in Training

ESTIMATED HOURS/MONTH	ARMY RESPONDENTS (123 units)	
	RRP PRACTICE	MTS PRACTICE
None	33.4	38.7
< 4 Hours	41.3	29.3
Between 4-10 hours	16.9	21.2
Between 10-15 hours	5.6	6.9
> 15 Hours	2.7	4.0

NOTE: A military peacetime work month is normally 160 hours.

Even in the vital training time spent in the field, as many as 22.9% of the Army's respondents estimate more than 90% of their time is spent on non-REDEYE tasks (Table 3-9).

TABLE 3-9. Estimated Time in Field Spent on Non-REDEYE Tasks

<u>TIME (%)</u>	<u>ARMY RESPONDENTS (%) (123 units)</u>
90-100	22.9
75-90	17.3
50-75	16.0
25-50	17.1
less than 25	26.7

Rehearsal or practice is one way of maintaining skills during a period of non-use. A number of researchers working in a variety of settings have examined rehearsal effects and practice as a means of minimizing loss of skill during periods of non-performance. These studies have generally shown rehearsal to be beneficial, even when only simple representations of task elements are utilized. Sitterly and his associates conducted a series of studies that examined the long-term retention of skills in the flying of manned spacecraft. Sitterley (1974) in the first study investigated the task involved in the manual control of simulated spacecraft from lift-off to orbit. Retention of procedural and control skills was examined for intervals ranging from one to six months. Several methods of retraining were studied using nine groups of five subjects (predominantly non-pilots).

One finding of this research was that distributed rehearsal of a static (or non-hands-on; no-active response) practice task with static visual cues could maintain the ability required for a fairly complicated spacecraft approach and landing at an acceptable level of performance for at least six months.

Rehearsal or practice, even with simple materials, is relevant to military training because, for the majority of personnel, the interval between initial training and application of the skill is not a true no-practice period. Personnel in military units perform duties related to their jobs, even if they do not have the opportunity to practice their critical tasks. In extreme cases, such as assignment to duties unrelated to their job, they do have a retention interval with interfering activities in the classical sense of the no-practice interval.

Shields et al. (1978) investigated the influence of refresher training on retention as part of their Chaparral study (see page III-8). Stated objectives were to determine the most effective schedule of refresher training and to collect data on the rate of Chaparral skill decay. The experimental design portrayed a model performance-oriented testing and training system. As shown in the experimental design (Figure 3-8), additional or refresher training was planned for all test subjects after arrival at their unit except for the control group, which received no training after AIT.

Soldiers were trained in their units to perform the six tasks to 100% criterion by their squad leaders. Use of the appropriate Technical Manual as

AIT COMPLETION	ARRIVAL IN UNIT	UNIT + 1 MONTH	UNIT + 2 MONTHS	UNIT + 3 MONTHS	UNIT + 4 MONTHS
I TEST	TEST/TRAIN/TEST	TEST/TRAIN/TEST			TEST
II TEST	TEST/TRAIN/TEST		TEST/TRAIN/TEST		TEST
III TEST	TEST/TRAIN/TEST				TEST
IV TEST			TEST		



Figure 3-8 Chaparral Skill Retention Design

a job aid to perform test tasks was enforced. The research team discovered small performance decreases over the four-month test period. This was true when data were examined in two different ways -- average percentage of performance measures passed at each test and percentages of soldiers passing all performance measures for each test. For example, Figure 3-9 depicts the former analysis, the decline in average number of soldiers who passed the tests. Using univariate regression analysis, Shields et al. (1978, p. 16) found significant results on most of their tests and stated that:

The results indicate that in the population sampled there is a relationship between percentage of performance missed and time since training, for all tests except test one. However, the slope of the time indicates a very gradual change with time. The positive regression coefficients indicate more misses as days progress which corresponds to the decrement in percent of performance measures correct.

Analyzing the data in a third way, Shields et al. addressed the question of whether refresher training after initial unit training to 100% criterion reduced rate of skill loss over a period of time. They found that refresher training (soldiers trained twice) did not significantly reduce the rate of skill decay for five of the six tests. The rate of loss was quite gradual for the sixth.

An important conclusion of the researchers was that soldiers using the "job aid" maintained a high degree of proficiency. The authors therefore believe that the amount of expensive refresher testing necessary might be reduced through use of job aids and performance tests.

Practice or rehearsal impact was also addressed in the REDEYE WSTE and TSEA (1977, 1978). Using questionnaire data and other data from the unit, the WSTE and TSEA researchers report the average amount of time spent in REDEYE related training is less than 19 hours per month. Average P_h for all units was 0.73 and average MTS training was 4.6 hours/month. This amount of practice or rehearsal was not enough either to increase initial skill to the level of or maintain skill at the desired level of $P_h = 0.85$. A comparison of unit MTS training hours per month with MTS proficiency demonstrates the relation between amount of practice and MTS proficiency. TSEA data collected from a larger sample is shown in Table 3-10. Analyzing these data, based on approximately 600 gunners from 13 units, a relationship between training hours per gunner per month and MTS proficiency, P_h , was established. This is shown graphically in Figure 3-10 and is represented by the equation:

$$y = .027x + .627$$

where x = MTS training hours/gunner/month

and y = MTS P_h

The correlation coefficients, calculated using simple regression analysis, were found to be $r = .677$, $r^2 = .458$ ($n = 13$, $p < .01$ statistically significant). TSEA estimated that an additional eight hours per section per month in the MTS, plus live aircraft tracking would achieve $P_h = 0.85$.

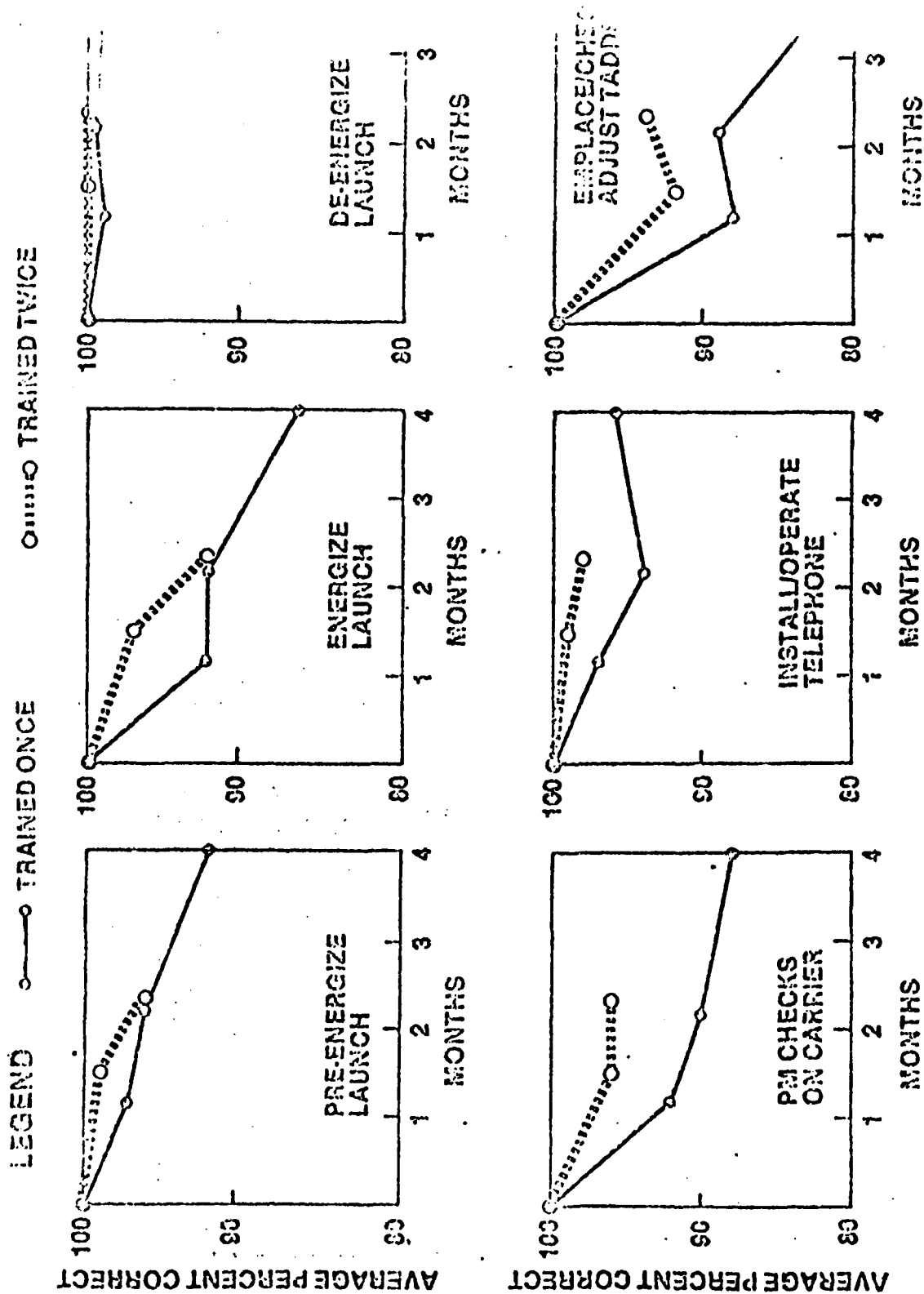


Figure 3-9 Decline in Chaparral Skills Over Time

(From Shields et al., 1978)

Table 3-10. REDEYE Unit Training Time and MTS Proficiency

TRAINING HOURS/GUNNER/MONTH ACTIVE ARMY UNITS (123 units)	PROFICIENCY (P_h)
6.1	0.73
8.0	0.87
3.2	0.81
3.2	0.80
8.0	0.84
3.2	0.72
0.4	0.58
4.5	0.76
6.8	0.78
2.2	0.64
3.1	0.60
4.4	0.87
Reserve Unit	
7.5	0.77

The RRP proficiency was also compared with the amount of training. Results show that the RRP, a difficult task poorly learned in the first place, was only marginally improved by limited monthly practice. With five hours per month training, proficiency is 0.4. If a linear growth rate is appropriate for this skill, it would require 18 hours per month to reach a 0.85 RRP proficiency. If, as is more likely, the learning growth curve flattens out, even more training time would be required. The authors conclude, based on these results, that the RRP cannot be retained by the gunner and, therefore, additional training would not solve the problem. This indicates a need for research into alternative solutions. The most promising avenue appears to be the design and use of skill performance aids (formerly termed job performance aids) or hardware development or modification.

Task Variables

Regarding the effect of the type of task on memory, Schendel et al. succinctly state that, "Procedural tasks and individual discrete motor responses are forgotten over retention intervals measured in terms of days, weeks, or months, whereas continuous movements typically show little or no forgetting over retention intervals measured in terms of months or years" (1978, p. 5). Procedural tasks require memorization of the steps or memorization of materials associated with the steps. Extensive research indicates that a small number of items like procedural steps can be memorized and retained (Miller, 1956). Smith and Matheny (1976) review a number of investigations conducted in military settings or for the National Aeronautics and Space Administration (NASA) that demonstrate superior retention of continuous motor skills over procedural and verbal memorization tasks. Retention is approximately the same for procedural and verbal tasks.

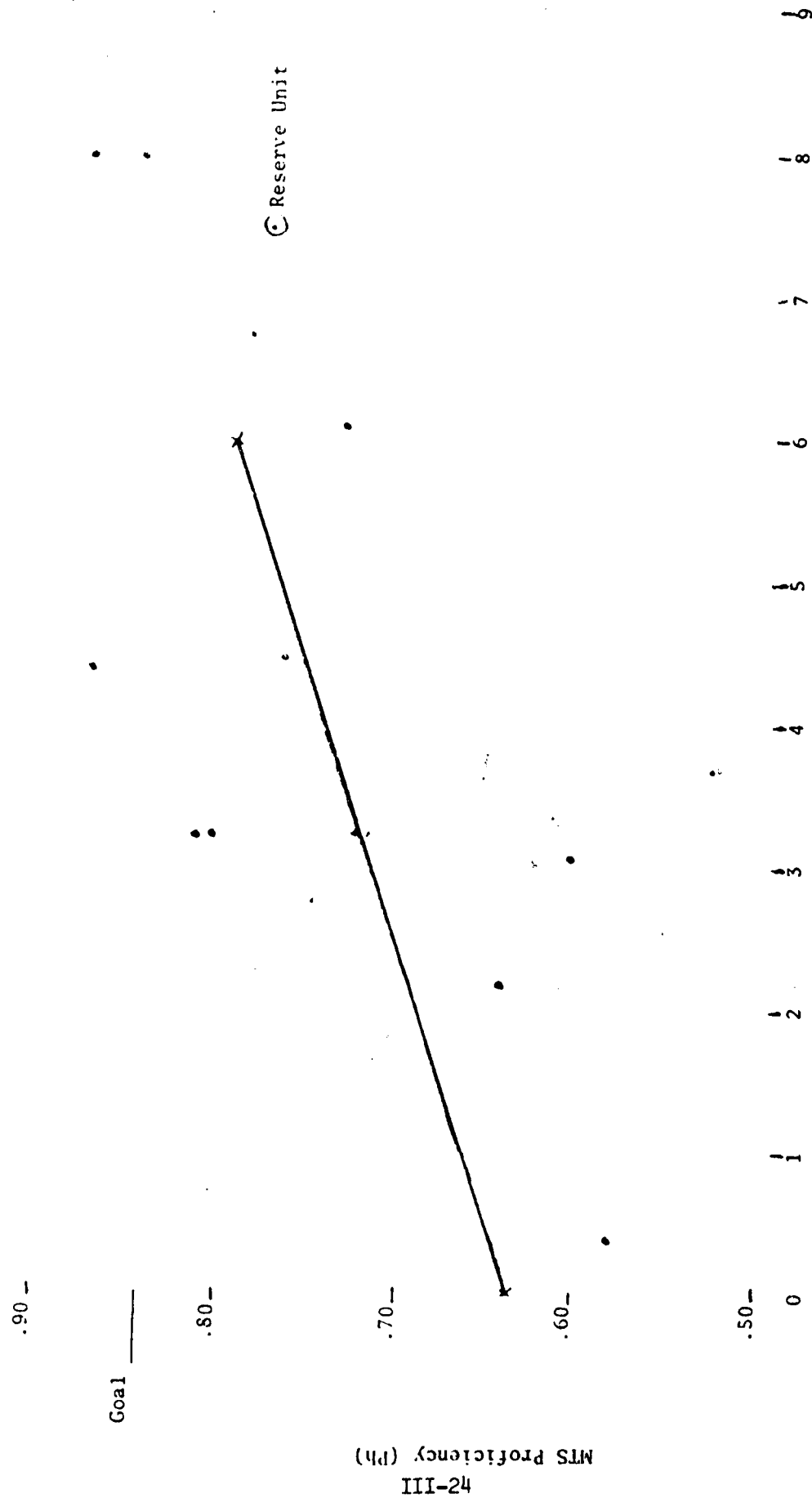


Figure 3-10. Relation of MTS Proficiency to Training Time

The NASA research conducted by Sitterley and his associates (1972) and Sitterley (1974) also examined retention of manned spacecraft flying skills. Tasks simulated spacecraft controls and procedures, including landing. Four groups of five pilots were trained, tested, and retrained using various techniques. Procedural tasks suffered sharp losses after only one month, and again after the third month. Continuous control tasks decayed somewhat during the first three months and sharply after that time.

In contrast to procedural tasks, continuous control tasks are characterized by a high degree of internal organization and provide continuous immediate feedback (Prophet, 1976a). Prophet considers task organization to be the critical difference in retention.

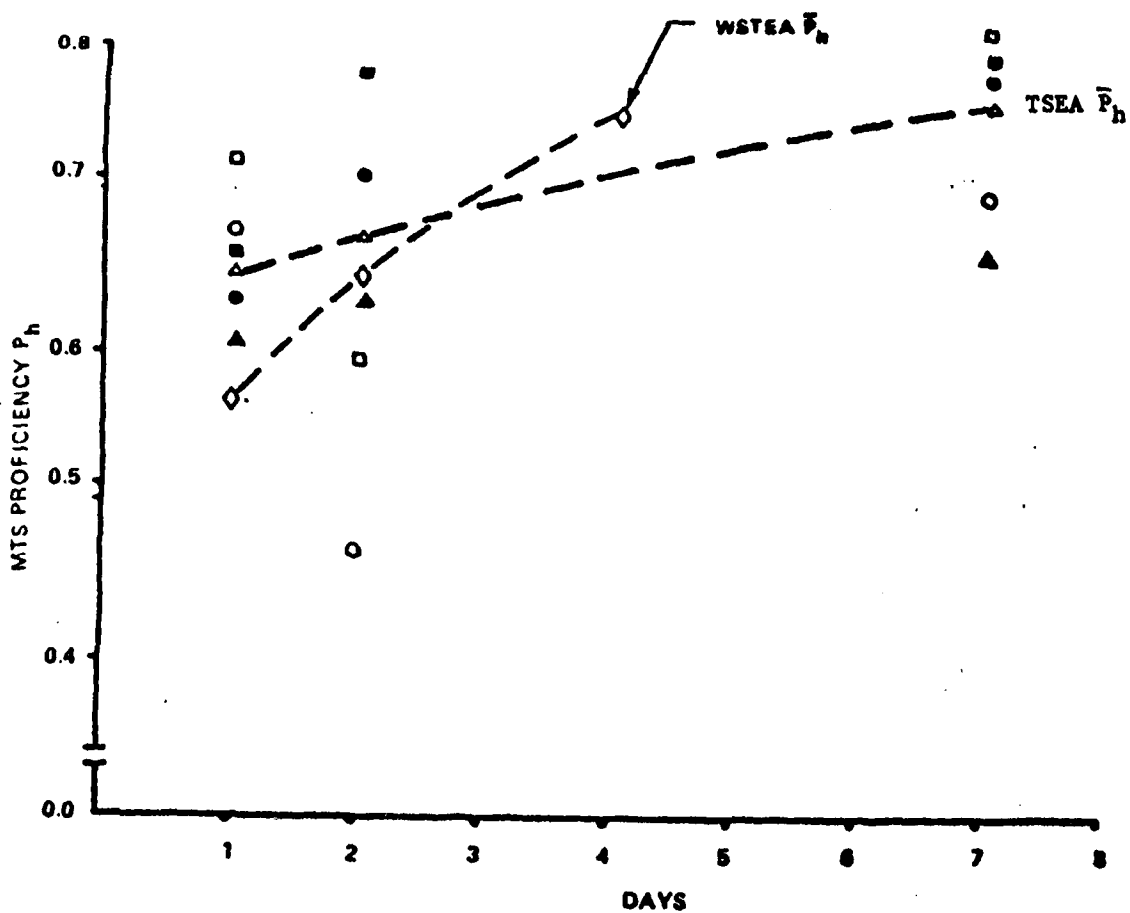
The degree of organization is also likely to influence retention of meaningful verbal material. The retention of organized, meaningful material is great enough that it drove scientists to devise nonsense syllables for experiments on memory rather than confound their results with interference effects and minimal forgetting.

Research by Naylor, Briggs, and Reed (1968) indicates that good task organization produces a higher level of initial learning (which leads to better retention) but that task organization does not increase retention per se. They studied eight groups of 16 subjects on a three-dimensional tracking task and a procedural task, with retention intervals of one or four weeks. A high level of task organization produced higher levels of training and retention varied directly with the level of training. The rate of decay, however, was not related to task organization. This research was conducted for the Air Force but used abstract tasks rather than simulated, complex tasks similar to actual jobs.

