A DEGRADATION ANALYSIS METHODOLOGY FOR MAINTENANCE TASKS

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FINAL REPORT
12 May 1985

A Thesis Submitted to the Faculty of the Division of Graduate Studies
Georgia Institute of Technology
Atlanta, Georgia
in Partial Fulfillment of the Requirements for the Degree
Master of Science in Industrial and Systems Engineering

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO. AD A155073
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) A DEGRADATION ANALYSIS METHODOLOGY FOR MAINTENANCE TASKS	5. TYPE OF REPORT & PERIOD COVERED FINAL REPORT May 1985
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) MAJOR David W. Harris	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Student, HQDA, MILPERCEN (DAPC-OPA-E) 200 Stoval Street Alexandria, Virginia 22332	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS HQDA, MILPERCEN, ATTN: DAPC-OPA-E 200 Stovall Street Alexandria, Virginia 22332	12. REPORT DATE May 1985
	13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report) UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; Distribution Unlimited

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

18. SUPPLEMENTARY NOTES

A Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Industrial and Systems Engineering

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

Protective Clothing, Human Performance, Chemical Warfare, Performance Degradation Degradation Models, Chemical Protection, Maintenance Operations, Task Taxonomy

Thesis

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

This ~~research effort~~ proposes a methodology for estimating the mechanical degradation of individual soldiers when wearing chemical protective clothing. With maintenance tasks as the investigative focal point, applicable areas of work measurement, human performance, maintenance management and degradation modeling were used to develop the Degradation Analysis Methodology for Maintenance (DAMM). Using a decision model and the appropriate Army technical manual, a taxonomy for maintenance task analysis divides individual repair jobs into

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) task elements according to their aim and the manual manipulation required. A procedurefor obtaining movement degradation values is developed and applied using field test data. The results are then incorporated into the Ballistic Research Laboratory degraded effectiveness algorithm.

Methodology evaluation is based on performance in predicting task-time degradation and its impact on unit effectiveness, as evaluated using the Army Unit Resiliency Analysis model. Applications of DAMM are recommended for the areas of tactical operations, training and chemical warfare modeling. In addition, proposed enhancements to DAMM are discussed.

Additional keywords: Chemical warfare; Army operations.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to Dr. Leslie G. Callahan Jr., chairman of my thesis committee, whose guidance was instrumental in the development and execution of this thesis. His enthusiastic support and help in focusing my work in the most fruitful directions were major factors in making this research effort a valuable learning experience.

I would also like to thank Dr. Thomas Sadosky and Dr. Russell Heikes for their suggestions and critique of this thesis. Their experience proved to be most valuable in its completion.

A very special word of thanks is extended to Dr. Charles Wick and Dr. Terry Klopcic of the U.S. Army Ballistic Research Laboratory, sponsors of this project. Without their strong support and encouragement, this investigative effort would have never been undertaken.

Most importantly, I want to recognize the contributions of my family. For two years, they have willingly sacrificed their time and personal desires to provide me with the best possible environment in which to achieve my academic goals. Because this thesis could not have been completed without this unwaivering support, it is lovingly dedicated to my wife, Judy, and children, Phillip and Michelle.

TABLE OF CONTENTS

TABLE OF CONTENTS Cont'd.

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES Cont'd.

SUMMARY

The modeling of performance degradation due to chemical protective clothing has become an area of increasing interest to military analysts but has been plagued by a lack of reliable data. This research effort proposes a methodology for estimating the mechanical degradation of individual soldiers when wearing this clothing. With maintenance tasks as the investigative focal point, applicable areas of work measurement, human performance, maintenance management and degradation modeling were used to develop the Degradation Analysis Methodology for Maintenance (DAMM).

Using a decision model and the appropriate Army technical manual, a taxonomy for maintenance task analysis divides individual repair jobs into task elements according to their aim and the manual manipulacion required. A procedure for obtaining movement degradation values was developed and applied using field test data. The results were then incorporated into the Ballistic Research Laboratory degraded effectiveness algorithm. DAMM constitutes an improvement over the subjective degradation estimates which predominate in current data bases and does not require costly field testing.

Methodology evaluation was based on performance in predicting task-time degradation and its impact on unit effectiveness, as evaluated using the Army Unit Resiliency Analysis model. Applications of DAMM are recommended for the areas of command guidance, Army maintenance doctrine and chemical warfare modeling. In addition, proposed enhancements to DAMM are discussed.

CHAPTER I

INTRODUCTION

Overview

One of the most difficult problems confronting the military operations analyst is the modeling of chemical warfare (CW). Except for the use of toxic chemical weapons during World War I, U.S. military forces have little experience to draw upon for such modeling efforts. While a chemical protective ensemble reduces an individual's vulnerability to chemical agents, it also tends to degrade the individual's performance and military operational capabilitiy. Widespread individual performance degradation causes a loss in overall unit combat effectiveness but the exact correlation between individual and unit degradation has not been established.

Although a wide variety of effects which contribute to this degradation have been identified, their impact has not been rigorously quantified and the evaluation of these effects has relied heavily on subjective data. The severe consequences of chemical weapons and the increasing threat of their use make a more systematic modeling of performance degradation a matter of continuing importance.

Military Aspects of Chemical Warfare

Chemical weapons are designed to achieve one or more of the military objectives listed in Figure 1-1. There are several types of chemical warfare agents, with widely differing properties. Some are

CREATE CASUALTIES	Very effective against poorly trained and equipped forces. The ability to penetrate defensive positions is a key advantage.
DEGRADE EFFECTIVENESS	The use of protective gear causes increased heat buildup, fatigue and loss of visual and tactile ability.
SLOW MANEUVER	Restrictions posed by protective clothing and need for special procedures to avoid moving into contaminated areas slows the pace of military operations.
RESTRICT TERRAIN	Liquid chemical agents are used to slow maneuver, channel attackers into kill zones and aid in the protection of flanks.
DISRUPT SUPPORT	Logistical centers are lucrative targets using liquid chemical agents. Decontamination of equipment and personnel is extremely time consuming and of limited effect.

Figure 1-1. Military Objectives of Chemical Weapons

quickly dissipated and lose their effectiveness in as short a time as a few minutes. Other, more persistent agents can last for a week or more depending on the atmospheric conditions. It is these persistent agents which require the full use of protective clothing.