The types of tasks that must be learned by REDEYE gunners probably influence the ease with which they are retained. Using the MTS is a continuous tracking task. This is a continuous control motor skill, more readily learned initially and retained better. Another skill -- application of the range ring profile (RRP) -- is procedural and it is confounded by the requirement to memorize a complex 5 x 6 matrix. Procedural and rote memorization typically require a longer period of mastery and are more difficult to recall after the passage of time. The REDEYE initial training data demonstrate this. During the two week of initial training, most gunners reach an acceptable level of MTS proficiency but not of RRP skill. The mean proficiency for each class and the combined classes is given in Table 3-11 and shown graphically in Figure 3-11. The average proficiency for all units was 0.73 with 4.6 hours/month training in the MTS.

Table 3-11. MTS PROFICIENCY (P_h GROWTH)

DAY	AIT CLASS						COMBINED	COMBINED
	44	45	46	47	48			
1 (Reel #1)	0.63	0.66	0.60	0.67	0.72	0.65		0.57
2 (Reel #5)	.71	.78	.63	.47	.59	.67		.64
7 (Reel #12)	.78	.79	.66	.70	.81	.76		.75



KEY:

- CLASS 44 AVG P_h
- CLASS 45 AVG P_h
- ▲ CLASS 46 AVG P_h
- CLASS 47 AVG P_h
- CLASS 48 AVG P_h
- ▲ TSEA COMBINED AVG
- ◇ WSTEA COMBINED AVG

Figure 3-11 AIT MTS Proficiency Growth

These data from the TSEA (1978) show that P_h does not reach the goal of .85. The WSTEATSEA concluded that the basic REDEYE course as currently taught produced gunners with a minimum acceptable level of critical task proficiency. The average range of the original learning lies at .60 - .75.

In contrast is the range ring profile REDEYE skill. Using an especially prepared test, the Range Ring Profile (RRPT), REDEYE trainees and gunners were tested during the WSTEATSEA. The format of test is shown in Appendix D. The test contained 18 questions consisting of illustrations that required constructed responses. The respondent was required to identify aircraft, determine range ring coverage, and decide action for 18 diagrams. All three subtasks had to be performed correctly to achieve success. The aircraft were to be identified from black and white drawings. Responses were supplied from the memorized matrix. The range ring proficiency for all units tested fell in the range 0.22 of 0.39.

	<u>NUMBER OF GUNNERS</u>	<u>ALL ACTIONS CORRECT PRRP</u>
Unit 1	33	.22
Unit 2	83	.37
Unit 3	94	.39
Unit 4	88	.28
Unit 5	58	.37

The data also show that MTS skill (a control task) is better retained than the RRP skill (a procedural task). As shown earlier (see Table 3-7 and Figure 3-5) MTS skill declines slowly over time.

The RRP test results for two units at the end of AIT were 0.33 and 0.32, respectively. Back in their units, the soldiers were tested once again for the RRP and MTS. Proficiency remained virtually unchanged from initial inadequately low levels: 0.32 and 0.29. The learning and retention difference between the two skills appears to be due, at least in part, to the basic influence of the two task types.

Recall Variables and Transfer

In the study of transfer of training, the influence of learning one task on the performance of another task is examined. When an interval is inserted between learning the first task and performing the second, the paradigm contains both retention and transfer. Strictly speaking, transfer may be more appropriate to describe the sequence from initial military training to job performance, since the school situation differs from the operational situation. Similarity between the recall task and the original task increases retention and transfer. This similarity can include display-control relationships, training device fidelity, and other environmental factors.

Recall and transfer variables related to skill retention have been investigated in a series of studies conducted by Wheaton and his associates (Wheaton, Fingerman, Rose, and Leonard, 1976; Wheaton, Rose, Fingerman, Korotkin, and Holding, 1976; Leonard, Wheaton, and Cohen (1976)).

Leonard et al. (1976) explored the relation between retention of training content and transfer of training to a criterion-referenced test. They also studied the impact of refresher training (using the original medium) on transfer of training to the actual task. Other questions addressed were the retention of criterion-referenced test performance levels and retention of training content. A three-phase, 17-week experiment was designed and six groups of Army enlisted personnel (n = 106) were used. Three groups received refresher training by re-exposure to the original training medium (Training Extension Courses (TEC)). The task was the selection, maintenance, and use of the hand grenade. One group was tested immediately after training, one at six weeks and a third after 17 weeks. Retention of training content was measured by a written test designed from the TEC materials and transfer of training was measured by a criterion-referenced test (CRT). Leonard et al. found that increased delay between training and the CRT measure of transfer diminished performance in general. After a six-week delay from initial training, subjects provided with refresher training out-performed those having no retraining on two of four subtasks. After 17 weeks, subjects given refresher training out-performed those with no refresher on three of the four subtasks.

Retention of CRT transfer performance levels was not affected by time. No significant decline in proficiency was found, even after 17 weeks. Training content, however, showed a steady decline over time. Researchers concluded that refresher training helped persons with the longest lapse between training and use, and was therefore well suited to the Army system (i.e., training - no use - use).

REDEYE Use of Simulators. Skill retention research has consistently found that similarity between the recall or transfer task and the original task increases retention. A number of training devices are used to train REDEYE gunners. Use of live firing for training (initial or unit) is limited because of the high cost of rounds of ammunition (\$545/round in FY 78 dollars). Corps-level aircraft tracking exercises, as carried out in Europe for several sections, employ high performance aircraft and last several days. Cost for this exercise is approximately \$95 per team member per day. Therefore, the Army has continually depended heavily on simulated training for these gunners.

Training Effectiveness of Devices. A small experiment was attempted as part of the REDEYE WSTE A to compare the training effectiveness of alternative devices, but available samples were too small to produce interpretable data.

The question of fidelity of transfer of simulator training to live firing in combat remains unanswered. In the words of the TSEA (REDEYE TSEA, 1978, p. 103):

The uniqueness, complexity, and high cost of a REDEYE round makes it a difficult weapon to simulate and prohibitive in cost to use as practice rounds in the same sense as other weapon systems.

These factors also limit research using a sample size large enough for statistically significant findings. Assuming that the REDEYE gunners can perform at $P_h = .78$, battlefield conditions of mental stress, unfamiliar and

difficult terrain, unfavorable weather conditions, etc., would be likely to lower the P_h . In order to assess the effectiveness of the REDEYE weapon system, P_h input from the WSTE and TSEA was used in the COMO III War Model, a computerized battle simulation. The COMO III, a Monte Carlo model, simulates an offensive/defensive battle of division size units using the mid-1980 European scenario. An average of 10 computer simulations yielded a probable 86 enemy aircraft killed by REDEYE. The effects of varying P_h are:

REDEYE GUNNER PROFICIENCY (P_h)	AIRCRAFT* KILLED
0.1	5.4
0.2	11.1
0.3	14.9
0.4	18.1
0.5	23.5
0.6	24.3
0.7	29.3
0.8	33.9
0.9	34.2
1.0	40.2

*Av of 10 runs

At best ($P_h = 1.0$), REDEYE would kill 47% of the aircraft; at doctrinal goal ($P_h = .85$) REDEYE would kill 40%; at average AIT ability ($P_h = .77, .78$) they would kill 38%.

The relation of transfer of training to job performance is another area highly significant for training and material acquisition policy formulation. The high cost of using sophisticated weapons with live ammunition, and expensive fuels, as well as finding suitable land for field exercises, has caused the Army to investigate the use of simulators. Some of the simulators, especially those employing computers, are also very high cost items, both to purchase and to operate. In a recent study of the cost effectiveness of computer-based military training, Orlansky and String (1979, p. 4) found:

The effectiveness of training should be measured by how well course graduates perform specific jobs in operational units. Instead, all studies use student achievement at schools as a measure of effectiveness. The relation between achievement at school and performance on the job is essentially unknown, even for conventional instruction.

Some research (Wheaton et al., 1976; Bialek et al., 1973; Grimsley, 1969) has found that effective training and transfer can take place from low fidelity simulators. Grimsley (1969) designed a study to assess the effects of high and low fidelity training devices on acquisition, retention, and retraining. The task chosen was the operation of the Section Control Indicator console of the Nike-Hercules guided missile system during preparation (Blue) and firing (Red) status.

The devices used were: a functioning duplicate of the tactical panel in which all lights, meters, intercom and other indicators worked (Hot Panel); a non-functioning duplicate of the tactical panel with no electrical power (Cold Panel); and a full-size cardboard artist's representation in color of the Hot Panel (Reproduced Panel). Sixty subjects (AIT trainees at Fort Ord, California) were randomly assigned to five groups ($n = 12$ per group). Using five different training conditions, all subjects were tested on ability to perform a 92-step procedural task immediately after training, were retested at four weeks, and again after six weeks. Following the final test, subjects were retrained to criterion.

Grimsley's results are shown in Table 3-12. He found no statistically significant differences in learning the task, in initial performance levels in the amount remembered after four and six week intervals, or in required retraining time, between individuals trained on high and low fidelity devices. He concluded that the fidelity of training devices used on procedural tasks can be very low with no adverse effect on training time, level of proficiency, retention, or time to retrain. He further stated (Grimsley, 1969, p. iv):

Since substantial financial savings can be realized by using low fidelity devices, training device selection should be based on a careful review of the tasks to be taught, so that inexpensive devices can be used where possible.

This is compatible with the conclusion of Orlansky and String (1979); ten years later they found that (p. 11):

Student achievement in courses at military training schools with computer-assisted instruction is the same as or greater than that with conventional instruction; the amount of additional achievement is small and has little practical importance. Student achievement in courses with computer-managed instruction is about the same as that with conventional instruction.

Further findings indicated while student time saved was in millions of dollars, investment costs of dedicated systems were estimated in billions of dollars.

Training to criterion or mastery with low fidelity devices, training embedded in existing tactical computers, and skill performance aids should not only be cost effective, but achieve very considerable savings.

Transfer effects should also be investigated, however, in relation to team training and performance variables. These variables, therefore, will be discussed in the following chapter, Team Input Variables: Team Composition and Tasks.

Table 3-12. Mean Scores on Independent Variables for Experimental Groups^a

Test	Treatment Group ^b				
	Hot/Hot	Cold/Hot	Cold/Cold	Repro/Hot	Repro/Repro
AFQT Score ^c					
Mean	78.1	78.8	58.4	79.2	70.5
SD	22.3	20.2	20.0	10.3	23.2
GT Score ^c					
Mean	122.0	124.0	106.0	126.0	116.0
SD	17.7	16.9	21.7	11.9	17.9
Time to Train (minutes)					
Mean	114.0	113.3	118.3	97.8	132.3
SD	21.9	30.1	30.0	30.5	37.2
Proficiency Score					
Mean	90.9	89.2	90.1	88.3	89.5
SD	1.0	3.1	1.6	3.4	5.6
Retest 1 Score					
Mean	75.7	75.0	75.4	75.1	71.7
SD	5.2	4.3	6.1	8.0	8.3
Retest 2 Score					
Mean	82.9	83.3	83.3	83.6	83.3
SD	4.6	4.8	6.5	5.0	5.5
Trials to Retrain					
Mean	2.5	2.5	2.3	2.2	2.5
SD	1.0	0.8	0.4	0.7	1.0
Time to Retrain (minutes)					
Mean	20.7	19.9	19.0	17.8	21.1
SD	10.3	6.9	4.0	8.3	10.4

^aDesignation indicates method by which the subject was trained and method by which his proficiency was originally tested.

^bAnalyses of variance for these groups showed that differences were not significant.

^cMean scores somewhat above the average Army input for all groups.

Grimsley (1969, p. 8)

CHAPTER IV

TEAM INPUT VARIABLES: TEAM COMPOSITION AND TASKS

The team's tasks, composition, and configuration are typically designated by the organization external to the team (Figure 4-1). Team composition encompasses the number and attributes of the team members. The type of task interacts with team composition to produce potential team productivity (Table 4-1). These team input variables, and formulas designed to estimate their influence on the team's potential productivity, are discussed in this chapter.

Table 4-1. Potential Team Performance Variables

- o Team Task
- o Team Member Ability
- o Number of Team Members

Team configuration refers to the structural organization of the team and the behavioral processes linking positions within the structure. While discussion of process variables is postponed until the following chapter in order to simplify the discussion of team input variables, it is important to note that due to the effects of the processes, actual productivity does not equal potential productivity. Team processes and structural problems depress team output so that the actual amount is below that predicted from team composition. Given this caveat, the present chapter describes the effects of tasks, member ability, and the number of members on potential productivity.

Team Composition

All individual skill retention factors described in the preceding chapter bear on the maintenance of the pool of skill in the team. Individuals are the team's resources, and it stands to reason that higher numbers of individual members provide more potential productivity than lower numbers of members.

Formulas designed to predict potential team productivity focus on the effects of adding members to the team. The relevance of team size to military team performance is usually the opposite: military teams lose members through casualties, personnel turbulence, and temporary assignments to duties unrelated to the team's mission. Bialek (1977), for example, reported that the soldiers he observed spent 43% of the work day at guard duty and other non-MOS related assignments. Military units are not always up to strength (i.e., they do not have all of their allotted personnel) or positions may be filled by inexperienced people needing on-the-job training.

Team Tasks

Even when employing a weapon designed for use by individuals, military personnel operate in crews or teams. The REDEYE gunners described in the preceding chapter are one example; infantrymen in fire teams and squads are another.

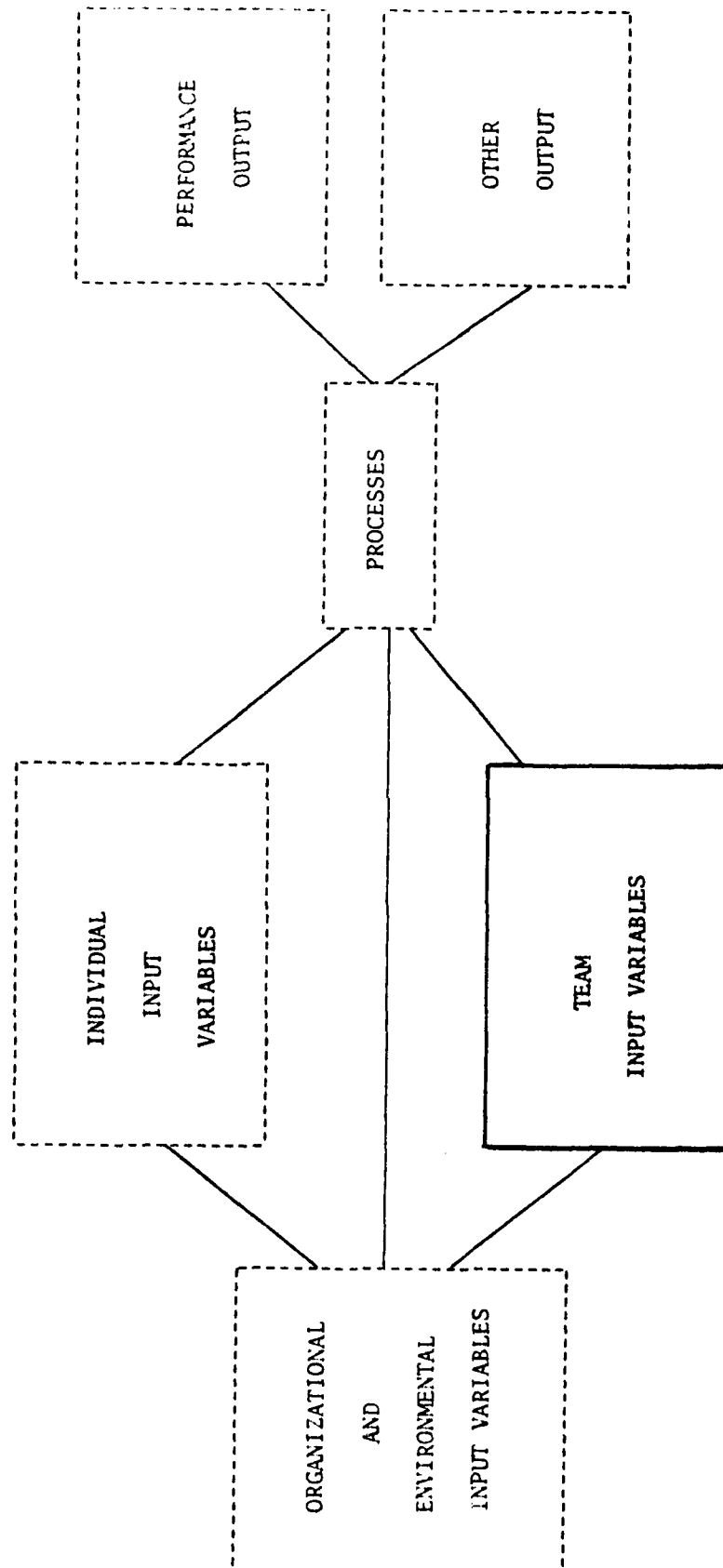


FIGURE 4-1. Team Input Variables in the Systems Model

The team's mission is greater in scope than can be accomplished by an individual, and contains multiple individual tasks. For example, Army Training and Evaluation Program (ARTEP) missions require that members perform individual job duties. In a single team task from the ARTEP, REDEYE gunners may perform all of their Soldier's Manual REDEYE tasks. The term "task," of course, is broader and more multi-faceted when it is applied to a team than when it is applied to individuals. Hare (1976) defines the team task in the broadest sense as the requirement for the team to deal with the situation in which it finds itself. In combat, the military team's task is to deal with the enemy force.

Thiabaut and Kelley (1959) suggest that differences relating to the scope of tasks may partially explain why sometimes, but not always, teams are superior to individuals who are working independently. For example, tasks that allow team members to work independently produce the same level of productivity as when individuals work in a non-team situation. Since military tasks in actuality are greater in size than tasks that one person can perform alone, the option of assigning an individual rather than a team is not available.

Because a team's task is typically multi-faceted, it can be divided into portions, or subtasks, of which some are performed by individuals and some by subgroups. Rifle squads, for example, are divided into two infantry "fire teams." Within the fire teams, some soldiers function as individual riflemen; others work in pairs operating machine guns and antitank weapons. In other cases, tasks are not as clearly divisible, nor assignments of members as prescribed by the organization. All divisible tasks, however, require that subtasks (e.g., tasks given to individual members) be assigned, coordinated, and finally combined into a team product. Solutions to these requirements have a strong impact on team performance. Research confirms the common sense notion that teams perform adequately if members are well-matched to the tasks, and perform poorly if they are not (Steiner, 1972).

Military research is interested in teams performing coordinated, structured activities to accomplish specific missions. The military has made extensive use of task analysis to define individual and team tasks, describe the relationship of tasks to military hardware, and to specify responsibilities and roles. This task analysis has improved job descriptions and job performance evaluation for individuals, but has not focused on dimensions that are critical to teams.

Davis (1969) reviewed classifications of team tasks and task dimensions and concluded that methodology has been primarily intuitive. Investigators select tasks that embody attributes relevant to their purposes. The most detailed definitions are provided by team task typologies. Some dimensions of team tasks (difficulty, criticality, automation, and response complexity) also pertain to individual tasks. Other dimensions, such as the ways that team members combine their activities and products, are unique to teams. Team-unique classifications pertain to this report.

Steiner's (1972) "partial typology of tasks" presents the most complete set of categories for team-unique tasks. Steiner categorizes as to whether tasks (a) are divisible or unitary, (b) have a prescribed process, (c) are maximizing or optimizing, and (d) permit members to combine their individual products.

Two of Steiner's dimensions have already been discussed. First, military team tasks are so broad and complex that they cannot be assigned to individuals

but are divided among team members. Steiner refers to the lowest level of division, where tasks are essentially non-divisible, as "unitary." Most military team activities are combinations of such unitary tasks. Second, while the military system prescribes methods for teams to use, teams may devise some of their own patterns of operation. Thus, they usually work under Steiner's "permitted process" condition, although their methods may or may not be as suitable for the task as the process prescribed by the organization.