Effectiveness of CW munitions is quite sensitive to the readiness of the unit under attack. Here, readiness includes the protective posture of the unit being attacked, the capabilities of their chemical defense equiment, and, of exceptionally great importance, their ability to effectively use this defensive equipment. Chemical warfare is rather special in that considerable protection and readiness to cope with the resulting environment can be achieved if one is willing to accept the performance degradation that will result from the use of protective clothing and equipment.

Individual and Unit Effectiveness

The chemical protective ensemble worn by U.S. Army and Air Force ground personnel, which includes a mask, impermeable gloves, overboots and a charcoal lined overgarment, is used to provide whole body protection against liquid chemical agents and some chemical agent vapors (see Appendix A). As mentioned previously, this protective clothing can degrade individual performance in several ways. The most common physiological and psychological factors associated with this degradation are described in Figure 1-2.

Unit effectiveness is degraded as a direct result of the restrictions imposed on individual soldiers. Degradation of unit effectiveness is most often manifested as an increase in time required to perform its assigned missions. Ultimately, a unit commander must weigh the tradeoff between the level of protection he wishes to assume against chemical attack and the loss of combat effectiveness due to the protective clothing itself.

Problem Areas

Degradation Modeling

Much of the renewed military interest in CW was stimulated by a report published in 1973 by the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME) [23]. Among other findings, this report called for the revision of military procedures in dealing with

HEAT STRESS	- Caused by the thermal build-up and is believed to have the most significant effect on performance - Has received the most emphasis in degradation studies
RESPIRATORY	- Inspiratory and expiratory resistance increased due to mask filters/valves - Major problem during periods of heavy exertion
MOBILITY	- Overgarment and overboots restrict full extension of limbs - Bulk of ensemble makes maneuver difficult in confined areas
DEXTERITY	- Gloves limit fine finger movements and cause significant loss in tactile sensation - Leather gloves are often worn over the rubber gloves to prevent damage, further degrading dexterity
VISUAL	- Mask causes loss of periferal and vertical vision and poor optical coupling with sighting devices - Reduced depth of field for far vision - Mask eyelenses subject to fogging/glare
AURAL/ORAL	- Voice muffled by mask and hood impedes sound reception - Some communication devices not compatible with hood/mask
PSYCHOLOGICAL	- Confining and isolating nature of ensemble can cause individuals to become disoriented and frustrated - Can degrade ability to concentrate

Figure 1-2. Degradation Factors

CW and supported the need for new chemical defense equipment. Much of the information needed to guide doctrinal revisions and equipment research comes from computer simulations of CW engagements. Unfortunately, most of the combat simulations which incorporate CW view it from the context of the field employment/behavior of chemical agents and the consequent chemical agent casualties [19]. Although several models include the assessment of heat casualties, personnel degradation caused by wearing protective clothing has not been extensively modeled.

Data Base

The representation of chemical degradation in CW models is highly dependent upon the degradation data available. However, there is little empirical data on the effects of protective clothing on individual and unit effectiveness, with the possible exception of heat stress. Although the nature of the effects anticipated can be specified and incorporated into a degradation model, many of the quantitative input parameters describing these effects must be considered assumptions. Given these limitations, it is not surprising to find indications that the amount of degradation associated with specific physiological factors or general task categories has been largely overestimated. A variety of recent studies [14,27,34,71] have reported significantly lower levels of task time degradation than currently being used in some models.

Within the last few years, a number of literature reviews have recognized that tasks need to be classified by their potential for degradation and recommended that further research should be aimed at those tasks most susceptible [19,60,79]. Unfortunately, the high cost of such research makes it unlikely that many of the data voids will be filled via experimentation in the near future.

Experimentation

Of those field experiments that have been conducted, the greatest availability of data exists for combat units, particularly for infantry maneuver missions [20]. However, the lucrative targets that support units present for the employment of persistent chemical agents has caused increasing interest in the degradation of logistical support. Maintenance requirements, with their high content of manual dexterity, have become a specific area of interest to both the U.S. Army and Air Force. Commanders have expressed a need to know more about the degradation they can expect in their ability to maintain combat equipment.

Military Implications of Problem

As discussed, the ability to accurately model performance degradation due to chemical protective measures has a direct bearing on the development of realistic combat doctrine, training and effective chemical defense equipment. At a lower level, it is essential that field commanders be able to make informed decisions concerning their combat missions and logistical support requirements when faced with a chemically contaminated battlefield.

Logistical functions such as organic and support maintenance are particularly sensitive to the assumption of a given chemical protective posture and may ultimately influence the decision to repair or abandon a contaminated item of equipment needing repair. Decisions such as these will have a major impact upon the logistical burden that battlefield units will face and must be based on an understanding of the performance degradation that can be expected for typical maintenance tasks. Based on the current state of CW modeling, it is questionable that effective training and doctrinal advice can be provided to commanders who have to make such decisions.

Research Objective

The primary objective of this research is to develop a methodology for classifying and quantifying the degradation of maintenance task performance associated with wearing chemical protective clothing. For the purpose of this investigative effort, only the mechanical degradation of task-time performance will be analyzed (e.g. the degradation of physical movement). Through a synthesis of existing literature, experimental data and personal experience with the subject area, the following intermediate objectives will be incorporated into this goal.

1. Develop a taxonomy for maintenance task analysis which captures the key elements of mechanical degradation due to protective clothing.
2. Using this taxonomy, estimate the individual degradation factors for each movement class and incorporate them into the Ballistic Research Laboratory degraded effectiveness algorithm.

3. Apply the revised degradation algorithm to the Army Unit Resiliency Analysis (AURA) model to test the sensitivity of unit effectiveness to the degradation factors developed.
4. Analyze and discuss future research efforts needed to improve degradation factor estimates.
5. Identify applications of the proposed methodology and discuss its possible expansion to other military tasks.

CHAPTER II

LITERATURE REVIEW

In order to provide the necessary foundation for a methodology describing and quantifying performance degradation, three major areas of emphasis were identified for investigation; maintenance management, work classification/measurement and human performance in protective clothing. In this chapter, each of these subject areas will be reviewed in the context of their applicability to the research objectives. This information will then be synthesized in later chapters in the development and evaluation of a proposed methodology for degradation analysis.