The distinction between maximizing and optimizing tasks simply is whether there is a standard or goal, or whether the team must do as much as possible of some activity or product. Artillery fire is an optimizing task, for instance, since the rounds must be shot to a particular location rather than shot as far as possible. Detection of enemy forces at the greatest possible range, on the other hand, is an example of maximizing a task.

The ways that tasks permit teams to combine activities and the efforts of individuals fall into several categories. Task types frequently cited in team literature employ disjunctive, conjunctive, compensatory, complementary, additive and discretionary combinations of member contributions (Table 4-2). Definitions of these "task types," interactions with team member ability, and with the number of individuals involved are discussed in the following paragraphs.

Table 4-2. TEAM TASKS

<u>TASK NAME</u>	<u>DESCRIPTION</u>
Disjunctive:	At least one team member must have the skill; the most skilled member determines the team potential productivity.
Conjunctive:	The least skilled member determines the team's potential productivity.
Compensatory:	Member inputs are averaged; members can make up for each other's weaknesses.
Complementary:	Each member performs the portion of the task for which he has the required skill.
Additive:	Team's potential productivity is a summative combination of the individual member's products.
Discretionary:	Members combine contributions as they wish.

Interaction of Task Type, Team Member Ability, and Team Size

Disjunctive. In disjunctive tasks, the team product is essentially an individual product sanctioned by the team. For example, the members of an artillery forward observer team may discuss the potential routes to an observation post taking into consideration such factors as speed, observation, communication, and the maneuver plan. One route must be selected. Problem solving and judgmental tasks, such as the choice among alternatives, are usually disjunctive. Although the team may discuss the problem, the procedure becomes the selection of one member's solution. The team can assign total weight to the most skilled member but at least one member must have the skill for the team to succeed. Furthermore, the team process must proceed as required by the task, and must use the available member resources properly in order for actual productivity to equal potential team performance. Thus, teams may fail at disjunctive tasks if none of the members has the skill, if members who have the skill do not apply it, or if other members do not accept the skilled member's contribution.

Lorge and Solomon (1955), Steiner (1972), and Steiner and Rajaratnam (1961), have devised formulas for the probability of team success based on the proportions of individuals who do and do not possess the skill, and the number of members selected for the team. If P is the proportion of people in the population who possess the skill, and Q is the proportion of people who do not possess the skill, then Q is also the probability of randomly selecting an individual who does not have the skill. The probability that no one in a team of size n has the skill is Q^n and the probability that at least one member with the skill is $100(1 - Q^n)$. As team size increases, the probability of success at a disjunctive task increases and the percent of potentially successful teams increases. In the military, improved training increases P and decreases Q . Increasing military team size to improve performance is not usually plausible. However, team performance will change (for better or worse) since loss of a member because of turnover or through battlefield casualties is highly likely.

The rate of change in potential productivity depends on the initial size of the team, and on the proportion of P and Q in the population. Adding or deleting a member has more impact on a small team than a large one. Each successive addition yields a smaller increment; each successive deletion of a member yields a larger decrement in team output. The curvilinear relationship between team size and potential productivity is shown in Figure 4-2 for two levels of Q . If the task is so easy that everyone can perform it, $Q = \text{zero}$, and the potential productivity of an individual is as high as that of the team. For fairly easy tasks ($Q = .2$) the curve asymptotes at a small team size. Adding members contributes little, and losing members does little harm. For a hard task ($Q = .8$) changing the number of members has a greater effect, and the effect occurs over a wider range of team sizes. Complex tactical decision-making is an example of a hard judgmental task, and it is one required of tank crews and rifle squads. The impact of loss of a member is predicted to have a strong impact on tactical performance of these types of teams.

Success can be treated as a continuous rather than dichotomous variable using procedures developed by Steiner and Rajaratnam (1961). They assume that teams are randomly assembled from a population in which skill is normally distributed. They use percentile scores of individuals who are most and least competent (Table 4-3). Standard score equivalents of the percentiles indicate that as team size increases, the ability of the most competent member in the

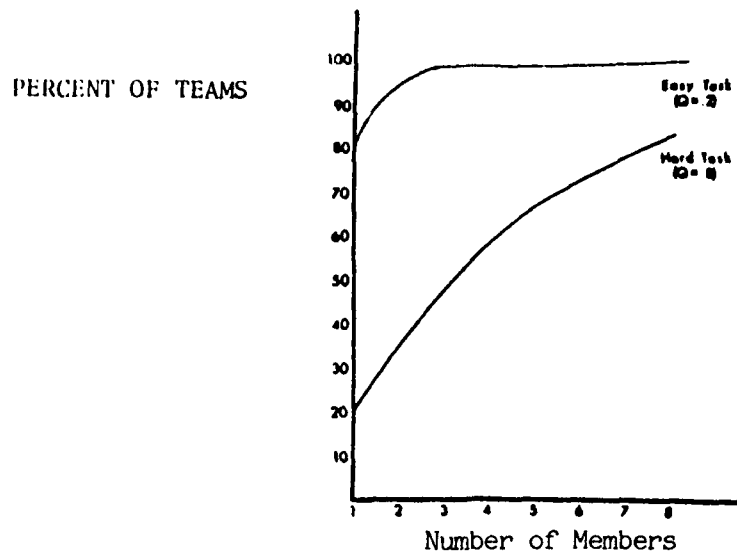


FIGURE 4-2. Potential Productivity As A Function of Team Size and Task Difficulty: Disjunctive Task

(Adapted from Steiner, 1972, p. 69)

Table 4-3.

Average Percentile and Standard Scores of Most and Least Competent Members of Groups^a

Group size	Most competent member		Least competent member	
	Percentile score	Standard score	Percentile score	Standard score
1	50	0	50	0
2	67	.43	33	-.43
3	75	.68	25	-.68
4	80	.84	20	-.84
5	83	.97	17	-.97
6	86	1.08	14	-1.08
7	88	1.17	12	-1.17
8	89	1.22	11	-1.22

^aThe values in this table are based on the assumption that groups are randomly assembled from a population in which competence is normally distributed.

(From Steiner, 1972, p. 71)

team is higher, but that the increments are successively smaller: the shape of the curve is the same as for the case of dichotomous scoring of the skill. The increase in potential team productivity depends on the heterogeneity of ability in the population. If the population has individuals with only small differences in ability, then adding a new "most competent" member has little effect (losing the most competent member is also minimal). In contrast, if individuals differ widely in skill, potential productivity of the team changes sharply. This treatment of skill heterogeneity emphasizes the problem of loss of "key" personnel by right of assigned leadership position (e.g., the tank commander is the most experienced and highly trained member of the tank crew) or individual ability. The loss of key personnel, as might be expected, is predicted to have a greater detrimental effect on the team's potential productivity than the loss of others.

Ideally, the military system selects, classifies, trains, and assigns individuals to jobs for which they are well-matched. Thus, the population from which teams are sampled would have low values of Q (tasks would be easy for the trained population and the ability to perform would be uniform), although the values of P and Q are expected to fluctuate over time because of the cyclical nature of training.

The assumption of random sampling, therefore, is not tenable with regard to military job assignments. Although some job mismatches occur, individuals generally are assigned to jobs for which they have been trained. However, given problems in the training cycles and training development and implementation, the selection of persons for teams is probably less systematic and closer to random than system planners prefer. Even if the assumptions for formulas are not met, however, formulas provide explicit and concise statements of the relationships among team size, team member ability, and potential productivity.

Conjunctive. Tasks that require team members to function in a chain-like sequence evoke the adage that "a chain is no stronger than its weakest link." When the team's performance depends on the member who performs least well, the task is called conjunctive. A military example is the sequence of events in requesting indirect fire. Mistakes by anyone in the chain (forward observer, fire direction center, and firing battery) degrade results. In determining overall performance, total weight is assigned to the least skilled member.

The team's potential productivity at conjunctive tasks can be computed for both dichotomously and continuously scored cases. In the dichotomous case, since the team succeeds only if the least skilled member performs successfully, adding more members weakens team performance. Using the same symbols, from Steiner (1972), P = proportion of people who have the skill, and n = number of team members, then $100 (1 - p^n)$ percent of the teams are expected to be unable to perform the task. As members are added, potential productivity decreases at a decelerating rate (Figure 4-3). The drop is acute for a hard task ($P = .2$, $Q = .8$). For easy conjunctive tasks that most members can perform ($P = .8$, $Q = .2$), potential team success starts high and rapidly decreases. At any level of difficulty, the successive decrements become smaller as the number of team members increases; potential productivity has a negative, curvilinear function.

Treating success as a continuous variable, Steiner and Rajaratnam (1961) therefore note that potential team productivity decreases as team size increases (percentile and standard scores for the least competent members determine the shape of the function; see Table 4-3). The degree of change depends on the heterogeneity of ability levels in the population.

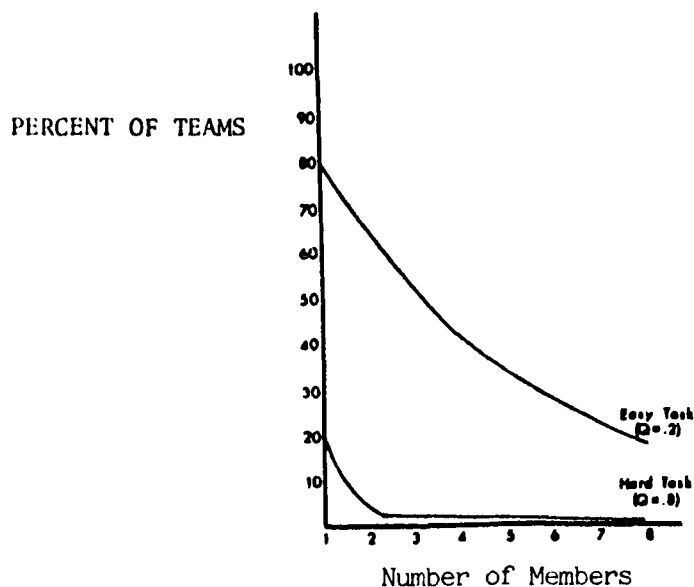


Figure 4-3. Potential Productivity as a Function of Team Size and Task Difficulty: Conjunctive Task

(Adapted from Steiner, 1972, p. 73)

If ability varies widely, then potential productivity decreases rapidly as team size increases. In contrast, if most people can perform at about the same level, the differences among standard scores are small, and changes in team size have little impact.

Although the conjunctive tasks depend on the efforts of all workers, and are therefore sensitive to failure by anyone, these tasks do not have to be sequential. An example of a highly interactive conjunctive task is provided by the roles of the tank commander and driver. Based on the driver's own skill and radio (intercom) instructions from the tank commander, the driver maintains positions and selects routes that allow the tank commander to scan the countryside while keeping the tank out of enemy view. The driver positions the tank for firing the main gun or other weapons, the crew fires, and the driver moves the tank to a new position to avoid detection by the enemy. The interaction is sequential to some extent, but the driver's interactions with the tank commander is an on-going process. Both of them must perform correctly for the actions to succeed.

Compensatory. Team members are popularly believed to compensate for or complement each other. In the compensatory model, inputs from several members are averaged. For example, each member of the team may estimate the distance to a target, and the team may average the judgments. Averaging reduces the

effects of opposing biases; in a large sample, if biases are normally distributed, the standard error of the team mean from the true score (Steiner, 1966). In application, biases are not necessarily normally distributed, however, so the formula for the standard error of the mean is not expected to be of value for predicting team accuracy. In judging distances to a target, all team members may believe the target is further away because it is smaller than they realize (e.g., a small helicopter rather than a large one). Steiner (1966) reports systematic biases in laboratory studies of this phenomenon.

Johnston and Briggs (1968) examined team performance as a function of compensatory and "fail-stop" task arrangements. They defined compensatory action as a member correcting an error after a teammate commits it, and "fail-stop" as a member preventing a teammate from committing an error. They also varied workload, and hypothesized that high load conditions understandably inhibit compensatory and "fail-stop" activities. Their task simulated air traffic control procedures. Results demonstrated that team performance was augmented by compensatory and "fail-stop" actions. Under high load conditions, however, team members could reduce the number of errors, but did not have time to correct errors after they were committed.

Considering compensatory tasks as "error correction" appears to have more utility than considering them as "average judgments." Dieterly (1978) notes that compensatory behavior is necessary in high priority situations; therefore, extra team members may be included in teams to serve as backup and replacement when a member is not functioning.

Complementary. In complementary tasks, members perform only the part of the task for which they have the required talent, while other members, who have other talents, perform remaining activities. Steiner (1966) shows that the average capacity, G , to perform the task is:

$$G_{f,n} = n P_f M_f$$

where P_f = proportion of individuals in the population who can perform task part f

M_f = mean amount task part f the individuals can perform

n = number of team members

Thus, this formula can be used to predict the productivity of teams with n randomly selected members if the abilities of individuals within the population are known. No tests of this hypothesis were reported in the literature. However, an interesting empirical demonstration would entail use of the Army's Skill Qualification Test scores to estimate the population parameters (when large numbers of soldiers have been tested), estimation of the predicted team output, and field tests of the team performance. For example, research might test the prediction of tank crew performance based on individual ability levels.

Additive. In additive tasks, the team's product is the accumulation of individual member's products. Members in some cases function in parallel, after which results are combined. In other cases, such as the maximum pull on a rope, all team members may pull at once.

With additive tasks, potential team productivity is expected to increase with team size, since members' products are cumulative. In reality, however, additivity holds only within a restricted range. For example, adding more typists to a clerical pool increases the typed output only if there is unlimited input. The curve depicting the relationship between team size and potential productivity levels off at either the top or the bottom, depending upon where restrictions produce threshold effects (Figure 4-4).

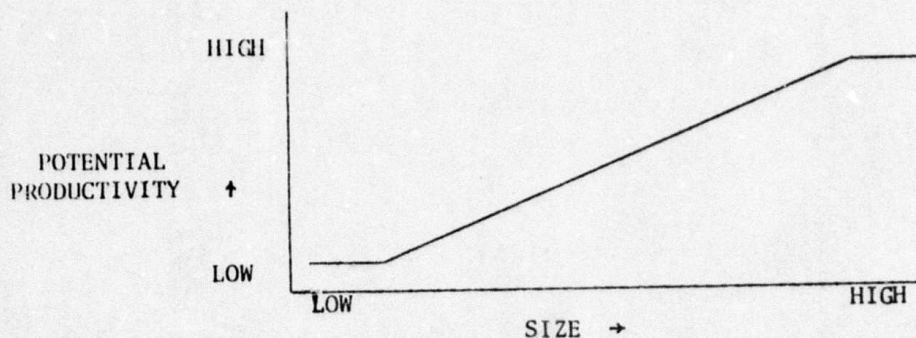


Figure 4-4. Potential Productivity as a Function of Team Size: Additive Tasks

System developers are interested in determining the minimum size of the team that can perform the assigned task efficiently (Meister, 1976). The problem for the system researcher is to determine this minimum team size, not to recommend increases in team members that may or may not increase productivity. Thus, while adding more members to work on an additive team task is expected to increase output unless the upper threshold is reached, the problem is to estimate the effects of the loss of members from a team that was designated by the military system because that team size was believed to be the minimal size for efficient output. Alternatively, the problem is to estimate the loss in output resulting from a team member forgetting how to perform the task.

For additive tasks, the effect of team member loss or of member inability to perform may lead the team to reach its maximum output at a lower point on the graph of potential productivity as a function of size. Laboratory studies of small group productivity (Steiner, 1972) which provide evidence of this function can be interpreted as supporting such a hypothesis. The literature review, however, found no empirical evidence of the effect of member forgetting on team output for these tasks.

Discretionary. Discretionary tasks permit individuals to combine their contributions as they wish. For example, with discretionary tasks, the team can assign the task to a single member, can divide the job between all members or give different members varying proportions of the work.

Discretionary tasks allow the team to combine member resources and products at will. Since any combination may be used, team size is unrelated to potential productivity for these tasks.

REDEYE Example

TRASANA's REDEYE research demonstrated many organizational and individual effects, and these data can also be used to show the impact of the training cycle and individual ability on potential team performance. Each REDEYE team is composed of two members -- a team leader and a gunner. Both members of the team are trained in gunnery, communication, enemy detection, and aircraft recognition. Both members of the team act as gunners to double the rate of fire during periods of intense air activity.

The overall team task is divisible, since the team leader has duties that the gunner does not perform. The principal subtasks (tracking, engaging, and firing) are unitary; each team member performs these subtasks operating his individual weapon. Individual weapon operation is disjunctive, since the operator makes the firing decisions and implements them (although he may use advice from the other team member). The mission, destruction of enemy aircraft, entails the additive combination of all the individuals' activities.

REDEYE Moving Target Simulator (MTS) scores gathered by TRASANA can be used as hypothetical estimates of the population ability levels (P_i) to serve as a hypothetical example of the pooling of individual team member skills. Ability level is high after initial Advanced Individual Training (AIT), decays during the interval of reassignment and travel to duty station, then increases during exposure to the unit's training for individual Skill Qualification Tests and collective Army Training and Evaluation Program field exercises.

For a disjunctive task, the probability that at least one of the team members has the skill is $1 - Q_i^n$, where Q_i is $1 - P_i$. The second column in Table 4-4 contains the values of Q_i^n , for the REDEYE team of two members, based on the P_i in the first column. The last column presents the percent of REDEYE teams expected to contain at least one member who has the required skill, given the P_i .

Table 4-4 estimates team performance if the paired REDEYE operators are of equal ability, i.e., it pairs two new graduates, two gunners with three months of retention interval, and so on. In actuality, the team leader would probably have been in the unit longer. Teams formed of individual members whose P_i differ from each other have expected team performance levels that fall between the highest and lowest shown in Table 4-4.

Table 4-4 Hypothetical REDEYE Team Performance

Training Cycle Phase	P_i	Q_i^2	$100(1 - Q_i^2)$
End of AIT	.78	.048	95.0%
3 months in unit	.58	.176	82.4%
6 months in unit	.68	.102	89.8%
13 months in unit	.80	.040	96.0%

At the individual proficiency level established by doctrine, $P_i = .85$, approximately 98% of REDEYE teams are predicted to contain at least one member who has the required skill. These estimates using the MTS data produce high predictions of team performance. The overall team productivity remains high even during the phase of low individual ability in the training cycle. REDEYE operation also depends upon use of the Range Ring Profile (RRP). RRP scores were only half as high as MTS scores. Thus, RRP scores would produce much lower estimates of team performance. However, the purpose here is not to make predictions of REDEYE success, but to demonstrate that team performance is enhanced when individual scores are pooled.

The TRASANA (1978) training system effectiveness analysis reported that turbulence of section leaders has an impact on training, especially in Korea where the maximum tour is one year. Implications, based on the shape of the individual proficiency functions and the estimated team performance levels, are several. First, turnover of leaders who have the most experience implies lower probabilities of pairing a new AIT graduate with an experienced team member. Second, the extent of skill decay after reassignment, the resulting travel and other hindrances to practice is unknown for these personnel who are not recent AIT graduates. Personnel who have been in the Army longer may suffer less skill decay through disuse and interference, but they are likely to lose some skill. They have increasing levels of rank and are more likely to be paired with a new AIT graduate in a team in the position of team leader. Team leaders have responsibilities other than gunnery, such as tactical decisions and loss of their skill has an impact on the team's performance that is not assessed by the formulas predicting team productivity by pooling individual abilities. It is therefore reasonable to hypothesize worse effects on team performance because of the turnover of leaders and other key personnel than that of non-leaders and less experienced soldiers.