Maintenance Management

In the past decade, the U.S. Army has been in a dynamic state of transition to cope with the problems associated with the modern battlefield and the influx of increasingly sophisticated equipment. The impacts on the maintenance system have been particularly severe. The need to provide support to a highly mobile force in a variety of high threat environments and the increasing complexity of weapon systems have spawned new interest in maintenance management. In a similar vein, the high cost of maintenance operations associated with increasing automation and mechanization has generated renewed interest in standards and management techniques for maintenance in civilian industry [51].

Characteristics

Part of the reason for singling out maintenance tasks for analysis lies in their unique characteristics and the impact they have on military operations. Job content for maintenance tasks is generally difficult to predict due to its non-repetitive nature. The procedures for performing such tasks are generally well defined but the actual work can vary both with individuals and with the conditions they encounter while doing the work [84]. Three characteristics are of particular importance in military applications:

1. Critical points in task. Certain aspects of some maintenance tasks require very little time to accomplish if no problems arise but performance time may double or triple if difficulty is encountered. This often occurs when assembling components which involve fine linkages and precise positioning. When chemical protective clothing is involved, it has been noted that correcting such problems is even more time consuming [26].
2. Low task proficiency. Due to the low frequency of occurance for many maintenance tasks, individual proficiency is generally lower than for other types of military tasks [36]. Learning effects are more likely to occur than with respective missions, making such tasks difficult to analyze (see Figure 2-1).
3. Moderate, manual work. At lower echelons of the Army maintenance system, repair tasks which are subject to

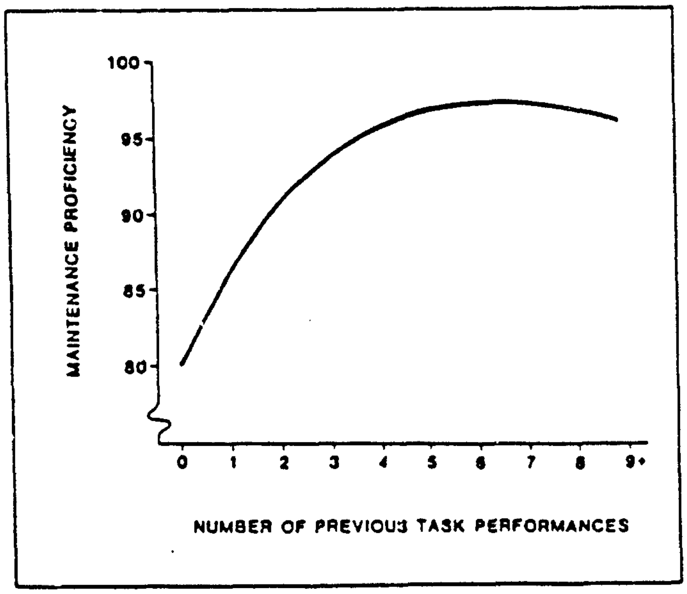


Figure 2-1. Maintenance Proficiency [36]

degradation are those that are likely to be done in a field environment. As a result, work is performed primarily with hand tools and is characterized by a high degree of hand and finger dexterity. Although exceptions exist, maintenance tasks are generally anerobic and are less susceptible to fatigue and heat stress at moderate temperatures (less than 70 degrees F) [45].

Army Maintenance Doctrine

In order to support current Army doctrine, a new three-level maintenance structure was implemented in 1983 [74]. The concept is designed to improve the responsiveness of the maintenance system by providing more support to deployed combat units (forward support). In addition to an improved ability to recover and evacuate damaged equipment, a definite emphasis has been placed on repairing equipment in forward areas of the battlefield. As a result, support maintenance teams will be more likely to perform their mission in protective clothing than in the past. Other ramifications of this new doctrine, as it pertains to performance degradation, will be discussed in later chapters.

The new Army maintenance system consists of three levels of maintenance as described in Figure 2-2. One of the "corner stones" in the Army maintenance system is the Technical Manual (TM). TMs exist

UNIT	At this level, maintenance is characterized by quick turnaround, repair by replacement, minor repairs, and performance of scheduled services. Unit maintenance is performed by the operator, crew or company maintenance section.
INTERMEDIATE	The intermediate level of maintenance has two orientations, direct support and general support. The focus of intermediate direct maintenance is mobile support as far forward as possible. Intermediate general support maintenance is performed in support of the theater supply system through the repair of assemblies, components and modules by units in semifixed or fixed facilities.
DEPOT	This level of maintenance maintains and accounts for war reserve stocks. Depot maintenance is performed in fixed facilities in the continental United States and the theater of operations, and is production-line oriented.

Figure 2-2. Army Maintenance Levels

for virtually all items of Army equipment and normally focus on a specific level of maintenance. Each manual describes what repair and preventive maintenance tasks are authorized for a given level of maintenance. Step-by-step procedures are provided for each authorized task along with detailed pictures and diagrams of important components. As a result, technical manuals provide a wealth of information for maintenance task analysis.

Tactical Operations

In terms of performance degradation due to protective clothing, unit and intermediate direct support maintenance levels are of primary concern in tactical operations. Units performing higher levels of maintenance typically operate out of permanent structures and are not in an open environment which is typically subject to liquid chemical contamination. Of key importance to combat unit commanders, the ability of organic maintenance personnel and equipment operators to perform unit maintenance while encumbered with protective clothing can make the difference between a decision to repair an item on the spot or to abandon it for ultimate evacuation by an intermediate direct support unit. To make this decision, a commander must weigh the additional time required to repair the equipment and the impact of its potential loss against his current tactical situation and mission. Without an accurate picture of the degradation involved, such tradeoffs are difficult to make.

As already discussed, the price for assuming a fully protected posture can be high. Thus, full protection may not always be worth the resultant reduction in combat potential when the mission is critical or when the threat of enemy use of chemical weapons is low. This need to balance protection with urgency of the mission led to the development of Mission Oriented Protective Posture (MOPP). This is a flexible system that allows commanders to raise or lower the amount of protection through five levels of MOPP; MOPP 0 through MOPP 4. Protection increases with progression from MOPP 0 to 4, but efficiency decreases. Selecting the MOPP level that provides the best balance requires judgement.

Standardized MOPP levels, shown in Figure 2-3, are used by commanders to allow them to easily increase or decrease levels of protection. Items of protective clothing that take the longest to put on and that degrade mission performance the least are put on first. Other items that can be put on quickly and degrade performance of individual tasks the most are put on last. This flexible MOPP system gives the soldier a head start at protecting himself from the effects of chemical attack.