Combining individual REDEYE scores for two team members assumes that one member can compensate for the performance of the other, perhaps by firing a second missile. Additional firings may not be feasible, especially at high performance aircraft. Hypothetical combinations of individual data are more defensible for the Light Antitank Weapon (LAW). LAW gunners are deployed in pairs and are instructed to fire both missiles at the target if necessary to destroy it. Unfortunately, data on the LAW training system are not available in sufficient quantities to substitute for the REDEYE data.

Relation Between Team Task and Team Structure

Naylor and Dickinson (1969) explored interactions between team tasks, work, and communication structures to account for differences in team performance. They hypothesized that:

$$\text{Team performance} = f(\text{task structure, work structure, communication structure})$$

They defined "task structure" as "demand characteristics" of the assigned task. "Work structure" referred to "the way that task components are distributed" among members, the operations to be performed, the sequence of operations, and interaction among team members. Thus, their concept of work structure corresponds closely to the concept of team structure but is differentiated from "communication structure." They handled communications separately in their

model, but they did not test the effects of communication. Results showed that task structure, but not work structure, influenced overall team output -- in contrast to the results of studies by Bavelas (1950), Cartwright and Zander (1968), and Guetzkow (1968) who all found team structure to be important in determining team performance. Although they removed the effects of communication in their experimental design, Naylor and Dickinson note that most research definitions of team structure include communications (the examples given -- Bavelas, Cartwright and Zander, and Guetzkow -- focus on communication as the major factor in team structure). Communication appears to be a critical component of team structure that may explain the divergent results of the studies.

Naylor and Dickinson's statement of team performance, however, as a function of the team's task, structure, and communications is important because it distinguishes the assigned task from the team's functional structure and tests both of these factors. Other studies have held the task constant and varied either the structure (Roby and Lanzetta, 1957), or communication patterns (Bavelas, 1950; Guetzkow, 1968). These two aspects of team performance (task and structure) do not always correspond because structure is not always configured optimally for the team to accomplish its mission.

Congruence between task and structure has implications for military team performance. Each military team is required to perform myriad tasks, but is limited in structure. Some of the team's tasks correspond to its structure and some do not. For instance, most military teams are hierarchical while some processes are sequential, and some are parallel. If teams alter patterns of interaction to adapt to the task at hand, and if they select a structure congruent with the task, then the team output is hypothesized to be higher than if they fail to adapt the congruent structure.

CHAPTER V

TEAM PROCESS VARIABLES: STRUCTURAL CONFIGURATION AND FUNCTIONS

The concept of team structure serves as a bridge between team input variables presented in the preceding chapter and team processes in the present chapter. Behavioral processes associated with team structure are intervening variables that mediate the effects of team tasks, team size, team member (individual) abilities, and organizational factors in their effects on productivity (Figure 5-1).

Positions, Roles, and Processes

Team structure, or configuration, has three components: team positions, roles, and interpersonal relationships that connect positions. The role associated with each position has a set of behavior patterns expected of, or typically displayed by persons in the position. Interpersonal relationships connecting positions include communication, task coordination, and social interaction. Activities that occur only when members are together constitute team functions and processes cited in models of team performance. Social interaction is evident even when the team is not engaged in a task, however, a point that may help distinguish between the structure of the team and the structure of the task. Observable evidence of structure is provided by activities of members as they carry out their roles and interpersonal interactions. Davis (1969) defines team structure as "a picture of the interpersonal processes among the positions taken at a particular point in time (p. 88)." The simplest way to portray team structure is to graph the positions connected by relationships, as shown in Figure 5-2 for two types of structure.

Formal and Informal Structures

Team structures that are imposed by the organization in which the team works are called formal structures; those that the team develops over time are called informal structures. The organization (e.g., the Army) determines for military teams a formal structure it believes will produce the optimal system output and assigns that structure to the team. To promote efficient group performance, each position consists of a set of functions readily performed by one individual and indicates whether he has responsibility to some other position, whether he has authority over some other position, or whether he is directly connected in communication networks with some positions but not with others (Cartwright and Zander, 1968). Military team members alter the structure of their team over time, as members change or abilities of members change.



Figure 5-2. Sample Team Structures

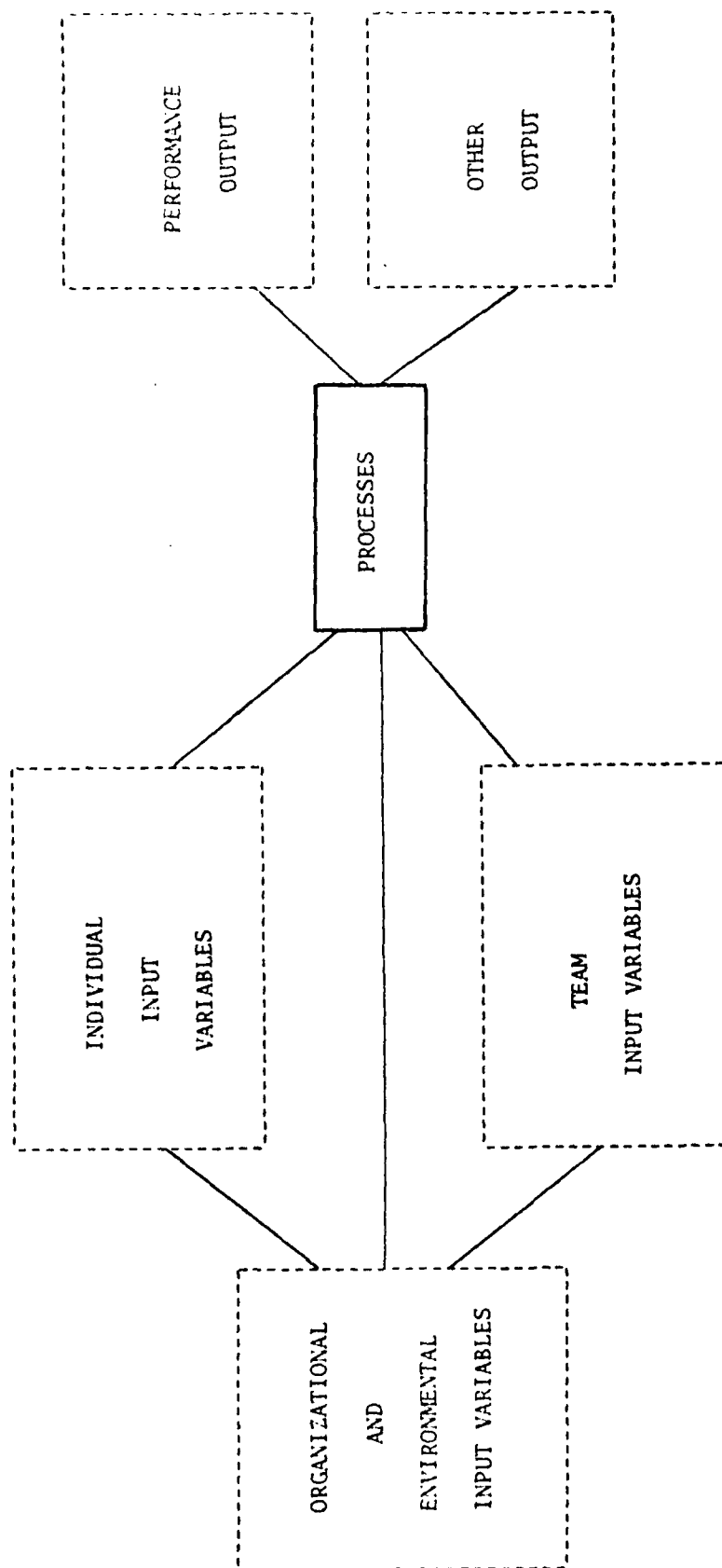


FIGURE 5-1. Processes in the Systems Model

The differences between formal and informal team structures may be trivial to the newcomer. At this point in the history of the military establishment, soldiers are entering existing team structures that are blends of the formal (which soldiers learn in military service schools) and the informal (as molded by the team or unit). An exception occurs during the formation of new types of teams, which have not had sufficient time to develop informal structures. Indirect fire support teams (FIST) currently being developed by the Army are an example of a new type of team.

Structural Configurations

The team structure determines, to some extent, team productivity since it determines the way member contributions are combined into the total team product (i.e., the system output). For example, team members may function in serial or in parallel fashion. In serial (or sequential) team structures the input to one member is based on the output of another; one member's activities follow and depend upon another's. For example, in indirect fire sequences, there is a chain from the forward observer to the fire direction center and then to the firing battery. Since all members must perform correctly to produce overall team success, a multiplicative model is hypothesized to describe serial team performance (Meister, 1976). For a two member team:

$$p = f(x)(y)$$

where p = probability of correct performance, team
 x = probability of correct performance, member x
 y = probability of correct performance, member y

If one member has a probability of .50 of correct performance, and the other has a probability of .75, then the probability of correct team performance is .38.

In contrast, the probability of correct performance in parallel team structures, the lowest level of team member interdependence, is additive:

$$p = x + y - (x)(y)$$

Given the same team member probabilities as used in the serial structure example, the probability of correct performance in the parallel structure is .87. In the parallel structure, either one of the members has to perform correctly, so the probability of team success is higher than for either team member of the serial structure.

The benefits of parallel structure are demonstrated by the way the Army uses the Light Antitank Weapon (LAW). The LAW is an individual weapon designed to destroy tanks. However, when LAW gunners work in pairs, the effectiveness of the weapon is increased. If the first gunner shoots and misses or does not destroy the tank, the second gunner shoots, thus increasing both the probability of a hit and the extent of damage to the enemy tank.

A small number of studies empirically tested the accuracy of the additive and multiplicative models for predicting team output. Zajonc and Taylor (1963), using a serial structure with a reaction time task, found that as more members were added to the series, the team was less able to accomplish its mission (they tested from two to seven members).

Egerman (1966) examined 18 teams in an operant conditioning-team training paradigm, with six of the teams in each of three structures: serial, parallel, and individual. The individual was trained with other members, but one pre-selected member's performance determined team success. Predictions computed for this individual alone, and for the serial and parallel teams by using the additive and multiplicative formulas, respectively, correlated .73 with actual team proficiency.

Waag and Halcomb (1972) used simulated, or synthetic, teams to explore the effects of team size and the structure of the team. They constructed the synthetic teams by drawing data points randomly from a pool of individual scores. Their synthetic teams contained from 1-5 members. Results indicated that increasing team size increased team performance, especially if only one of the members had to succeed in order for the team to accomplish its mission (e.g., target detection by at least one member). Large size teams with parallel structures made the most detections, but also the most false alarms. To minimize false alarms, the serial structure was best, virtually eliminating the problem. Team size had some effect while team structure had a large effect on team performance.

Parallel tasks in pure form are not likely to appear outside the laboratory, however. In the experiment, the members' products are compiled by the experimenter. In a real work situation, the products must be compiled by a leader or supervisor. A frequent example is the clerical pool, in which each clerk or typist has an independent work assignment. For every clerical pool, however, there is a supervisor who plans the work and the pacing, or time sequence. In real work situations, team structures that are parallel in the laboratory are hierarchical in actuality, because the leader, or supervisor, performs the "data reduction" that the researcher handles in the experiment.

The team structure most often imposed by military systems is hierarchical (pyramidal) as shown in Figure 5-3. Authority as well as responsibility for exclusive portions of the team task is vested in a designated leader, such as platoon leader, vehicle commander, squad leader, or fire team leader. In the enlisted personnel system, for example, those who have more experience typically have higher positions in the pyramid (although grade is not perfectly correlated with ability). Within each team, as well as within the system as a whole, there are fewer positions in progressively higher levels of the pyramid because not all experienced persons reenlist, and there would not be positions for all in any case. While this works for the overall system, the loss of an experienced leader can be critical for a team because of his knowledge and position in the communication structure.

The hierarchical team structure, with a member in a central leader or communication link role, permits the leader to coordinate and organize the team to perform efficiently (Meister, 1976). It is critical to have the most effective team member occupy this central position; if the central member does not do his job or does not assume authority, the hierarchical structure is not effective (Davis, 1969).

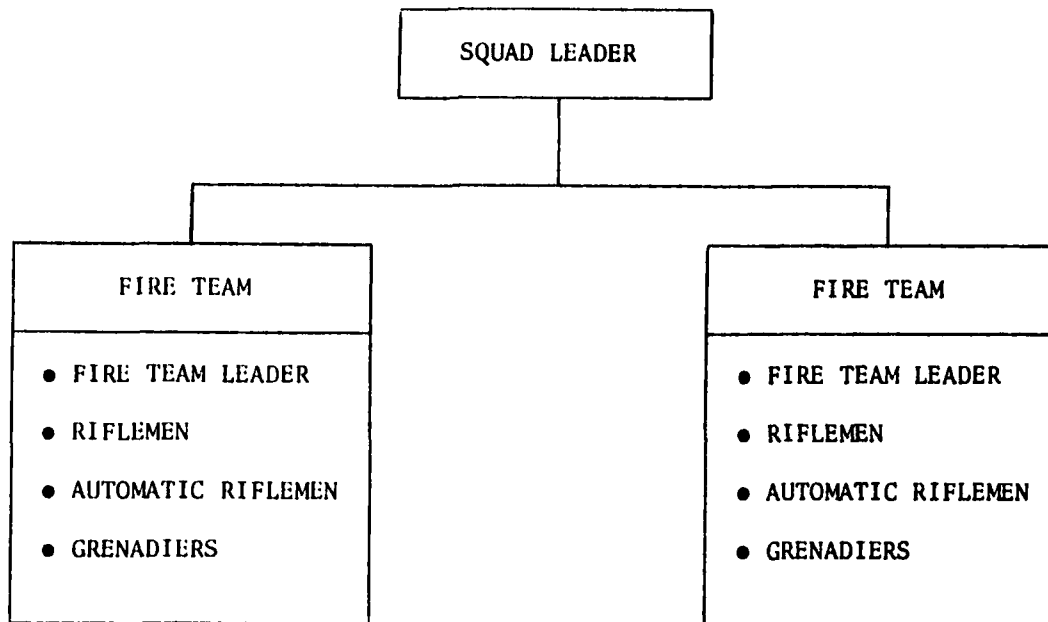


FIGURE 5-3. Hierarchical Structure of Infantry Rifle Squad

Team Processes

Behavioral team processes link team positions. Meister noted in 1976 that research attempts to clarify and categorize team processes have been plentiful but have not produced a satisfactory taxonomy of team process dimensions. Some researchers abstracted the elements of the work situation and investigated analogues of these elements in the light of particular theories. For example, Glanzer and Glaser (1959, 1961) focused on communication network theory, and Rosenberg and Hall (1958) used reinforcement theory. Others based their research on military or civilian tasks without abstracting the elements or dimensions. For example, Roby and Lanzetta (1957) simulated aircraft crews, and Naylor, Briggs and colleagues investigated radar operator tasks (e.g., Naylor and Dickinson, 1969).

More recently, Nieva, Fleishman, and Rieck (1978) developed a team performance taxonomy of the type based on abstractions of team dimensions "that enable the team to work together as a unit, over and above individual member performance of specific behaviors" (Nieva et al., 1978, p. 59). They have identified four major performance categories, and several performance dimensions within those categories. The categories are the team functions of orientation, organization, adaptation, and motivation.

Orientation. Team orientation functions are processes of information distribution: specifically, the extent to which teams elicit and distribute information about goals, tasks, and team member resources and constraints.

Organization. Team organization functions are coordination processes including: division of labor (matching member resources to task requirements); activity sequencing and pacing; load balancing of subtasks among members; and priority assignments among subtasks.

Adaptation. Team adaptation functions are cooperative processes by which team members complement each other by making mutual adjustments and carrying out accepted strategies. Dimensions within this category are: mutual correction of error and critical evaluation (that is, feedback internal to the team); mutual compensatory performance, especially in emergency situations such as equipment failure or temporary overload of some members; and mutual compensatory timing by which team members adjust their work pace so that the team's overall mission is accomplished smoothly.

Motivation. Team motivational functions are the way teams define objectives and energize members toward those objectives (task orientation). The dimensions in this category are: development of team norms and generation of acceptance of these norms; establishing performance rewards; reinforcement of task orientation; balancing team orientation with individual competitive orientations; and resolution of informational, procedural, and other interpersonal conflicts within the team.

The dual strengths of Nieva et al.'s team process taxonomy are comprehensive coverage and performance orientation. The categories and dimensions cover the important ones cited in reviews of the application of group process research to military team training (e.g., Collins, 1977). The processes are stated as observable behaviors in most cases, so they are amenable to operational definition and measurement. Many already have served as variables in prior research, enabling future scientists to sharpen their definition and measurement.

Communication

Communication is an important component of the interactive structural processes. A large amount of research has been conducted on communication, particularly communication networks. Unfortunately, variables are too abstract to generalize to military or other actual work situations (Meister, 1976), and the dependent measures are focused on interactive processes themselves rather than system output. Burgess (1968) summarized his criticism of communication network system research by stating that after nearly two decades of research, inconsistencies are embarrassingly prominent.

Relative centrality (Bavelas, 1950) of team position constitutes one product of the communication network research that pertains to military team performance. Team members who hold relatively central positions make more decisions, send more messages, solve more problems, and demonstrate more leadership behavior (Davis, 1969). Relatively central members, whether by virtue of being assigned leaders or by emerging as informal leaders, are key in the team. The effect on team output is expected to be greater when these key members are lost than when other, non-central, members are lost.

The most consistently demonstrated effect of communication on team performance has been that the extent of communication is inversely related to team performance (Johnston and Briggs, 1968; Meister, 1976; O'Brien and Owens, 1972; Steiner, 1972). Team communications, especially communications not required by the task, have a negative effect on team performance, and should be minimized (Meister, 1976). Communications are an example of team processes that can degrade team performance. Process degradation of performance is demonstrated by Roby and Lanzetta's research concerning team structure.

Roby and Lanzetta conducted a series of studies (e.g., Roby and Lanzetta, 1957) in which they defined team structure as the interrelation and specialization of assignments in the team. They investigated the concepts of load-balancing (total work of the team distributed evenly among members) and autonomy (member who needs information is the primary source of the information). They modeled teams after bomber crews and assigned simulated aircraft flying tasks. Both load balancing and autonomy had significant effects on team performance. When the load was balanced and when members did not need to obtain information from other members, the teams performed more effectively. Moreover, the less members had to communicate, the better they performed. Thus, in a research setting that simulated military teams (and is more similar to real world settings than most communication research), Roby and Lanzetta confirmed the hypothesis that communication often degrades team performance.

Hackman and Morris (1975) note that the challenge is to identify, measure, and correct the aspects of team processes that inhibit output. The following section addresses this challenge with regard to the problem of maintaining team performance.

CHAPTER VI MAINTAINING TEAM PERFORMANCE

The preceding chapters described input and process variables in the systems model. The three major blocks of input variables are organizational and environmental, individual, and team-specific. As shown in mathematical form by the Lorge-Solomon and Steiner formulas, variables that influence task-related performance output are the ability and the number of the individual team members. The applicability of different formulas for different team tasks illustrates the importance of the task in determining team output. Potential productivity estimated by these formulas increases as the proportion of skilled individuals increases in the population, and, depending on the type of task, potential productivity may increase with larger numbers of members.

Process variables are team interactions (communication, orientation, organization, and motivation) mediating the effects of input variables on productivity. Task-related productivity is one component of the team's performance output, and is the topic of the bulk of the present chapter (Figure 6-1). Other output includes changes in individual attitudes, team communications, and other team interactive processes. Since the latter variables are tangential, rather than central, however, to the problem of task-related performance, they are dealt with briefly as they influence team training.