The effective use of MOPP and knowledge of the degradation associated with it can be major factors in a unit's ability to accomplish its mission. Commanders must perform a MOPP analysis to balance the risk of chemical agent casualties and failure to accomplish the mission. As illustrated in Figure 2-4, the difference in terms of chemical casualties can be significant. Although the use of MOPP involves risk, the better the commander is able to analyze the complex factors that control the need for protection, the lower the risk and the higher mission performance is likely to be.

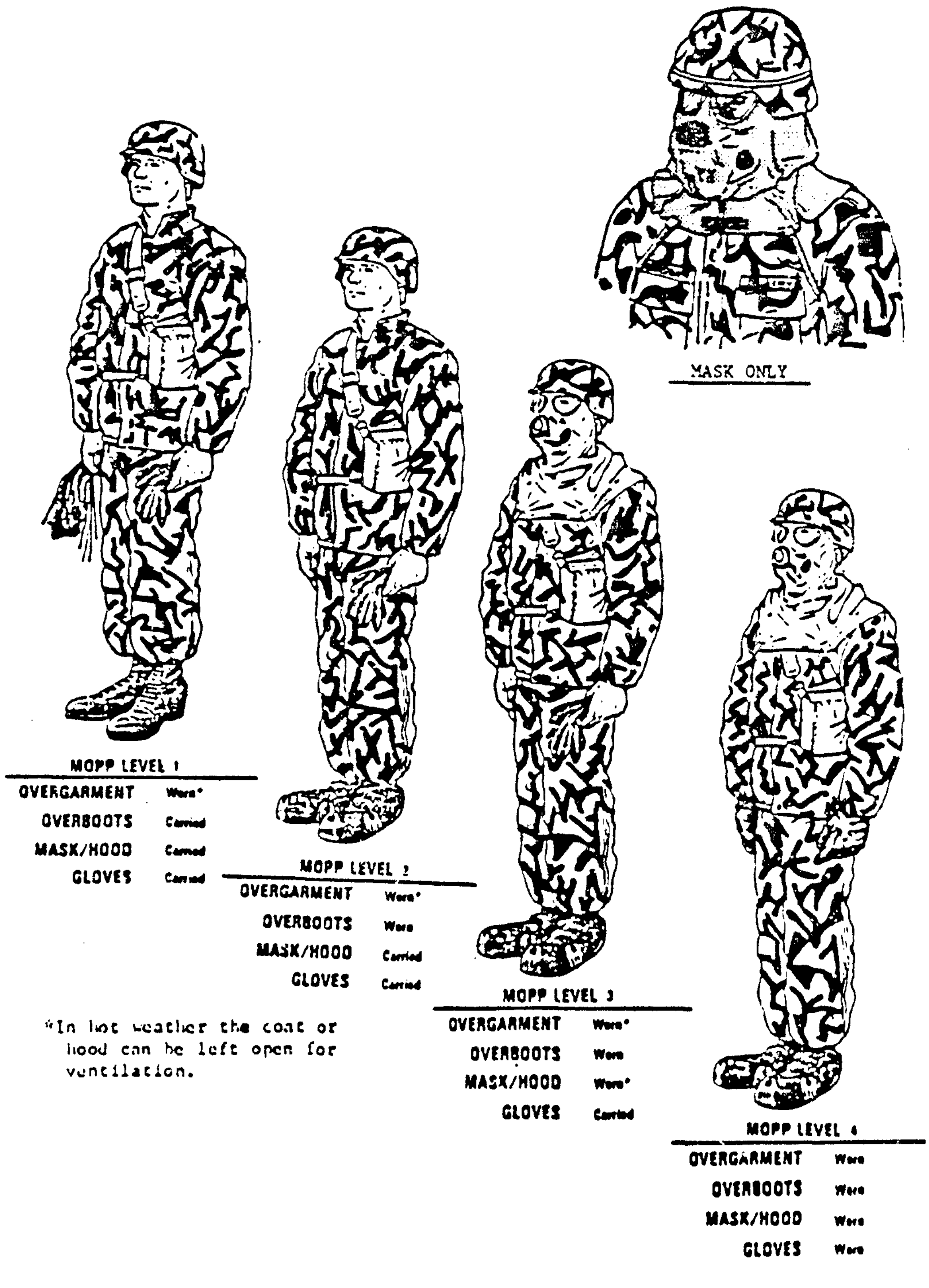


Figure 2-3. MOPP Levels [4]

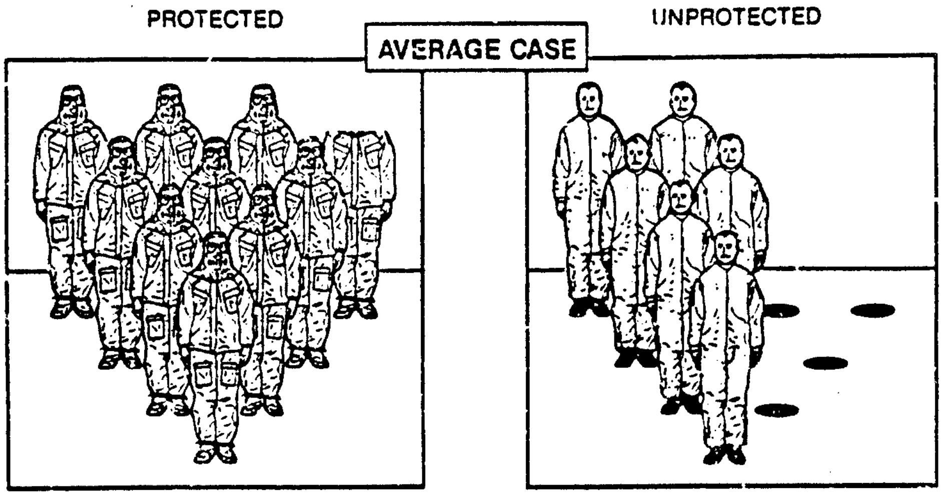


Figure 2-4. Potential CW Casualties [54]

Work Classification/Measurement

In the preceding section, information was provided on how maintenance tasks differ from other types of work and a brief introduction to Army maintenance operations in tactical situations was given. The purpose of this section is to investigate how such tasks can be classified and measured.

Task Taxonomies

To satisfy the objectives of this research, it is necessary to be able to classify maintenance tasks by their susceptibility to mechanical degradation. Such a classification system is often referred to as a taxonomy. Miller [55] describes a taxonomy as ". . . a way of simplifying a complicated universe of individual events and objects according to the way in which groups of individuals (or observations) have things in common or differ." In short, a taxonomy is a way to classify data according to the natural relationships of interest. The general goal is to facilitate a stepwise task breakdown into smaller elements in a logical and systematic way which focuses on key relationships. In this case, degradation due to protective clothing is the relationship of interest.

Helmrich [38] described a typical basis for work classification as shown in Figure 2-5. Of particular interest in the degradation of maintenance tasks are the aim of the task element, the object operated on, the aids required to perform the action and the environment. It should be noted that the physical characteristics of the objects being manipulated (e.g., size, shape, type of linkage) and the aim have considerable impact upon the degree of precision that must be exercised in maintenance tasks.

There are a wide variety of taxonomies which focus on the human perceptual and psychomotor requirements which affect job performance.

-BEHAVIOR	Physical behavior; e.g. grasp, reach, get
-AIM	The goal for a work element; e.g. assemble clutch
-ENVIRONMENT	Layout of work place or surroundings
-OBJECT	The item for which actions are done
-AIDS	Equipment like tools, utensils, or machines which are used to influence the object
-MEDIUM	Used in conjunction with the aids for accomplishing the aim; e.g. coolant for drilling

Figure 2-5. Basis for Classification

Although a comprehensive review of taxonomies is beyond the scope of this research, a detailed analysis was recently conducted by the Air Force Human Resources Laboratory in an effort to obtain a description of the ability required for performing the tasks of 35 Air Force career fields [70]. As a result of their review, a taxonomy containing 13 perceptual/psychomotor classes was developed. Of these 13 classes, the six classes shown in Figure 2-6 are applicable to the study of performance degradation due to protective clothing.

Each ability class is further divided into two levels of ability, high and low. Using finger dexterity as an example, activities such as typing or accurate manipulation of an implement (small tool, pencil, etc.) were classified as requiring a high degree of finger

FINGER DEXTERITY. Skillful, coordinated, precise finger movements that involve the use of one or more fingers to achieve quick and accurate manipulation, insertion, or grasping of small objects.

MANUAL DEXTERITY. Skillful, well-directed, coordinated arm and hand movements to manipulate objects quickly and accurately (but not controlling a machine).

CONTROL PRECISION. The ability to perform rapid, precise, fine controlled adjustments by either arm and hand movements or leg movements.

VISUAL SPEED AND ACCURACY. The ability to preceive small details quickly and accurately.

AUDITORY DISCRIMINATION. The ability to discriminate and interpret sounds.

DEPTH PRECEPTION. The ability to determine the position of objects in space and to perceive in three dimensions.

Figure 2-6. Performance Classes

dexterity. Tasks such as pulling the trigger on a weapon or activating a light switch were classified as low ability because little precision for positioning is required to accomplish these tasks. However, no specific criteria, other than examples, was provided for classifying tasks into the appropriate level.

Using the taxonomy, questionnaires were developed to obtain data from Air Force personnel qualified to evaluate the tasks normally performed by the career fields of interest. Two types of data were of primary interst [70]; (1) how much each ability is involved in the performance of each task (amount) and (2) the amount of variability in the quality of task performance as a function of each specific ability (performance quality variability). The first data item provided a measure of the relative saturation of an ability in the performance of a task (or career field). The second type provided an indication of whether or not the ability separated good from poor task performers. Across all 35 career fields, many of which involved maintenance tasks, the four most highly rated perceptual/psychomotor abilities for both amount and performance quality variability were visual speed and accuracy, finger dexterity, manual dexterity and visual memory. In the conclusions of this study, it was stated that "A high correlation (R=.97) was found between the ratings of 'amount' and of 'performance quality variability'. This suggests that only one or the other of these factors need to be included in future investigations of this type." [70]

Work Measurement

Whereas task taxonomies were investigated to assist in the classification and breakdown of tasks, the objective of this section is to determine how the physical movements required by task elements are measured and analyzed. Ultimately, it is desired to determine which body movements most frequently relate to the mechanical degradation associated with maintenance operations in MOPP.

Work measurement (or analysis) is based on the principle that the time required of people to perform certain basic or elemental motions is approximately the same for different people [21]. As a result, the time to perform manual work can be predicted by describing the job as a sequence of these elemental motions that have known time requirements. As shown in Figure 2-7, Eady has described a "family tree" for work measurement techniques [30]. Because one of the objectives of this research is to analyze maintenance tasks without direct observation, predetermined time (PDT) systems are of primary interest. A PDT system, as defined by Barnes [13], consists of ". . . a set of time data and a systematic procedure which analyzes and subdivides any manual operation of human tasks into motions, body movement, or other elements of human performance, and assigns an appropriate time value." Because of the wide use of PDT systems and the applicability to performance degradation, the remaining portions of this section will concentrate on this technique. The following sections offer a brief review of PDT system factors which are applicable to the analysis of performance degradation.

Generality. As shown in Figure 2-7, PDT systems can be classified according to the scope of their data. A generic system is oriented toward human behavior with elements recognizable as distinct human actions. As a result, it has maximum universality. Functional systems are oriented toward work actions "on and by the parts and tools involved" [44] and therefore adapted to a particular type of activity. A specific system, often referred to as standard data systems, are developed for a particular industry or organization and therefore lack universality.