Actual Team Productivity

A considerable amount of team and group productivity research indicates that the quality and quantity of team productivity exceeds that of individuals. However, when individual products per individual or per individual unit time are considered, the team advantage is less evident. Furthermore, the superiority of teams over individuals occurs primarily in very small teams (Davis, 1969; Davis and Restle, 1963; Johnston and Briggs, 1968; Meister, 1976; O'Brien and Owens, 1972; Steiner, 1966, 1972; Taylor and Faust, 1952; Waag and Halcomb, 1972).

The Lorge-Solomon and Steiner formulas predict that larger numbers of members increase the team's pool of resources and thus the team's potential productivity. Forgetting, other loss of skill, or loss of a member are predicted to have less impact on a large team than a small one. In actual circumstances, team productivity is determined by the task, which interacts with the abilities and numbers of members, and by the team structure.

The theoretical effects of team size, expressed in the formulas predicting team productivity by pooling individual productivity, refer to potential. Potential team productivity is the highest amount the team can produce using all resources advantageously. Pooling formulas do not account for factors such as communication, coordination, and other interactive team functions which require time and effort and divert resources from the team's task or goal. As a result, actual productivity is less than the amount predicted by pooling formulas.

Steiner (1966) applied the term "process loss" to the degradation of team performance produced by interactive process variables and expressed its relation to productivity as:

$$\text{Actual Productivity} = \text{Potential Productivity} - \text{Process Losses}$$

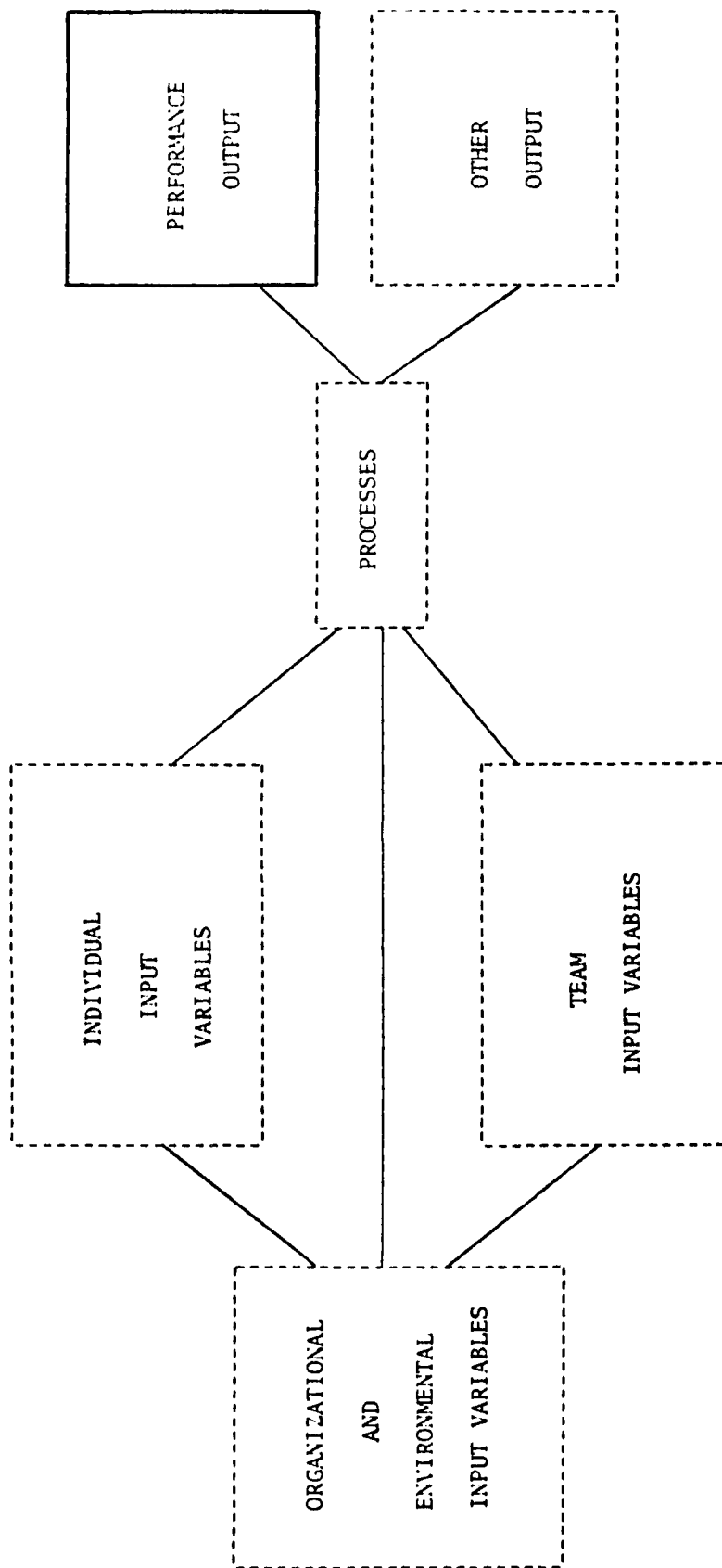


FIGURE 6-1. Performance Output in the Systems Model

While potential productivity is greater for larger teams than for smaller ones because there are more resources to employ, larger teams suffer loss of output because they have more members to coordinate, require more communication, and operate with more complicated procedures than smaller teams.

Coordination problems increase rapidly as team size increases. Steiner (1972) demonstrates empirically the increase in process losses for teams containing 2, 3, and 8 members and the relationship of process losses to the extent of coordination required. One coordination link is required between members of the dyad; three links are required for three members; and 28 links are required for eight members. The task required the team to pull on a rope, and the criterion measure was the strength of their pull in kilograms. The average force exerted for one individual was 63 kilograms and this value was used to compute the total possible force for each group by its product with the number of members. The results are presented in Table 6-1, showing the number of members, number of coordination links, potential and actual force exerted (productivity), and process losses. Process losses increased substantially, even for a team as small as three members.

The superiority of non-interactive, individual productivity over coordinated team activity has been demonstrated for many types of tasks. Meister (1976) reviews several cases demonstrating the advantage of increasing the number of individuals performing a monitoring task, when the individuals monitor independently. In each case, team member interaction or requirements for more than one member to respond correctly depressed the total system output (e.g., as in research by Waag and Halcomb, 1972, described in Chapter V, Team Processes). Taylor and Faust (1952) demonstrated the same type of effect for teams performing cognitive problem solving tasks. Groups of two or four members produced more problem solutions in terms of elapsed time to solution. Analyzing products in time per team member, indicated that teams produced less than the same number of individuals produced working alone. Cost-effectiveness, in personnel time per solution, was higher for independent work.

Table 6-1. Potential and Actual Productivity

Group size	Number of coordination links	Potential productivity	Actual productivity	Process losses	Relative process losses
1	-	63	63	-	-
2	1	126	118	8	.87
3	3	189	160	29	3.17
8	28	504	248	256	28.00

(From Steiner, 1972, p. 81)

In general, military teams are designed to be as small as possible to accomplish the assigned mission. For example, the four members in a tank crew each have a full complement of tasks to perform, and loss of a member or a member's failure to perform degrades the efforts of the crew. The Army is considering adding a fifth member to the tank crew, largely to act as a replacement when one of the regular members is missing or incapacitated. Thus, the intent is not to produce a five-member team but to ensure at least a four-member team for seldom will addition of team members be plausible as a solution for military team problems.

Process losses demonstrate a serious implication of skill loss. If team members are present in the team but not functioning adequately, they contribute to process losses without contributing to productivity making productivity particularly low. Such situations are more likely to occur during low proficiency periods in the training cycle.

Since process losses increase with size, actual productivity may best be increased by increasing member skill, decreasing coordination requirements, and training individual members on how to facilitate communication and other interactions. Thus, Burgess' (1968) demonstration of a steady state that emerges after teams have had experience working together and have overcome communication network impediments is especially germane. It seems reasonable that team productivity would be enhanced by enabling team members to practice together even if they cannot practice their entire mission so they can learn to communicate more efficiently. Interactive team simulators and war games are two vehicles for training of this type.

Team Task Effects on Performance

The Lorge-Solomon and Steiner formulas (expressing relationships between team productivity, team member productivity, and number of members) differ slightly in application to different types of tasks. The applicability of different formulas for different tasks indicates that the nature of the task also interacts with the variables that predict team performance. If the team performs purely additive tasks, such as in a laboratory setting, adding members increases output. In theory, each member performs his part of the task, and the team product is the sum of individual parts. Thus theoretically, team output increases linearly with the number of members. In reality, individual contributions must be coordinated by a team leader or supervisor and this coordination produces process losses. Obtained productivity, therefore, is less than the sum of individual products.

Increasing team size also theoretically increases potential productivity when the team performs disjunctive tasks. Since at least one member must perform correctly, here the probability of success actually does increase with the number of members. Conversely, if the team loses members or some members have forgotten skills, productivity decreases.

With conjunctive tasks, the Lorge-Solomon-Steiner formula predicts that increasing the number of members decreases the level of team productivity. This formula has been applied and tested in laboratory situations. Since adding a member in these studies implies adding links to the chain, the likelihood of error increases with each extra link. According to the formulas and research, loss of a member enhances team productivity because it reduces the number of links, thereby reducing potential error.

Real life military team situations do not, of course, operate the same way: loss of a team member does not simplify the task. On the contrary, loss of a member in a conjunctive task may break the chain, causing weapon system failure. For example, loss of the forward observer precludes initiation of the call for fire that sets off the indirect fire request sequence. Adding an assistant forward observer, who is actually a part of the forward observer party in the Army's new FIST implementation (so this is not hypothetical), does not degrade performance of the system but provides a backup, or redundant member to improve probability of success.

The assistant forward observer, therefore, is not an "extra link" in the sequence. Within the forward observer team, he provides additional skill. Thus, the forward observer party is additive (more accurately, hierarchical, since the forward observer outranks the assistant) even though the party as a unit is linked sequentially with the fire direction center and the firing battery. Likewise, within the fire direction center several artillerymen work additively. The number of men in the fire direction center does not add steps to the sequence, thus does not degrade system performance.

Examining team task types and individual task types with regard to predicted outcomes for team tasks and to individual skill decay expected for individual tasks, may shed some light on possible recommendations, however. Some individual tasks decay more rapidly than others: procedural tasks are lost in a matter of weeks, while continuous tracking tasks are remembered for months. If tasks are structured sequentially, or if the task is conjunctive (the chain is no stronger than its weakest link) then the effects of individual skill loss have a strong impact. Consider a two person chain in which one member has forgotten (or never knew) the procedure: the probability of team success becomes zero. Combinations of this sort constitute tasks that need more frequent training, since team members cannot compensate for each other.

In contrast, consider the example of the LAW gunners: if one gunner in the pair misses the tank, the other gunner shoots it. Although each individual task is disjunctive (and requires some procedures as well as some continuous tracking skill), the team task of hitting the tank is divisible, and the two team subtasks (one shot by each member) are additive. One member can compensate for the error of the other, thus substantially increasing the probability of team success.

Categorizing tasks by their anticipated effects on skill retention, including retention of team performance, is a valuable aid in developing recommendations for initial and refresher training. Table 6-2 shows examples described in this section.

Team Training

Major issues in team training are concerned with team instructional systems design, feedback, communication and other interactive variables, and criterion measurement.

Team Instructional Systems Design

Team task taxonomies are needed to determine the generalizability of the wealth of team performance studies and predict future effects of variables on

Table 6 - 2 Skill Retention Task Categories

Team Task Types	Individual Task Types			
	Motor		Cognitive	
	Procedural	Continuous Tracking	Rote Memory	Understanding
Disjunctive	REDEYE RRP	REDEYE MTS		
Conjunctive	Indirect Fire Sequence			
Compensatory				
Complimentary				
Additive	LAW Firing in Pairs			FO Party
Discretionary				

team performance. Present taxonomies are beneficial, but not sufficiently detailed. Given the strong impact of team tasks on other variables, taxonomies must account for technical task differences in order to be applicable to improve military team performance.

Definition and classification of team tasks constitute part of the first phase of an instructional systems development (ISD) model for team training. All of the five main phases of ISD, as shown in Table 6-3, have been applied to team training research. The ISD phases are: analyze objectives, design, develop, implement, and evaluate training (TRADOC Pamphlet 350-30, 1975).

Table 6-3. Team Training ISD Research

<u>ISD PHASE</u>	<u>TEAM TRAINING APPLICATION</u>
I Analyze Objectives	Collins, 1977 Eggemeier & Cream, 1978 Faust, 1976 Thurmond & Kribs, 1978
II Design	Thurmond & Kribs, 1978
III Develop	Eggemeier & Cream, 1978 Thurmond & Kribs, 1978
IV Implement	Thurmond & Kribs, 1978
V Evaluate	Collins, 1977 Thurmond & Kribs, 1978

Collins (1977) examined the first and last phases, i.e., the analysis of team tasks to determine training objectives and the evaluation of team training. Most of the researchers who have tried to formulate a team ISD have examined the team task analysis phase (Eggemeier and Cream, 1978; Faust, 1976; Thurmond and Kribs, 1978). Eggemeier and Cream analyzed training objectives, developed a team training device, and conducted an evaluation of this device. Only one study of team training (Thurmond and Kribs, 1978) systematically investigated all five of the ISD phases. Using the Army computerized artillery fire control system (TACFIRE) for embedding team training, they developed sample training materials based upon a team ISD model. The conceptual framework for the instructional strategies involved consideration of three major elements: (1) team task dimensions and team training objectives; (2) learner characteristics and strategies; and (3) characteristics of the training delivery system used to implement the strategies. Although they addressed the entire span of the ISD model in the application of a computerized system for the training of Army teams in indirect fire, they found several deficiencies that prevent the model they designed and implemented from being used as a step-by-step procedural guide. These deficiencies include: a methodology for preparing, analyzing and categorizing team learning objectives; evaluation designs which would address team member interactions as well as individual and team achievement; and the incorporation of applicable knowledge regarding small group behavior into team training development.

Procedures for the analysis of team tasks are not well specified. Although analysis of team tasks is a necessary first step to an ultimate team training ISD approach, no adequate methodology has been developed.

Eggemeier and Cream (1978) expanded the traditional individual task analysis technique for use with teams. In order to select tasks to incorporate into a flight simulator for crew training, they applied three criteria: criticality, difficulty, and frequency of task performance. Over one-half of 700 tasks they identified for the training involved interaction between hardware systems, between crew members or both. In order to handle the high degree of coordination required, they separated the total aircraft mission into logical sections. Specific tasks for each team member were listed in an analysis of each segment. They described interactions among team members when performing coordinated actions, and examined actions that emerged from the combination of single tasks. Some tasks that had initially been rated low in difficulty or criticality when performed by a single crew member (or described as the task of a single crew member) were more complex and critical when performed in the mission context. Eggemeier and Cream cite several examples of complex problems that arise from coordination requirements.

Thurmond and Kribs (1978) provide additional detail concerning steps in analyzing team tasks. Every act was broken down into three elements: input (stimuli), process (response), and output (stimuli that result from the process). Each act was then linked to other acts by either a man-man or man-machine-man interaction. This allowed a team task flow chart to be developed and summary tables to be devised for the task/subtasks of each processing mode of a fire mission. The table listed: (1) team member involvement; (2) type of team structure (serial vs parallel); (3) type of interface (man-man, man-machine-man); and (4) task (training) dimensions (roles, attitudes, communication). Finally, emergent situations were noted at each interactive point with possible contingencies specified.

None of these studies are clear or definitive in their application of ISD to teams. Attempting to fit team training, therefore, into the model of individual ISD may be ill advised. The benefit of such a model, however, is that it organizes team training development along dimensions not addressed by the team performance models, taxonomies and literature reviews. Use of the ISD model, or a similar one, reminds researchers to consider all aspects of the systems approach to training even though definitions and appearance of team tasks are very different from individual tasks.

Feedback

Learning proceeds more rapidly, attains a higher level, and is retained longer when the trainee receives feedback. In fact, learning may not occur without it. Fortunately, team training presents opportunities for feedback at a variety of levels. The first and most direct level is individual feedback, in which the trainee receives information concerning his responses just as he would in individual training. The other levels are called "confounded feedback" -- reflecting intermingled contributions from more than one individual. Confounded feedback includes consequences of the team's behavior, or at higher levels, the consequences of larger parts of the system. In field exercises, for example, an infantry rifle squad may receive feedback concerning individual riflemen, the fire teams, the squad as a whole, the platoon, or larger units.

In team situations, individual feedback speeds training and results in a higher level of performance (Meister, 1976; Rosenberg and Hall, 1958; Zajonc, 1962). Confounded feedback in which team members receive team-level information, however, produces compensatory behavior. That is, team members offset each other's mistakes and are effective in maintaining team output equal to that of the team receiving individual feedback (Rosenberg and Hall, 1958).

It is practical for team training to provide feedback at multiple levels. For example, the Army's engagement simulation systems, such as SCOPES (US Infantry School, 1975) and REALTRAIN (US Army Armor School et al., 1975) use individual numbering systems and objective casualty assessment systems to provide individual as well as unit feedback during tactical maneuver force training. Military training techniques, including type and level of feedback, are reviewed by Wagner, Hibbits, Rosenblatt, and Schulz (1977); their material is not repeated here.

Communication and Other Interactive Team Variables

Treatises on team training typically address the issue of whether individual training is superior to team training, the value of various "mixes" of individual and team training and the sequences for various amounts of individual and team training, as well as other comparisons (Collins, 1977; Nieva et al., 1978; Wagner et al., 1977). The mediating variable usually appears to be the extent of communication or other interactive requirements imposed on the team. Team training concerning communication and other interactive skills (the processes described in the taxonomy of team functions by Nieva et al.) is valuable when tasks require communication and coordination skills, when the work situation is emergent, and when task requirements are highly complex. In some cases, communication is inherent in the job itself, for example, the job of staff members in the tactical operations center (TOC). Company level TOC personnel communicate with platoon leaders and the company commander as a central objective of their mission. In other cases, interactive requirements stem from the need to perform in an emergent situation. Thus, an infantry squad in combat must repeatedly reassess the situation, make decisions, and communicate changes or updated information to squad members.

The last case to be considered is cited by Collins (1977), who further developed concepts initially noted by Briggs and Johnston (1967). These authors concluded that the relative value of individual and team training depends on the complexity of the work situation. Complexity in this instance refers to the array of stimulus inputs, control operations, and to the level of uncertainty in the task as a whole. They cite the operations of full-scale air traffic control and of air defense systems, in contrast to precisely controlled situations in laboratory experiments where the superiority of individual training over team training is demonstrated. Teams that have worked together for some time develop efficient operating structures, even if they use communication networks that typically are believed to be inefficient. Burgess (1968) demonstrated the "steady state" effect by requiring small groups to solve from 900 to 1100 problems. He criticized communication network research for not requiring a sufficient number of problems to demonstrate effects that would occur in teams that worked together. His research is optimistic given the fact that military teams have many assigned tasks to perform. Possibly, over time and repeated task performance, military teams, like Burgess' small groups, learn the flexibility to perform even if they do not have the ideal structure for the

task. This "steady state" phenomenon may account for Eaton and Neff's (1978) finding that tank crews are more effective if they have worked or trained together.

Hackman and Morris (1975) discussed changes that take place over time in interactive processes. These "Other Outcomes" (Figure 6-2) subsequently mediate the influence of input variables on future performance. Teams that work together repeat cycles of performance mediated by processes that in turn alter their interactive functions and individual members' characteristics. Interactive functions refer to those categorized in the taxonomy by Nieva, Fleishman, and Rieck (1978). Examples of individual characteristics are job satisfaction and other attitudes.