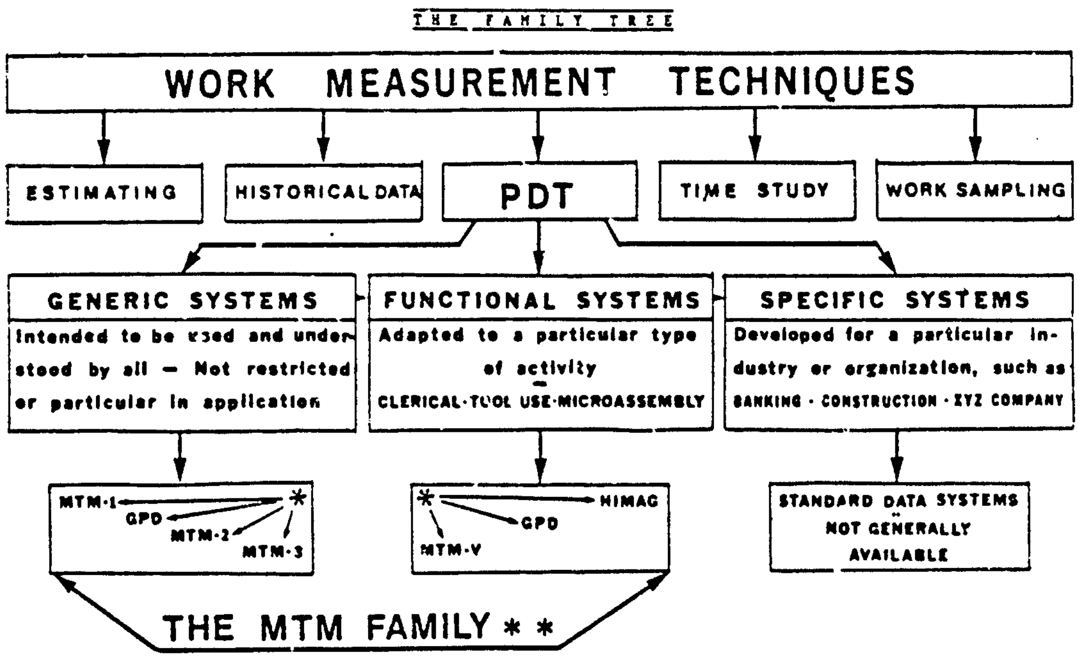


Figure 2-7. Work Measurement Techniques [30]

Speed of Application. The speed and ease of PDT system application is largely a function of the level of detail for which the system is designed. Systems with a large number of data elements are generally more difficult and time consuming to apply. The smaller amount of time typically associated each data element in a highly detailed system can dramatically increase analysis time. As an example, Figure 2-8 compares the major elements of three Methods-Time Measurement (MTM) systems, the most dominant PDT system [30]. Also provided is an estimate of the number of time values which are likely to be required for describing manual work. As the level of aggregation increases, the number of time values decrease rapidly.

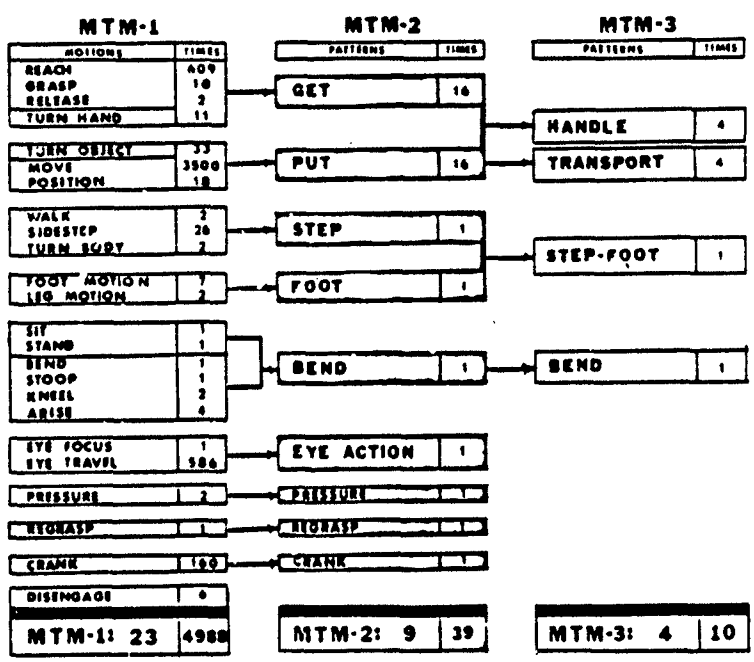


Figure 2-8. Comparison of MTM Systems [30]

Accuracy. As with application speed, the amount of precision that one obtains from a PDT system is related the level of system detail. System accuracy is predominately a function of the average length of a motion or time element of the system [31]. Application accuracy, which is the variation in analysis times by different analysts using the same PDT system, is often combined with system accuracy to provide an estimate of the total system accuracy. Total accuracy, expressed in a unit called "balance time," is defined by Eady [30] as

> . . . the nonrepetitive cycle in Time Measurement Units (1 TMU = .0036 seconds) at which variations up to ±5% may be expected 95 percent of the time. Stated in another way, it is the cycle time at which 95 out of 100 analyses of a given job would fall within ±5 percent of the true value of the job.

Using the variance chart shown in Figure 2-9 and a cycle time of 1000 TMU (36 seconds), system variation ranges from a low of ±6.4 percent for MTM-1 to a high of ±36 percent for MTM-V (a system used

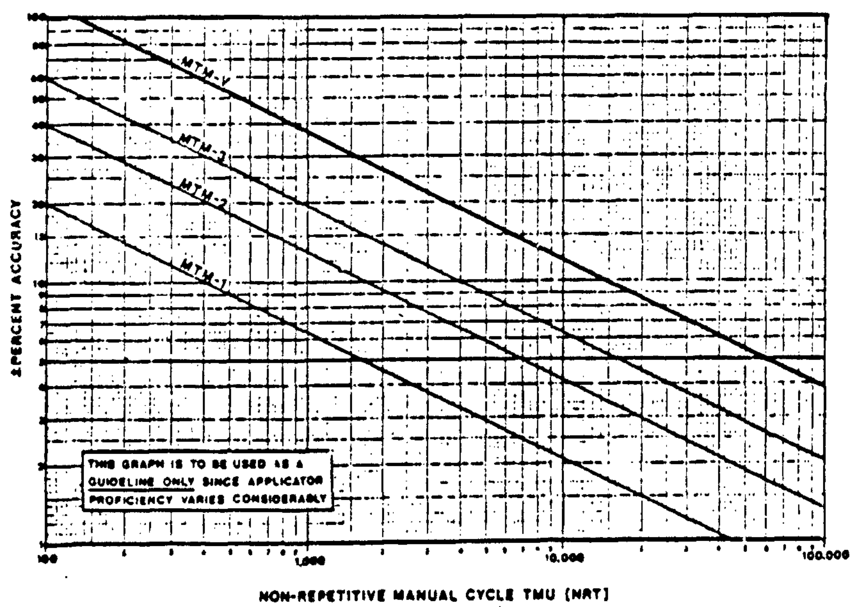


Figure 2-9. MTM System Variability. [30]

for manual work involving machine tools such as lathes, drill presses, etc.). The key point to be made here is that PDT systems, particularly aggregated ones like MTM-3, are limited in their accuracy.