The research community has continued to emphasize interactive processes (Collins, 1977) but the results of empirical research and theory concerning the effects of these processes remain ambiguous (Hackman and Morris, 1975). The conclusion based on the present review of literature, similar to that of Collins, is that it would be profitable to stress performance/production-oriented research, including task oriented ISD for team training.

Criterion Measurement

Criterion measurement is the most frequently cited, and the most problematic, of all team performance and team training issues. Prior literature reviews have covered the topic thoroughly (Collins, 1977; Wagner et al., 1977).

Empirical laboratory attempts to pool individual skill in order to estimate team performance levels have not fared well. Studies that tested the Lorge-Solomon-Steiner formulas as predictors of team output were described in an earlier section. Few empirical investigations have directly investigated the problem of maintaining the reservoir of talent in the team. Two have, however, examined the pooling of individual recall on such abstract tasks as memorization of nonsense words.

Hoppe (1962) adapted the Lorge-Solomon model of team performance to apply it to recall by individual team members. Hoppe inserted the probability of individual recall in place of individual proficiency level (P_i), but otherwise the formula remains the same as derived by Lorge and Solomon.¹ Hoppe used the formula to predict mean recall for teams from the average rate of individual member recall of nonsense words. Team performance predicted from the pooling formula significantly overestimated actual performance. Hoppe's results substantiate, therefore, that the Lorge-Solomon-Steiner pooling formulas fail to account for recall performance as well as for team performance losses due to communication and other interactive team processes. Therefore, pooling does not provide a good criterion measure.

In another experiment on team recall, Zajonc and Smoke (1959) reasoned that since memory is imperfect in an individual, more than one team member should have some of the same information in order to maintain a reservoir of knowledge. Assignment of a larger amount of information to an individual, however, produces overload and performance declines. The researchers sought to define the amount that each team member needed to learn in order to produce correct total team recall. They assumed that the probability of recall is constant for all individuals and that is is constant for all items. They found

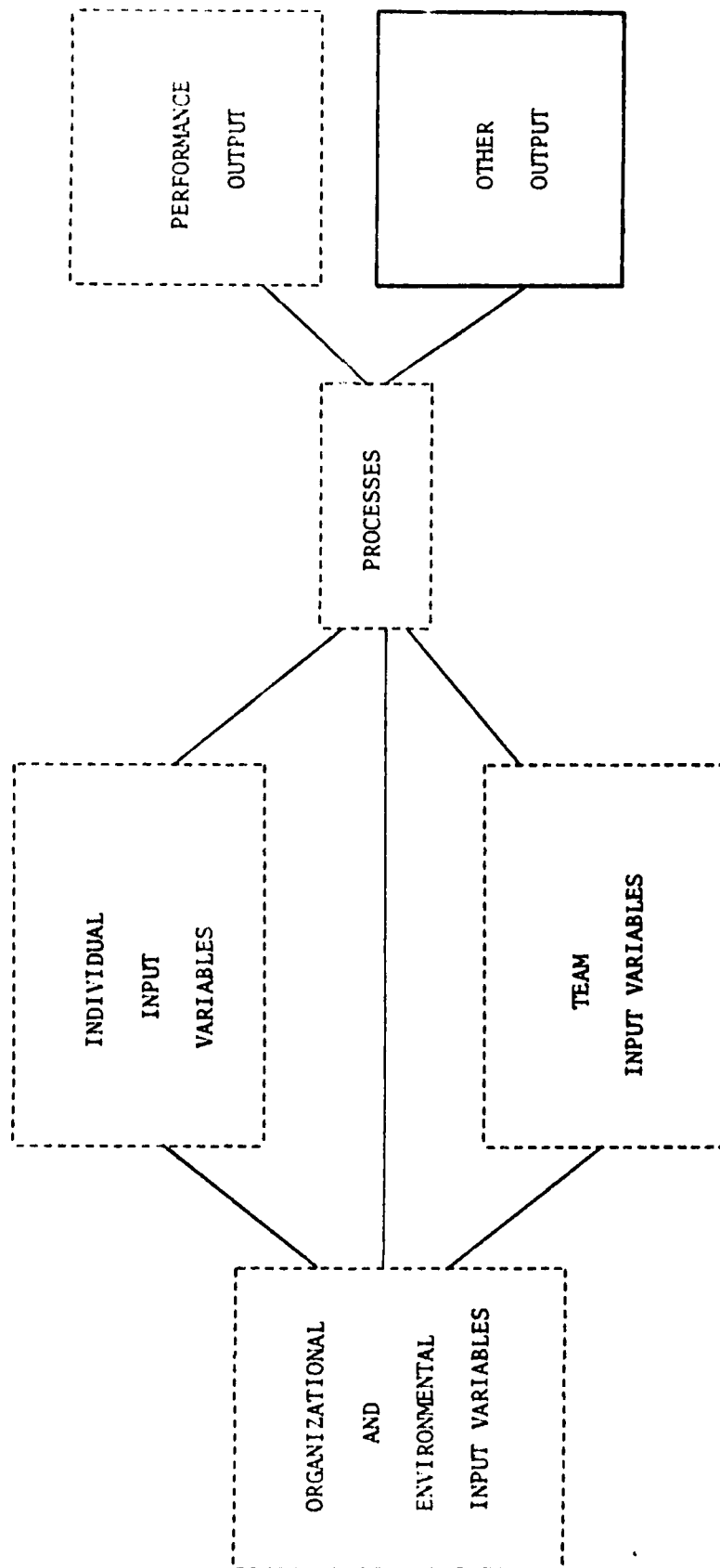


FIGURE 6-2 Other Output in the Systems Model

that the most efficient amount for each member to learn was the number of items that resulted in the member remembering 84% of them, i.e., that each member should learn 16% less than the amount designated as the criterion for the team. They claim that this amount is stable, regardless of the size of the team or the extent of the task. Results appear to be confounded by assumptions (constant probability over items and individuals), and have not been tested in real groups with real work situations. Therefore, this method also fails to produce a good criterion measurement.

The review by Wagner et al. described progress toward criterion measurement of military team and unit performance, but concludes that a great deal of improvement is still needed. The most objective measures of outcomes for combat units are provided by engagement simulation techniques (SCOPES and REAL-TRAIN), and these techniques will be expanded by the use of laser technology in the Army's new Multiple Integrated Laser Engagement System (MILES). MILES will provide objective casualty assessment for battalion level combined arms task force training and performance evaluation. Engagement simulation provides measures of both individual performance (casualties) and unit or team performance (mission accomplishment) (Scott, Meliza, Hardy, Banks, and Word, 1979).

CHAPTER VII SUMMARY AND CONCLUSIONS

The purpose of this research was to examine factors that influence the maintenance of team performance. The concept of skill retention, when it applies to team rather than individual performance, is best thought of as the team's reservoir of talent. This reservoir includes the number of team members and their abilities. The team's resources and the team's tasks are designated by the organization in which the team operates -- in the case pertinent to the present report, the organization is the military system. Military teams train for or work in emergent combat situations; the nature of these situations imposes coordination requirements which have been demonstrated to depress team output.

Recent empirical and theoretical research on team performance and team training has compiled existing theory and data, organized variables into models of team behavior, and extended techniques gleaned from individual instructional technology to apply to teams. Performance models, including the systems model used to synthesize literature in the present project, show relationships among the large number of interactive variables pertaining to team performance. Mathematical formulas, such as those derived by Lorge, Sclomon, and Steiner, provide explicit statements of these relationships which can be tested. Although the formulas address only a few of the more important variables, they are a first step.

Some data have been collected in military jobs, as exemplified by the Army training effectiveness analyses. The REDEYE analysis is the most thorough empirical example at present, but other analyses are in progress. A goal of the present research is to provide guidance for collecting team performance data to augment individual skill data obtained in training effectiveness studies.

Attempts to apply instructional systems design (ISD) to team training help to organize knowledge relating to improvement of team performance, even if team ISD turns out to be very different from ISD for individual training.

Conclusions and recommendations from several sources cover material that pertains to individual skill retention and team performance in general. Conclusions based on the present report are restricted to those emphasizing retention of team skill, rather than issues of team performance or team training in general.

Points based on individual skill retention literature are:

1. Training to a high level of initial performance enhances skill retention. Minimal initial training (e.g., training until the first time the trainee can demonstrate the skill) is inadequate to sustain proficiency.
2. Skill on procedural tasks decays more rapidly than on continuous control tasks. Therefore, procedural tasks need more training, more frequently.

3. Since skill performance aids (e.g., technical manuals and other job aids) reduce reliance on memory, they enhance performance maintenance.
4. Skill retention decreases with time unless the individual practices or rehearses.

Hypotheses derived from team performance and team training literature are:

1. Task type and team size interact with team processes; for example:
 - (a) Adding redundant members enhances potential team productivity for additive, disjunctive, complementary, and compensatory tasks;
 - (b) Adding team members degrades potential team performance on conjunctive tasks if the addition increases the number of steps in the sequence.
2. Increasing team size degrades performance if it increases the communication and coordination requirements regardless of the type of task.
3. Decreasing requirements for interactive processes (e.g., communication) enhances team performance.
4. Task type and situation (emergent or established) interact with applicability of team training.
 - (a) Tasks performed in emergent situations benefit from team training.
 - (b) Tasks that are communication-oriented (e.g., tactical operations center staff tasks) benefit from team training.
5. In operational military units, mission-related experience maintains or improves skills, even if it does not provide ideal or high fidelity simulation training.
6. Lower team member ability reduces team productivity regardless of task type, team size, or other team performance variables.

In 1976, the Defense Science Board recommended several directions for team performance research. Substantive research topics recommended were: a taxonomy of teams; team process models; cost-effective team training; improved effectiveness of simulators through application of instructional technology; methodology to coordinate personnel, training, and hardware systems, and the interface between individual and team training. The present project combines information on team process models and the interface between individual and team skill retention. As a result, it appears important to categorize tasks according to effects on individual and team performance. Identifying tasks

that decay rapidly and are performed in team contexts preventing compensation or follow-up by other team members, is a valuable step in designing training programs. Improved methodology for team performance research, especially criterion measurement, is required for thorough investigation of team-related variables.

Some progress in the application of instructional technology -- largely the development of instructional systems design procedures adapted to team training -- is evident in the literature. Further progress in this area, however, depends upon developing taxonomies of teams and of team tasks.

In addition to procedural innovations, there are technological advances in hardware, including computers, which may be employed. Hardware innovations are rapidly being applied to individual training, so far, but few have been used in team contexts. Problems in applying technology to team training and performance has stemmed from lack of knowledge concerning teams, but it is now possible to identify useful hardware innovations. Given these considerations and the critical role of teams in the military, additional application of advanced technology deserves high priority.

Implications for Further Research

The literature and implications of the systems model indicate that future research should address:

1. Continued application of instructional systems design procedures and advanced hardware innovations to improvement of team performance.
2. Development of team task taxonomies based on skill retention and team configuration.

Team task taxonomies depend upon further refinement of taxonomies of the teams themselves, as recommended by the Defense Science Board (1976). Another recommendation by the Defense Science Board -- investigation of cost-effective team training -- remains to be addressed. Improved methodology for research on team performance, particularly criterion measurement, is also required.

ANNEX A
GLOSSARY

AFQT	Armed Forces Qualification Test
AIT	Advanced Individual Training
ARTEP	Army Training and Evaluation Program
ASVAB	Armed Services Vocational Aptitude Battery
BATS	Ballistic Aerial Target System
CONUS	Continental United States
DA	Department of the Army
FIST	(Indirect) Fire Support Teams
FM	Field Manuals
IR	Infrared
MOS	Military Occupational Specialty
MTS	Moving Target Simulator
OCONUS	Outside Continental United States
OF	Operator and Food
OSUT	One Station Unit Training
POI	Program of Instruction
RCMAT	Radio Controlled Miniature Aerial Target
RELS	REDEYE Launch Simulator
REDEYE	Air defense guided missile system that homes on infrared emissions produced by aircraft engines
RRP	Range Ring Profile
RRPT	Range Ring Profile Test
SM	Soldier's Manual
SQT	Skill Qualifications Test
TEA	Training Effectiveness Analysis

TEC	Training Extension Course
THT	Tracking Head Trainer
TOC	Tactical Operation Center
TOE	Tables of Organization and Equipment
TRADOC	(U.S. Army) Training and Doctrine Command
TRASANA	(U.S. Army) Training and Doctrine Command System Analysis Activity
TSEA	Training System Effectiveness Analysis
USAADS	United States Army Air Defense School
VACR	Visual Aircraft Recognition
WSTFA	Weapon System Training Effectiveness Analysis

ANNEX B
BIBLIOGRAPHY

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ANNEX C
LITERATURE ABSTRACTS

Literature Search

As part of the background research required for the study of individual skill retention and subsequently team performance and performance degradation, an extensive literature search and review was conducted. Among the bibliographic and abstracting information systems consulted were the Defense Documentation Center (DDC), National Technical Information Service (NTIS), Education Resource Information Center (ERIC), Psychological Abstracts, Scientific and Technical Aerospace Reports (STAR), and Sociological Abstracts. The facilities utilized were the Army Research Institute Library (Alexandria, Virginia), the Navy Department Library (Washington Navy Yard), the libraries of George Mason University (Fairfax, Virginia) and the Georgetown University (Washington, D. C.) as well as the Litton Mellonics Washington Scientific Support Office Library. Examples drawn from the findings of the search are included in the main body of this document.

Individual Retention Reviews

A number of excellent comprehensive reviews of the variables related to long-term individual skill retention were found. Prominent were Naylor and Briggs (1961), Gardlin and Sitterley (1972), Prophet (1976), Wheaton et al. (1976), Annett (1977), Johnson (1978), and Schendel et al. (1978). These reviews are described by their distinguishing characteristics of time span, perspective, setting, behavior, and focus in Table C-1. The earliest, Naylor and Briggs (1961), is generally acknowledged as the first major review of long-term skills retention relevant to military tasks. Subsequent reviews have relied on Naylor and Briggs as an adequate summary of the literature of the first 100 years of this century.

TABLE C-1 OVERVIEW OF SKILL RETENTION AND LOSS LITERATURE
REVIEWS BY AREAS OF EMPHASIS

Areas of Emphasis	Naylor & Briggs (1961)	Gardlin & Sitterley (1971)	Prophet (1976)	Wheaton et al. (1976)	Annett (1977)	Johnson (1978)	Schendel et al. (1978)
Time span	1960	Largely '60's	70's, 60's	50's, 60's, and '70's	1885-1976	1860-1977	Largely 1950-1977
Perspective	Cognitive to task	Perceptual-motor skills	Perceptual-motor skills task	Cognitive to task	Cognitive to task	Cognitive to task	Cognitive to task
Setting	Academic	Military	Military	Academic & military	Industrial, military, academic	Academic	Academic
Behavior	Mostly verbal	Simulation, Essential element, Verbal	Mostly psychomotor	Verbal & psychomotor	Perceptual motor	Verbal	Psychomotor
Focus, specialty	Military, U.S. Air Force	Simulators, long-term retention, space craft skills, NASA	Long-term flight skills or complex performance	Initial training, transfer, training device effectiveness	Skill loss, areas for further research	Retention/transfer on procedural task; cognitive style	Retention over lengthy no practice intervals

Strategies: State-of-the-Art (Wagner et al. 1977), Team Performance Research: A Review (Trussell et al. 1977), and Team Dimensions: Their Identity, Their Measurement and Their Relationships (Nieva et al. 1978).

The work of Wagner et al. was undertaken at HumRRO for the Defense Advanced Research Projects Agency (DARPA). Its purpose was to provide an information base DARPA could use as a foundation to facilitate decisions regarding future team training research program support. DARPA had identified this area as one possibly requiring future investigation. Team training research programs promised to develop better team training methods and technologies as well as provide new measurement techniques and procedures for team evaluation. The stated objectives of this review were:

1. Describe existing instructional strategies and evaluation techniques relevant to team training.
2. Identify state-of-the-art gaps in team training and evaluation and suggest new team training strategies and evaluation techniques which warrant further study.

Current military team training techniques and on-going research were also reviewed. Literature search was restricted to the 10 year period preceding the study.

The second review was conducted by Trussell et al. for the Advanced Systems Division, Air Force Human Resources Laboratory (AFHRL) Wright-Patterson Air Force Base. Performed by Systems Research Laboratories of Dayton, Ohio, the research was conducted in August-September 1977.

The stated purpose of this review was to search the literature to gain insight into available information about crew performance under task overload conditions. Literature was searched to develop a bibliography of research on team performance studies, further refined to include only those studies pertaining to interactions of small groups (consisting of five or less individuals), and to tasks which may overload mental or physical capacity. Studies which identified types and quantity of tasks which were interrupted when a series of priority

Naylor and Briggs (1961) note that published studies of skill retention had appeared at the rate of two per year from 1900 to 1960, but that many of those were only tangentially relevant to military tasks. The research prior to 1950 was concerned with verbal learning and memory, was usually conducted in academic laboratory settings, and served as the forerunner for both the more recent human information processing and task performance and psychomotor skill retention research relevant to military technical training. Most of the literature reviews depend heavily on the earlier, verbal learning research and focus on the individual knowledge or performance level. They are unanimous in concluding the effects of the variables on skill retention summarized in Table 3-2 (Page III-7 of the main report) which is repeated as Table C-2 for the convenience of the reader.

These variables include the level of original learning, retention interval, task variables, and recall variables. Synopses of the reviews of Prophet (1976); Wheaton et al. (1976); Annett (1977); Johnson (1978); and Schendel, Shields and Katz (1978) are found in Annexes C-1 through C-5.

Other research concentrated on one or, at most, a few of the skill retention affective variables. A sample of the large body of work reviewed for this literature search, is shown in Tables C-3 and C-4. Designed to be used together, Table C-4 lists the variables indexed by relevant documents. The documents are referenced by number. Table C-4 lists the relevant documents with their numbers and indexes them by retention variables referenced by the variables numbers from Table C-3.

Team Performance Variables

Three reviews of comprehensive literature searches of research in team performance have been recently published. They are Team Training and Evaluation

Table C-2 Individual Skill Retention Effects

<u>Variable</u>	<u>Hypothesized Effects</u>
<u>Original Learning</u>	1. The higher the original learning, the higher the retention. 2. The absolute loss in performance is not affected by amount of original learning; decay functions for different levels of original learning are parallel.
<u>Retention Interval</u>	1. Retention decreases with time. 2. Interference (habits, activities, both before or after original learning) decreases retention. 3. Practice or rehearsal increases retention.
<u>Task Variables</u>	1. Continuous control tasks show superior retention (months/years) to discrete procedural tasks (days/weeks). 2. Degree of task organization increases original learning.
<u>Recall Variables and Transfer</u>	1. Increased similarity between the transfer task and the original task increases retention. 2. Similarity of task trained to the job increases amount of original learning.