Measurement of Non-repetitive Work

For the purpose of this research, knowledge of how non-repetitive work such as maintenance is measured is required. Because work measurement for maintenance activities is perhaps the most difficult application of any, it typically receives the least attention [84]. As a result, the choice of available systems is relatively small. In the following subsections, several generic and maintenance oriented systems will be briefly reviewed.

MTM-3. Although the MTM series of generic PDT systems was briefly introduced in Figure 2-8, MTM-3's [50] application for low repetition, long-cycle tasks bears a little more attention. This system, as with MTM2, is based exclusively on MTM-1 motion sequences and has only four codes and ten time values. A simplified decision model for MTM-3 is shown in Figure 2-10 [44]. The main elements are Handle and Transport. Handle consists of obtaining, moving, placing (if necessary) and then releasing an object. Transport is Handle minus the obtaining and releasing.

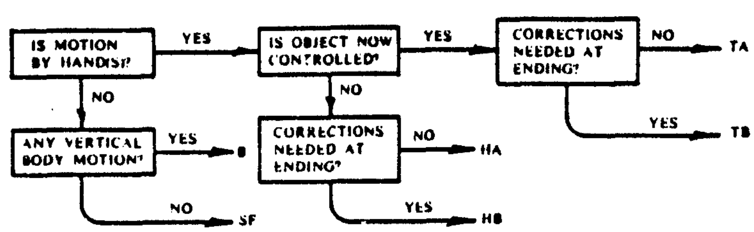


Figure 2-10. Simplified MTM-3 Decision Model [44]

MEK. MEK (MTM for Einzel und Kleinserienfertigung) [62] was developed by the German MTM Association to measure one-of-a-kind and small batch production. This system consists of seven different time elements as listed in Figure 2-11.

-Get and Put

-Handle Aid

-Put

-Operate

-Motion Cycles

-Body Motion

-Visual Control

Figure 2-11. MEK Time Elements

Designed to be applied without direct observation, the analyst determines that Gets and Places do occur, the accuracy of the Places, the distance the objects must be moved and the weight and bulk of the object. These variables are determined from a parts list, a drawing of the assembly and knowledge of the workspace layout. The key rationale behind this system is that the analyst does not need to know the exact motion sequence to perform the analysis as with MTM.

UMS. Universal Maintenance Standards (UMS) [84] was developed to solve the problems of non-repetitive jobs in maintenance operations. Studies of maintenance work have shown that about 80 percent of maintenance jobs require less than eight hours to perform [51]. Because of the problems associated with setting standards for such short jobs, UMS estimates the standard time for a job by comparison with a range of classified jobs, called benchmarks, whose basic times have been determined by detailed analysis. Benchmark jobs are normally classified according to task-area and time-range. Each time range identifies a specific "pigeonhole" [84]. The job of the analyst is to place the job being analyzed into its proper pigeonhole based on its similarity, in terms of work content, to the benchmark tasks used to develop that pigeonhole. The job being estimated is then given the average time for its assigned slot. It has been shown that, over a period of time, errors that occur cancel each other out to an acceptable level for time estimation purposes [45].

Data Block Synthesis. Data Block Synthesis [67] relies on the classification of mechanical maintenance work into a number of motions which are characteristic of maintenance tasks. Figure 2-12 lists the data blocks used to identify these motions and provides an example of how they are defined.

In essence, Data Block Synthesis accounts for the body and manual motions to obtain and replace tools within the immediate work area, hand and tool actions to loosen, tighten, assemble and other motions necessary to remove or replace fasteners. As with MTM, data blocks are classified according to a set of decision models. An example is provided in Figure 2-13.

Times for each motion are established using MTM2 for different groups of tasks. As with MEK and UMS, it is not necessary to see all jobs to be estimated in order to make a data block analysis. An

DATA BLOCKS IN MECHANICAL REPAIR WORK

Description	Code
Threaded fastener	TF
Non-threaded fastener	NTF
Handle—fit fingers	FF
" fit one hand	F1H
" fit two hands	F2H
" fit assisted	FA
" fit lifting gear	FLG
" remove fingers	RF
" remove one hand	R1H
" remove two hands	R2H
" remove lifting gear	RLG
" captive	HC
" preparation	PREP

The data blocks are carefully defined, as you will see from the example of threaded fastener.

DATA BLOCK: THREADED FASTENER—TF

DEFINITION: A single unit (such as a bolt) or a composite unit (such as a nut, bolt and washer) which joins or is joined to other items by means of mating threads.

Figure 2-12. Data Blocks [67]

ALGORITHM FOR PARTS HANDLED

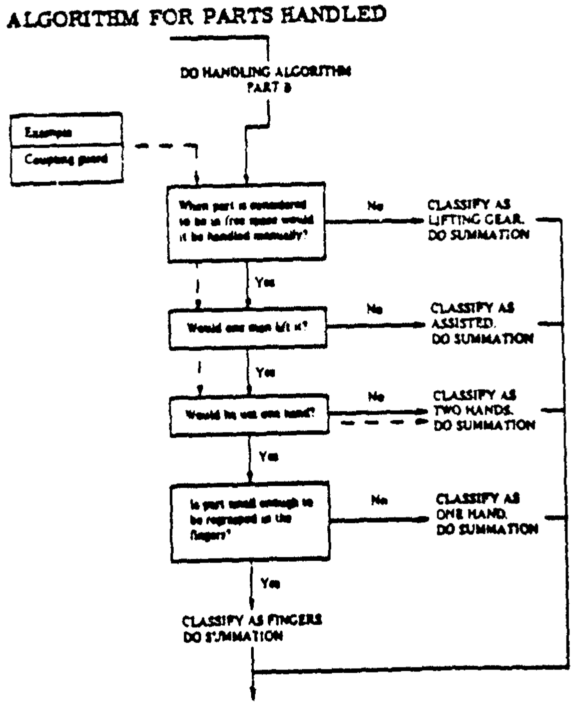


Figure 2-13. Parts Handling Algorithm [67]

experienced craftsman can use a list of parts to be handled and classify them using the decision models provided.

Human Performance in Protective Clothing

Background

Given some general techniques for work classification and measurement, a relationship between these techniques and performance degradation must be established. The objective of this section is to investigate how performance is degraded due to protective clothing. Although there are a large number of work situations outside of the military which require the use of protective clothing, an extensive literature search concerning human performance in such situations yielded very few documents. Those references that were found and reviewed [1,33,58,61,69] were safety oriented. Specifically, the performance of the clothing in protecting the individual was of primary concern. Where human performance was of interest, performance in the protected state was subjectively evaluated since comparison to an unprotected state was rarely applicable.