Table C-3

VARIABLES FOUND TO AFFECT SKILL RETENTION INDEXED BY RELEVANT DOCUMENTS

Variable	Relevant Documents (from Table C-4)
1. Individual/Demographic (age, sex, ability, etc.)	3,8,16,31
2. Training	
a. Level of original learning	5,9,10,24,31
b. Knowledge of results	4,5,10,11,16,22
c. Training device characteristics	6,16,32
d. Schedules of practice	1,12,13,19,20
3. Task	
a. Nature of response	1,7,9,14,20,23,25,26,27,28,31
b. Task difficulty/duration/ stimulus variability	17,29,31
c. Task type	8
d. Functional environment	24,30
e. Task structure/Organization	2,21
4. Retention Interval	
a. Length of time	15,18,21,25,31,33
b. Practice/rehearsal/refreshers	18,26,27,31,33
c. Interference	29

Table C-4

RELEVANT DOCUMENTS INDEXED BY VARIABLES FOUND TO AFFECT SKILL RETENTION

Document	Variables (from Table C-3)
1. Adams, J.A., and Hufford, L.E. (1962)	2d, 3a
2. Anderson, R.C. and Faust, G.W. (undated)	3e
3. Baldwin, R.D and Wright, A.D. (1961)	1
4. Buckout, R., Naylor, J.C., and Briggs, G.E. (1963)	2b
5. Caro, P.W., Isley, R.N., and Jolley, O.B. (1973)	2a,2b
6. Chapman, G.C. (1966)	2c
7. Catterman, T.E. and Wood, M.E. (1967)	3a
8. Fox, W.L., Taylor, J.E., and Caylor, J.S. (1969)	1,3c
9. Gardlin, G.R. and Sitterley, T.E. (1972)	2a,3a
10. Geiselhart, R. (1966)	2a,2b
11. Gerathewohl, S.J. (1969)	2b
12. Goldstein, D.A. (1974)	2d
13. Goldstein, D.A. and King, W.J. (1961)	2d
14. Grimsley, D.L. (1969)	3a
15. Hollister, W.M., LaPointe, A., Orman, C.M., and Tole, J.R. (1973)	4a
16. Johnson, S.L. (1978)	1,2b,2c
17. Katz, M.S. (1977)	3b
18. Leonard, R.L., Wheaton, G.R., and Cohen, F.D. (1976)	4a,4b
19. McGuigan, F.J. and MacCaslin, E.F. (1955)	2d
20. Mengelkock, R.F., Adams, J.A., and Gainer, C.A. (1971)	2b,3a

Table C-4 (continued)

RELEVANT DOCUMENTS INDEXED BY VARIABLES FOUND TO AFFECT SKILL RETENTION

Document	Variables (From Table C-3)
21. Naylor, J.C., Briggs, G.E., and Reed, W.G. (1968 and 1962)	3e,4a
22. Newell, K.M. (1977)	2b
23. Prophet, W.W. (1976)	3a
24. Shields, J.L., Joyce, R.R., and VonWert, J.R. (1978)	2a,3d
25. Sitterley, T.E. (1974)	3a,4b
26. Sitterley, T.E. and Berge, W.A. (1972)	3a,4b
27. Sitterley, T.E., Zaitzeff, L.P., and Berge, W.A. (1972)	3a,4b
28. Smith, J.F. and Matheny, W.G. (1976)	3a
29. Stelmach, G.E. and Kelso, J.A. (1975)	2b,4c
30. Valverde, H.H. (1968)	2d
31. Vineberg, R. (1975)	1,2a,3a,3b,4a,4b
32. Wheaton, G.R., Fingerman, P.W., Rose, A.M., and Leonard, R.L. (1976)	2c
33. Wright, R.H. (1973)	4a,4b

task were directed and where individual or group capabilities were surpassed were specifically reviewed. These reviewers consulted both military and civilian data sources to identify all potentially useful research efforts pertaining to team task performance. Over 20 data sources were used. From these data sources approximately 4600 items (articles, technical reports, abstracts, books or bibliographies) were reviewed for applicability to the topic of interest.

The third major search for work related to team performance was made by Nieva et al. in 1978 to answer basic questions about the nature of team performance and the factors affecting it. The stated objectives of this project were:

- o to identify team characteristics that are related to group performance;
- o to develop a taxonomy of team performance that can provide order and meaning to information already available and
- o to generate hypotheses relating team characteristics to team performance

Review was keyed on the areas of group performance and team training. Although the authors note that these areas have common concerns, they found that, for the most part, research in each area has proceeded independently of work in the other. This report presented (1) a close examination of the research literature examining the relationships between various team or group characteristics (e.g., size or cohesiveness) and team or group performance; (2) a summary of the major hypotheses relating group or team characteristics to its performance that appear to be supported by available literature; and, (3) a number of fundamental shortcomings in this body of literature, which are seen as blocking further understanding of the area.

Although the searches by Wagner et al., Trussel et al., and Nieva et al. were conducted almost concurrently, none cited the others' efforts. This can be explained since the work was not yet published and accessed by the major

military documentation services and because the Services' research and training activities are so wide-spread and varied. Wagner et al., working in the Washington area, used the major computerized abstract banks and emphasized Army and Navy/Marine Corps. team training effort.

Trussell et al. employed a greatly expanded search of computerized data bases (twice as many as Wagner) and contacted many more in-service data sources, primarily Air Force and Navy. These authors were the only ones to utilize the Scientific and Technical Aerospace Reports (STAR) published by NASA, also a primary sponsor of team training research.

Nieva et al. bring a unique view of team performance literature, drawing heavily on civilian sociological literature. This group was the only one to use Sociological Abstracts.

A comparison of the comprehensive array of data sources reviewed by these three groups is shown in Table C-5. Precis of the reviews are found in Annexes C-6 through C-8.

Table C-5

DATA SOURCES CITED IN RECENT LITERATURE REVIEWS OF TEAM PERFORMANCE

Data Sources	Reviews		
	Wagner, et al.	Trussell, et al.	Nieva, et al.
BIBLIOGRAPHIC/ABSTRACTING INFORMATION SYSTEMS			
Armed Services Technical Information Agency (ASTIA)		X	
Defense Documentation Center (DDC)	X	X	
National Technical Information Service (NTIS)	X	X	
Education Resource Information Center (ERIC)	X	X	
Psychological Abstracts/Psychological Abstracts Research Service (PASAR)	X	X	X
Scientific and Technical Aerospace Reports (STAR)		X	
Readers Guide to Periodical Literature		X	
U.S. Government Research and Development Reports		X	
Sociological Abstracts			X
AGENCIES			
Advisory Group for Aerospace Research and Development		X	
Air Force Human Resources Laboratory		X	
Air Force Office of Scientific Research		X	
Air Force Medical Research Laboratories		X	
Navy Medical Research Laboratories		X	
Naval Training Device Center		X	
Office of Naval Research		X	
Smithsonian Institution		X	
U.S. Army Human Engineering Laboratory		X	
U.S. Army Transportation Research Command		X	
HumERO Library	X	X	
ARRO Library			X
ARI Library	X		X

Table C-5 (continued)

DATA SOURCES CITED IN RECENT LITERATURE REVIEWS OF TEAM PERFORMANCE

Data Sources	Reviews		
	Wagner, et al.	Trussell, et al.	Nieva, et al.
PREVIOUSLY COMPILED BIBLIOGRAPHIES			
Hare, 1972			X
Terauds et al., 1960			X
PROFESSIONAL JOURNALS			
Human Factors Journal		X	
Journal of Applied Psychology	X	X	X ^{1/}
Journal of Personality and Social Psychology		X	X
Personnel Psychology		X	
Sociometry		X	X
Administrative Science Quarterly			X
Training in Business and Industry	X		X
Human Relations	X		X

^{1/} Searched by means of computerized procedures using PASAR and Sociological Abstracts.

ANNEX C-1

SYNOPSIS OF REVIEW

Prophet, Wallace W. Long-term retention of flying skills: a review of the literature (HumRRO Final Report 76-35). Alexandria, Virginia: Human Resources Research Organization, October 1976.

Wallace W. Prophet published in 1976 the results of a major survey of the state of behavioral science knowledge as related to long-term retention of flying skills. The work was undertaken for the Office of the Assistant Chief of Staff, Studies and Analysis, HQ, US Air Force in support of SABER WINGS II (studies of pilot proficiency and management of the rated force). He has published his findings in two volumes.

The first volume is in the form of an annotated bibliography of relevant studies. One hundred and twenty studies are reviewed and an additional 80 are listed as reviewed but not found pertinent to the needs of the SABER WINGS II project. Prophet categorized the literature as (1) flight skill retention studies, (2) non-flight skill retention studies, (3) miscellaneous aviation studies and (4) literature reviews and references. The two hundred documents reviewed were chosen from over 1,400 items provided by DDC, the results of a wide range computer search dealing with flying skill acquisition, forgetting and retention. General learning and forgetting academic literature was not covered systematically.

The second volume presents the results of the literature survey in an interpretive commentary that relates the literature to areas of concern to the Air Force. Prophet discusses three categories of variables: (1) general retention factors, (2) task or skill factors, and (3) retraining factors. A brief description of the factors follows.

1. General Retention Factors

Level of Learning. In the area of general retention factors Prophet finds overwhelming and consistent support for level of learning or skill prior to the non-practice period as the single most important factor in determining absolute level of performance after periods of non-practice. Marked inter-individual differences in performance, however, appear related to differences in retention, although this decreases at the higher or autonomous phase of skill retention in such complex skills as flying

In contract, the literature suggests that the amount of decrement, is largely independent of level of initial skill or training and is much more a function of length of the no-practice interval and other factors. A natural consequence of this relationship is that the relative amount retained (i.e., post-retention level of performance relative to pre-retention level) will be related to level of original learning.

Length of Retention Interval. The majority of the laboratory studies examined by Prophet (1958-1976) and the reports of the airlines all suggest that basic perceptual-motor skills exhibit devrement as a result of non-practice but are retained fairly well for extended periods, and such loss as does occur is fairly easily reinstated through retraining. This factor is found to interact with many other factors -- e.g., type of task, personal characteristics, habit, interference, etc. -- in highly specific ways.

Habit, Interference and Transfer. The relationships that exist among level of training, time, and retention are complicated in specific instances by a variety of factors. One important group of such factors is that relating to the events and activities that take place during the retention interval.

Prophet finds evidence to support forgetting or performance decrement resulting from habit or activity interference rather than the passage of time, per se. Most such interference would result from activities during the retention interval.

Rehearsal Effects. A variety of researchers are found to have examined rehearsal effects and distribution of practice as means of minimizing decrement. Their results have generally shown rehearsal to be beneficial, even when involving fairly simple representations of task elements.

2. Task/Skill Factors

Control and Procedural Tasks. Prophet finds that the literature suggests there is no fundamental difference between continuous control tasks and procedural tasks as far as learning and retention are concerned, if task organization is taken into account. Despite this, in practice investigators report that procedural tasks exhibit more rapid and greater relative decrement than do continuous control tasks.

In contrast, the literature on continuous control tasks indicates that retention is generally high, even for extended time periods. Such tasks typically have a high degree of internal organization and provide continuous, immediate, and clear-cut feedback or indications of response correctness to the performer.

Instrument and Contact Tasks. Several investigators found a differential in decrement functions for instrument flight tasks and contact flight tasks. Instrument control skill with its heavy procedural task loading experienced higher degradation than contact tasks.

Information Processing Tasks and Other Task Factors. Prophet was unable to find literature dealing with retention of information processing skill although he feels that one legitimate description of the pilot's task is that it is principally an information processing task.

Retention of specific subordinate skills (weapon employment, communications) and performance under stress may also affect overall skill retention although investigative work was not located.

3. Retraining Factors

Prophet also examines retraining factors. While not presently germane to this investigation of skill decay, he finds them related to retention factors. Principal factors he discusses are (1) use of devices, (2) nature of training, (3) individual characteristics (e.g., age, experience).

ANNEX C-2

SYNOPSIS OF REVIEW

Wheaton, G.R., Rose, A.M., Fingerman, P.W., Korotkin, A.L., Holding, D.H., and Mirabella, A. Evaluation of the effectiveness of training devices: literature review and preliminary models (Research Memorandum 76-6) Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences, April 1976.

As part of a study conducted in 1975-76 to develop and validate a predictive model for evaluating the effectiveness of training devices, George R. Wheaton and his associates conducted a review of nearly 2000 documents. The emphasis of their study was the development of a predictive model. The detailed descriptions of related model development, a major emphasis in their literature search, are pertinent to the predictive skill decay model design.

Ten previous models and methods that attempt to prescribe or predict effective training are discussed. Wheaton concludes that no existing model is entirely adequate for predicting the effectiveness of training devices: Most analyze and prescribe training needs. Wheaton finds that the models and methods follow one of three general approaches based on the depth of the task analyses undertaken to provide model input data. A brief description of the approaches follows.

Prescriptive task - analytic approach

The prescriptive task analytic approach relies initially on a systems analysis to supply task descriptions. These tasks, arranged in categories or sets and examined, will provide specific knowledge about them and the skills required to perform them. This information in turn will permit derivation of training requirements and indicate the best available method for training individuals to perform the tasks. The emphasis in systems based on this approach is on initial skill acquisition (Haggard, 1963).

Micro - Analytic Approach

The micro-analytic models (two types) substitute a micro-analysis of stimuli and responses for the more traditional task analysis. The first or predictive type model analyzes stimuli and responses in both the operational task and the training task, compares them, and predicts transfer as a function of similarity (Caro, 1970). The second, or prescriptive type, analyzes stimuli and responses in the operational task. Then a training task is created to be as similar as possible, with the possible addition of techniques to facilitate training (e.g., augmented feedback). (Smode, 1972).

1. Most of the models were prescriptive rather than predictive, and were developed for specifying the design of training. Thus, they tended to focus on an analysis of the content of training but fell down in the specification of precise methods for implementing training.
2. Virtually all of the models had a scope limited to acquisition. None of the systems adequately considered both acquisition and transfer aspects of training device effectiveness.
3. There is a tendency to utilize a single level of description for input to the model (whether at the molar or molecular level). This limits the flexibility of the basic data to be processed and thus the output.
4. The definitions and procedures for data acquisition and processing tend to be complex, cumbersome and in many cases ambiguous.
5. A tendency exists to ignore the multidimensional nature of the problem and to oversimplify the approach by limiting the consideration to one or two dimensions (e.g., similarity, fidelity, etc.) thought to impact on transfer.

6. None of the methods is sufficiently concerned with the problem of quantification; thus, none supplies acceptable and workable metrics for the crucial variables they consider. This limits the form and usefulness of the outputs they provide.

7. Insufficient empirical support exists for both the underlying rationale and the procedures of the models.

The authors therefore identify as inclusions for an adequate, multi-dimensional, multi-level model (for their particular investigation) the following:

1. Task analysis, at a gross behavioral level as well as a more molecular level.
2. Acquisition analysis. This would include an examination of the trainee's capabilities (skill or response repertory), and a comparison to the skills needed in the operational task. Additionally, difficult tasks and the amount or stage of training necessary to achieve the desired transfer should be considered.
3. Principles of learning and training techniques should be considered as they impact on acquisition of each kind of task. Additionally, principles of transfer and techniques of training should be considered in terms of the impact on transfer of various manipulations of acquisition and transfer conditions. These analyses would also be conducted task by task, so that possible interactions or lacks of generalizability may be detected.
4. Finally, the obtained information needs to be collated to predict training device effectiveness in terms of transfer of training. The synthesis should determine the particular dimensions of the model that are or are not important on the basis of their interactions with other aspects of the model.

Wheaton's next section discusses theoretical positions and issues - the similarity theories and the mediation theories of transfer and the theoretical issues in modeling. Substantive variables that impact on training are identified as well as the relevant source documents. Categorized into three general classes these variables are:

- (1) Training variables
 - a. amount of practice
 - b. knowledge of results
 - c. previous specific experience of trainees
 - d. trainee characteristics
 - e. training requirements
 - f. part - whole training
 - g. augmented feedback
 - h. adaptive training
 - i. stimulus predifferentiation
- (2) Device variables
 - a. fidelity (environmental, stimulus, response)
 - b. control parameters
 - c. device characteristics and utilization patterns
 - d. motion simulation
 - e. display control relationships
 - f. stimulus - response association
- (3) Specific task variables
 - a. task difficulty
 - b. task duration
 - c. task organization
 - d. stimulus variability
 - e. task analysis

Much of the discussion of theory is relevant to a study of retention since many of these variables are also those upon which retention depends.

It is possible that retention may be another measure of device effectiveness but this relation is not explored in Wheaton's study.

ANNEX C-3

SYNOPSIS OF REVIEW

Annett, John. Skill loss: a review of the literature and recommendations for research. Prepared for the Training Services Agency, London. Coventry, England: University of Warwick, September 1977

This review, conducted by John Annett of the Department of Psychology, University of Warwick for the Directorate of the Training Services Agency, was carried out to "find answers to some of the key questions relating to skill loss and to identify areas where further research are needed." This was deemed necessary because the rate at which skill is lost during extended no-practice periods and ability to refresh unpracticed skills by retraining are relevant to industry trainers.

Over 120 items were reviewed, beginning with Ebbinghaus, 1885 and continuing through the mid 1970's. On the premise that much of the current extensive work in memory is concentrated on verbal memory with little relevance to problems of industrial training in manual or mixed manual and intellectual skills, the review concentrated on the retention of perceptual - motor skills. Reporting principally on work in British and American journals, Annett found the majority of studies concerned artificial laboratory tasks tested using students and servicemen. He found, however, that the studies using workers in real task situations in general confirmed the laboratory findings. Annett identified a number of unsolved methodological problems that affect general conclusions on skill loss. The most serious are the lack of a method for comparing performance and retention on different task types and the lack of a generally agreed method of classifying real life and laboratory tasks.

Annett's principal findings were as follows:

1. Well-learned skills are generally well-retained over periods of a year or more without practice.
2. The generalization that motor skills are better retained than verbal knowledge cannot be supported due to methodological difficulties of comparing unlike tasks using different performance indices.
3. Procedures, e.g., emergency drills seem particularly sensitive to skill loss through disuse. More coherent or integrated tasks appear to be better retained. However, little is known about the characteristics of tasks which favor retention.
4. Different training methods have not been shown unequivocally to result in different degrees of retention. More research is needed on the effectiveness of new methods in promoting retention.
5. Activities in the lay-off period can either facilitate or interfere with retention but little is known about the effects of unemployment or unrelated employment on a skill retention.
6. A deteriorated skill is readily relearned in a fraction of original learning time. Skill may also be refreshed by rehearsal.
7. Retention is generally a function of the degree of original learning; the better the original learning, the better the retention. However, over-learning yields diminishing returns.
8. There are problems in exercise of skill after a long no-practice period. Recalling an unpracticed skill may be stressful and retention may be affected by stress. Some tasks seem to benefit from a 'rest'; others from a warm-up.
9. Task-specific and general individual ability probably affect retention but there is little evidence relating age to skill loss. Further work on the effects of ability and age on skill loss and retention are needed.

Of especial interest is that Annett holds that there is no generally valid curve of retention - no single function relating degree of retention to the duration of the retention interval. He contends retention curves are necessarily composite since the act of measuring retention provides an opportunity for rehearsal. A further hypothesis of Annett's is that the shape probably depends on the nature of the task and is strongly influenced by the measure of retention since different measures of retention do not correlate perfectly. He includes an Appendix containing ten different learning/retention curves found in the literature.

ANNEX C-4

SYNOPSIS OF REVIEW

Johnson, Steven L. Retention and transfer of training on a procedural task; interaction of training strategy and cognitive style. Prepared for Air Force Office of Scientific Research (NL), Bolling AFB, DC 20332. Buffalo, NY: Calspan Corp., 30 January 1978.

In 1977-78 Johnson conducted a study that investigated the effectiveness of three training strategies with respect to initial training, retention, and transfer of training with special emphasis on the interaction of training strategy and the trainees' cognitive style. Recent research supports the theory that different individuals utilize different means of encoding and storing information. Johnson was interested in the effect of these differences on initial training, retention and transfer of training. As part of his work he conducted a thorough literature search of 162 documents spanning 117 years (1860-1977). He reviews the relevant research and discusses it in three categories: (1) the relationship between cognitive styles and the effectiveness of different training strategies, (2) training device characteristics and training effectiveness, and (3) the capabilities of humans to learn and retain a skill and to transfer that skill from one task to another.

Recent work (Pask, 1976) indicates that student learning performance is influenced by the match or mis-match of his learning (cognitive) style and teaching strategy. Johnson finds that studies dealing with one type of cognitive style, mental imagery (including all sensory modalities) and its psychological correlates support a two-system approach to information processing. One of the systems processes spatial/abstract material; the other system processes verbal, analytical material. The physiological results also indicate that, to some extent, people can be categorized as imagers or non-imagers (usually referred to as verbalizers) on the basis of physiological indices.

Research in behavioral assessment of mental imagery is extensive and indicates that there are reliable individual differences among people with respect to their vividness of imagery. Johnson reports that Paivio and his co-workers (1969-1974) conducted a series of memory experiments that specifically investigated imagery encoding and verbal/symbolic encoding. Their research strongly supported the idea of a dual-coding memory mechanism, one being imagery (analog) based and the other being symbolic (propositional). They found that the two modes are additive in that showing both a picture and the corresponding word resulted in better recall than either one presented twice.

The key section of Johnson's literature survey in relation to the current study of skill decay is the section that investigates the role of mental imagery in learning and retention. This section addresses how the imagery differences can be utilized in the area of learning and retention.

A definition of imagery specifically applied to a learning and retention context is reported found in Bernstein and Gonzalez (1971a): "Imagery, as related to retention, denotes the use of visual mental representations of relatively concrete objects as mediators for storage" (p. 6). Johnson feels this definition, however, suffers from the constraint of including only visual imagery particularly when considering mental imagery in the context of continuous perceptual-motor or procedure following tasks. He finds that Sheehan (1967c) was one of the first investigators to study the properties of mental imagery that facilitated learning and retention. Sheehan concluded that the "organizational" aspect of imagery is the property that is relevant to retention. Further, a study by Morris and Stevens (1974) is noted that supports Sheehan's conclusion in that they found that imagery is only facilitative when

the images link (associate) items together. Johnson says the problems of interpretation of the data and possibilities for extraneous confounding of data in the areas of mental imagery and mental practice in learning and retention are severe, particularly when extrapolating from one type of task (e.g., verbal learning and retention) to another (e.g., perceptual-motor procedure following: learning and retention).

In reviewing research and extensive literature searches of the last 30 years, Johnson concludes, "In addition, although statistically significant experimental results lead to more secure conclusions, what the scientific community knows about retention is about the same as what the 'man on the street' knows: we can't remember what we didn't learn and we forget over time." Related to these two conclusions about retention, there is one interesting impression given by the literature. It has been found in many experiments and is discussed in many review papers that procedural tasks result in less retention than continuous motor tasks (Ammons, et al, 1958; Gardin and Sittenley, 1972; Naylor and Briggs, 1961; and Sitterley, Zaitzeff, and Berg, 1972). That is, complex continuous tracking skills are retained relatively well for a long duration (at least 24 months, Fleichman and Parker, 1962); however, procedural tasks are very poorly retained (Hufford and Adams, 1961; Mengelkoch, Adams, and Gainer, 1960, 1971). One method that has been found to be effective in reducing forgetting is to practice (rehearse) the task during the retention interval (Brown, Briggs, and Naylor, 1963; Macek, Vilter and Stabbs, 1965, and Naylor and Briggs, 1963)."

Johnson relates these findings to those of Paivo and his associates who found that the concreteness of an item affected its image-evoking value and is an important aspect of imagery in learning and retention. And finally, he reports the results of a study conducted by Smith, Barresi, and Gross (1971).

They found that, using imagery or repetitive instructions, visual imagery was effective in long term memory (referred to by Smith et al. as secondary memory) but not effective in short term memory (referred to as a primary memory). Therefore, depending on the time frame of a retention study, imagery effectiveness could be interpreted differently.

Much of the preceding discussed research done using conceptually oriented verbal material or abstract visual patterns. Johnson now turns to studies more relevant to his own investigation, characterized as set in the context of "perceptual-motor procedure following behavior." Early work by Perry (1939) is quoted to show the positive effect of mental practice. Johnson finds that a problem exists relating verbal and motor learning as well as the more serious problem in transferring from laboratory studies to "real world" situations. He summarizes this section by saying that there is some documented evidence that procedural tasks are forgotten within a relatively short time. It can also be concluded that forgetting is a function of time and the number of factors involved during training, during the retention interval, and at the time of recall.

The concluding section of his literature search focuses on one of the primary factors involved in the training phase, the equipment used to train procedural tasks. One facet of work on training devices is found relevant to this examination of skill retention factors. Johnson notes a series of HUMRRO studies that investigated the closed-loop vs open-loop aspect of training devices for procedural tasks and found (1) no differences in training time on ten panels of low to high fidelity simulation, and (2) no differences in transfer or retention over a limited total time span (tests at four weeks and at six weeks, two days.)

Johnson summarizes the research literature findings as follows:

1. Individuals do vary in their preferred modes of processing information and these modes can be referred to as cognitive styles.
2. The matching of individual cognitive style and training strategy is beneficial (for particular tasks).
3. There are both physiological and behavioral indications that individuals differ in their use of mental imagery and that it is a meaningful and potentially useful aspect of cognitive style.
4. Mental imagery can be reliably "measured" with the Betts QMI and the ratings on the QMI are related to other performances in a consistent manner.
5. Mental imagery plays a role in learning and retention and that it appears to be one means of encoding and/or storing information in memory.
6. Procedural tasks are becoming more predominant in the human operator's job, but the information base related to the human's capability to learn and remember procedures is limited.
7. Training devices for procedural tasks need not be of high fidelity indicating that the human can replace the cueing and feedback usually presented by devices with information stored in memory.

ANNEX C-5

SYNOPSIS OF REVIEW

Schendel, J.D., Shields, J.L., and Katz, M.S. Retention of motor skills: Review (Technical Paper 313). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences, September 1978.

This review is a summary of an extensive literature survey related to the variables known or suspected to affect the retention of learned motor behaviors over lengthy no-practice intervals. Emphasis was placed on research conducted by or for the military. The variables that may affect the retention of motor skills were categorized as task variables and procedural variables. The task variables that may underlie the long-term retention of motor skill include (1) duration of the no-practice period, or retention interval; (2) nature of the response required to accomplish a particular motor task; (3) degree to which the learner can organize or impose order upon the elements that define the task; (4) structure of the training environment; and (5) initial or "natural" ability of the learner in performance of a task without prior practice.

The procedural variables that may affect the long-term retention of motor skill include (1) degree of proficiency attained by the learner during initial training; (2) amount and kind of refresher training; (3) transfer of skills on one task to performance on another task; (4) presence of interfering activities; (5) distribution of practice during training; (6) use of part-task versus whole-task training methods; and (7) introduction of extra test trials prior to final testing.

Task Variables.

1. Retention Interval. The period of no practice between the acquisition and subsequent test of performance. The classical forgetting curve is believed to apply. The shape of curve depends on many other variables: amount of practice, length of time between training and retention means, nature of response to be retained and activities that interfere with acquisition or retention.

2. Nature of the Response. This may be discrete or continuous (neither are absolutes). Procedural tasks are usually a series of discrete motor responses. The main problem is usually selection of correct response ('what to do' not 'how to do it' - not always one but sometimes both). The data indicate procedural proficiency cannot be maintained without regular practice.

3. Organization. Tasks amenable to learner organization are learned at a faster rate than less structured tasks. Low-moderate ability trainees retrained at a higher level when learning is organized, whereas high initial ability trainees experienced no difference.

4. Training Environment

- (a) fidelity of training devices
- (b) compatibility of display - control relationship
- (c) specificity of task displays
- (d) augmented feedback

5. Individual Ability Levels. In acquisition of motor tasks, individuals having higher initial ability levels generally require less time to attain a specified criterion than individuals having lower initial ability.

6. Procedural Variables

- (1) Level of Original Learning - single most important determiner of motor memory
 - (a) knowledge of results
 - (b) response - produced feedback
 - (c) overtraining/mastery training
 - (d) physical/mental practice
- (2) Refresher Training < 50% original training time
 - (a) longer for longer retention intervals
 - (b) longer for more difficult tasks
 - (c) longer for procedural tasks than continuous tasks
 - (d) longer for more highly trained persons than less trained
 - (e) practice during interval equals better performance
 - (f) provides opportunities for new learning
 - (g) provides improved on the job safety and performance
 - (h) conditionally, a warmup activity promotes retention.

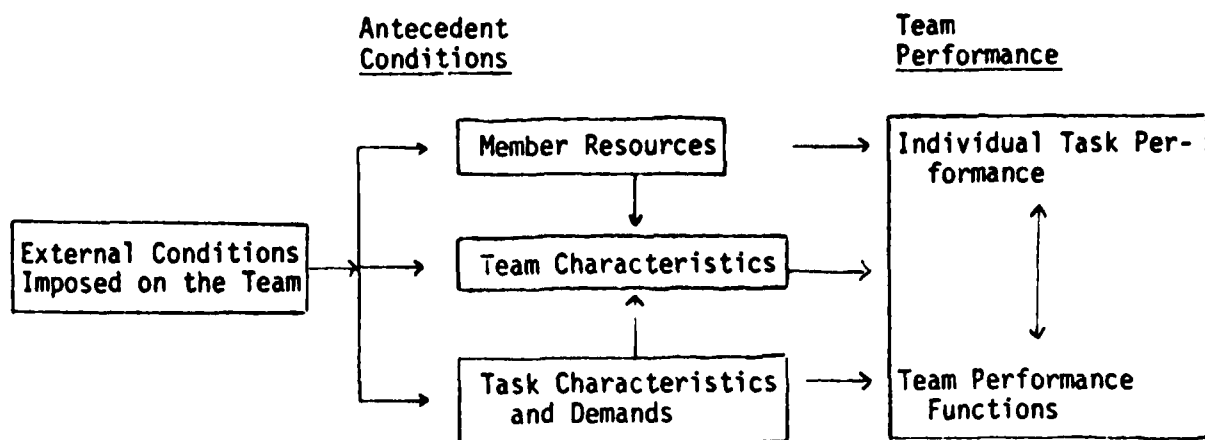
ANNEX C-6

SYNOPSIS OF REVIEW

Nieva, F.F., Fleishman, E.A. and Rieck, A. Team dimensions: their identity and their management and their relationships. Washington, D.C.: Advanced Research Resources Organization, 20 November 1978.

Nieva, Fleishman, and Rieck (1978) made two major contributions to team performance research: a model and a taxonomy. They worked from a simplified definition of team: "two or more interdependent individuals performing coordinated tasks toward the achievement of specific task goals" (page 51). They emphasized that their definition has two major components. Teams have, first, a task orientation shared by all team members and second, task interdependence among team members.

Their model of team performance synthesized a large number of variables that appear in team performance literature. The dependent variable, team performance, has two major factors. The first factor is the task performance by individuals. The second factor subsumes task related processes, functions, and behaviors at the team level. In their model, team performance is a function of four classes of variables. First are the external conditions imposed on the team. These include a variety of environmental factors, the external system in which the team works, and the embeddedness of teams (such as military teams) within the organization where they function. The second class of variables consists of the member resources such as individual abilities and personality variables. Individual proficiency is cited as one of the most important influences on team performance. A third class of variables covers team characteristics such as cohesiveness, authority structure, communication and size. The fourth class of variables are task characteristics and demands (for example, disjunctive and conjunctive tasks).



Nieva et al's Conceptual Model of Team Performance
(1978, p 52)

The following hypotheses are drawn from Nieva et al's model:

1. Team performance consists of individual task behaviors and team performance functions.
2. Team member resources are determined, in large part, by external conditions imposed on the team.
3. Member resources directly affect individual task performances.
4. Team characteristics are determined by team member resources, by task characteristics and demands, and by externally imposed conditions.
5. Team characteristics affect both individual task behaviors and team-level functions.
6. Task characteristics are usually determined by externally imposed conditions.
7. Task characteristics affect individual task behaviors as well as team performance functions.

The Nieva et al. team performance taxonomy (Table C-6) focuses on the interactive team dimensions "that enable the team to work together as a unit, over and above individual member performance of specific behaviors" (page 59). They have identified four major performance categories, and several performance dimensions within those categories. The categories are team functions of orientation, organization, adaptation, and motivation, as described in Section V of the main body of this report.

Table C-6
Provisional Taxonomy of Team Performance

- I. Team Orientation Functions**
 - A. Elicitation and distribution of information about team goals
 - B. Elicitation and distribution of information about team tasks
 - C. Elicitation and distribution of information about member resources and constraints
- II. Team Organizational Functions**
 - A. Matching member resources to task requirements
 - B. Response coordination and sequencing of activities
 - C. Activity pacing
 - D. Priority assignment among tasks
 - E. Load balancing of tasks by members
- III. Team Adaptation Functions**
 - A. Mutual critical evaluation and correction of error
 - B. Mutual compensatory performance
 - C. Mutual compensatory timing
- IV. Team Motivational Functions**
 - A. Development of team performance norms
 - B. Generating acceptance of team performance norms
 - C. Establishing team-level performance-rewards linkages
 - D. Reinforcement of task orientation
 - E. Balancing team orientation with individual competition
 - F. Resolution of performance-relevant conflicts

Nieva, Fleishman & Rieck (1978).

ANNEX C-7

SYNOPSIS OF REVIEW

Trussel, J. N., Watts, G. W., Potter, N. R., and Dieterly, D. L.
Team performance research: a review AFHRL-TR-77. Dayton, OH:
Systems Research Laboratories, Inc., November 1977.

Trussell et al. addressed the following stated problem: "The successful interaction of team members determines task accomplishment in a group effort. Several parameters affect satisfactory completion of the group task; however, it is the individual capability of the group members which is very critical. The interaction of team members becomes even more critical when the group members performing the tasks are functioning under stress or mental/physical task overload conditions" (1977, p.1).

Thus, the objective of their literature search was to identify previous small group and team performance research efforts that emphasizes task overload conditions.

Trussell et al. developed a bibliography of research on team performance studies including only those studies pertaining to small group interactions (consisting of five or less individuals) performing tasks which may overload mental or physical capacity. Studies identifying types and quantity of tasks which were interrupted when a series of priority tasks were directed and where individual or group capabilities were surpassed were specifically reviewed. Also, reports relative to air-crew performance were emphasized. Detailed abstracts of articles which appeared to be of special interest and of major significance to the search are attached as an appendix. Both military and civilian data sources were extensively reviewed to identify all potentially useful research efforts pertaining to team task performance. Over 20 data sources were used. From these data sources approximately 4600 items (articles, technical reports, abstracts, books or bibliographies) were reviewed for applicability to the topic of interest.

Team performance research studies were found to be not always directly and specifically relatable to task performance analyses. Rather, efforts have been directed toward the evaluation of task performance as it related simultaneously to various, specific human factor attributes such as: leadership, group cohesiveness, training, skills, motivation and fatigue. Each factor was not an isolated independent entity, but rather was investigated as an interacting concept along with other relevant factors. This literature review serves to emphasize this point. They found group cohesiveness cannot be considered independently of the leadership of the group, the overall motivation of the members, the type of task to be performed, and how much group interdependency is needed for task accomplishment. Fatigue levels similarly are highly confounded with motivation, emotional and environmental stress. The impact of the environment often depends more on the tolerance levels of the individuals than their physical condition, age or motivation to do the job. Trussell et al. identified hundreds of potential moderator variables operating to change the factors and their relationship to human task performance but no treatment of the quantitative nature of the interactions.

It was further found that there has been very little research concerned with the way in which group attributes (such as capabilities and level of training) impact group performance. Small group researchers ordinarily have selected input variables and related them to output variables involving performance, final satisfaction with the situation and ultimate interpersonal attraction among members. Little attempt has been made to study how various input variables produce their ultimate effect, in terms of intermediate processes and events.

The research team concluded their report as follows (Trussell et al., 1977, p. 10):

The material reviewed indicates a major emphasis in the area of team research. The increase in research has generated a considerable amount of information but it does not lend itself to a single systematic analysis of what is known and what is needed. Essentially then to proceed it is

necessary to attempt to formulate some program of research which will systematically pull together the pieces of evidence available and introduce the cement to anchor them in place, prior to attempting to establish a theory or set of principles about team performance. It is suggested that five areas are important in exploring team research: (1) individual capabilities, (2) team function design, (3) decision process, (4) communication, and (5) control. If these are considered along with a more comprehensive definition of task overload, a more productive research product will be obtained. From this baseline we must move upward in our understanding of team performance.

ANNEX C-8

SYNOPSIS OF REVIEW

Wagner, H., Hibbits, N., Rosenblatt, R. D., and Schulz, R. Team training and evaluation strategies: state-of-the-art (Technical Report 77-1). Alexandria, VA: Human Resources Research Organization, February 1977.

This report contains a review of the literature relevant to team training. Wagner et al. surveyed and described current instructional and evaluative techniques within the Military. State-of-the-art gaps were identified and research needs documented as an aid toward planning improved research programs in team training and evaluation.

This review of team training and evaluation was undertaken by HumRRO to provide an information base that the Defense Advanced Research Projects Agency could use as a foundation to facilitate decisions regarding future research program support. The reviewer found the Services conduct most of their training in the operational commands. In the past, most training research has been focused on individual training at schools and at other institutional locations. Considering the amount of team training conducted by the Services, either formally recognized as training or combined with operations, the funds committed to R&D support of such training are relatively small.

The stated purpose of this literature review was to provide information that would be useful for planning research and development programs in the area of team training. Such programs are needed to develop improved team training methods and technologies, as well as to provide new measurement techniques and procedures for evaluation. The specific objectives in preparing this review were to address the following questions:

1. What state-of-the-art gaps are there in team training strategies and evaluation techniques?
2. What new team training strategies appear to hold promise for application to the DoD environment?
3. What new evaluation techniques can be used to assess team training?

Team training research was discussed under the following categories:

1. Two Conceptual Approaches to Team Training Research
2. Established vs. Emergent Situations
3. Individual vs. Team Training
4. Team Skills
5. Simulation Fidelity
6. Feedback/Knowledge of Results
7. Team Structure and Composition
8. Systems Approach to Team Training

Techniques for evaluating team training were also evaluated and current approaches to military team training were described. These methods include:

1. Army Team Training
 - a. SCOPES (Squad Combat Operations Exercise, Simulation)
 - b. REALTRAIN
 - c. MILES (multiple Integrated Laser Engagement System)
 - d. CATTS (Combined Arms Tactical Training Simulator)
2. Navy Team Training
 - a. Device 2F87, Weapons Systems Trainer
 - b. Device 14A2, Surface Ship ASW Early Attack Weapons System Trainer
 - c. Device 14A6, ASW Coordinated Tactics Trainer

- d. Device 21A37/4, Submarine Fleet Ballistic Missile (FBM) Training Facility
- e. Tactical Advanced Combat Direction and Electronic Warfare System (TACDEW)
- 3. Marine Team Training
 - a. TESE (Tactical Exercise Simulator and Evaluator)
 - b. TWAES (Tactical Warfare Analysis and Evaluation System)
- 4. Air Force Team Training
 - a. B-52 Weapons System Trainer
 - b. C-5 Mission Flight Simulator
 - c. C-130 Flight Simulator and C-141 Flight Simulator
 - d. Functional Integrated Systems Trainer (FIST)

Wagner et al. identified five areas that warranted substantial future research support. These were team feedback (knowledge of results), assessment training, simulation fidelity, team composition/structure, and skill training sequencing. They suggest that combined studies dealing with more than one of these issues are feasible.

ANNEX C

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