Military applications typically concern both safety and human performance because of the criticality of the mission normally associated with the profession. In some circumstances, most notably CW, the use of protective clothing can be varied with a concomitant acceptance of risk to the soldier in return for improved individual and unit effectiveness. However, it should be noted that military use of protective clothing covers the widest range of applications and includes the majority civilian usages found in the literature as shown in Figure 2-14.

- HIGH ALTITUDE/SPACE FLIGHT
- FIRE FIGHTING
- ARCTIC/TROPICAL SURVIVAL
- RADIOLOGICAL/CHEMICAL HAZARDS
- COMBAT PROTECTION
- EXPLOSIVE ORDNANCE DISPOSAL
- DEEP SEA SURVIVAL

Figure 2-14. Usage of Protective Clothing

In order to evaluate human performance in protective clothing, the variables which influence individual output need to be considered. A model outlining the interrelationship of performance shaping factors and performance, developed by the U.S. Army Human Engineering Laboratory [20], is shown in Figure 2-15. Variables include those outside the person (extra-individual) and those internal to the person (intra-individual). Extra-individual factors refer to those situational characteristics which determine the conditions under which the task is completed, the equipment needed and specialized job instructions. Intra-individual factors are those psychological elements, physiological stresses and organismic factors (skill level, intelligence, etc.) which are unique to each individual.

Given this breakdown of human performance factors, it is essential to have a clear method for evaluating performance which, in turn, dictates how degradation is defined. Specific types of jobs have different standards of performance (or performance degradation); task time

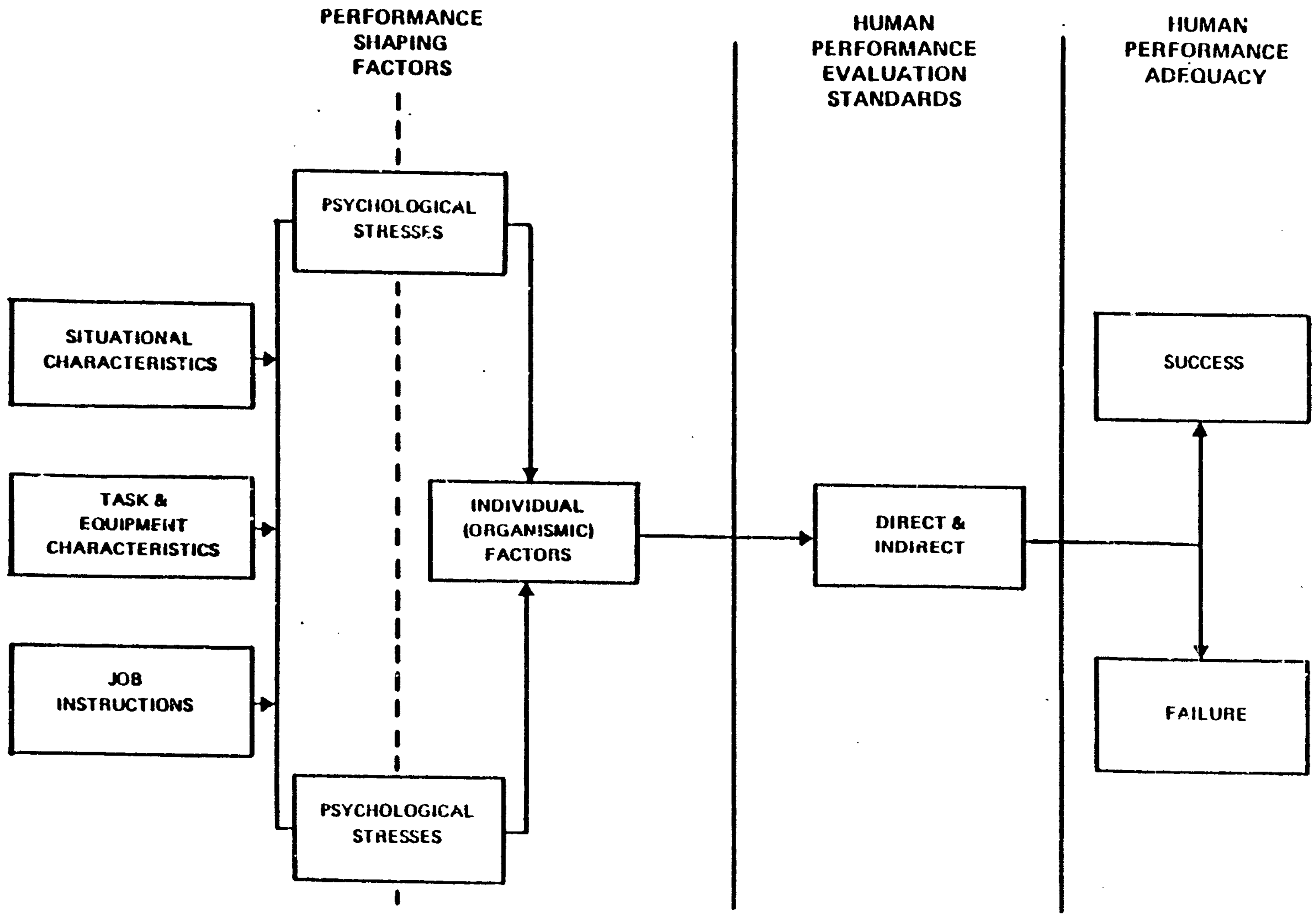


Figure 2-15. Factors in Human Performance [20]

and quality/accuracy (in terms of allowable errors) to name a couple. In degradation studies, the relationship between accuracy and rate of performance is of interest. As discussed by Bauldauf and Klopcic [14],

> It is generally possible to increase the rate at which a task is performed (number of rounds fired, number of messages sent) if accuracy can be sacrificed (increased probable error in weapon accuracy, increased number of messages not understood). Normal training, however, specifies a minimum accuracy which must be maintained.

In many cases, the requirement for accuracy is inherent in successful job accomplishment and need not be specifically addressed. In other situations, the distinction may not be as easy to make. Figure 2-16 depicts a hypothetical relationship between the accuracy versus rate tradeoff curves for an individual. As indicated by Bauldauf and Klopcic [14], there is a possible ambiguity as to the effect of degradation in that lower quality, quantity or some combination of these may result.

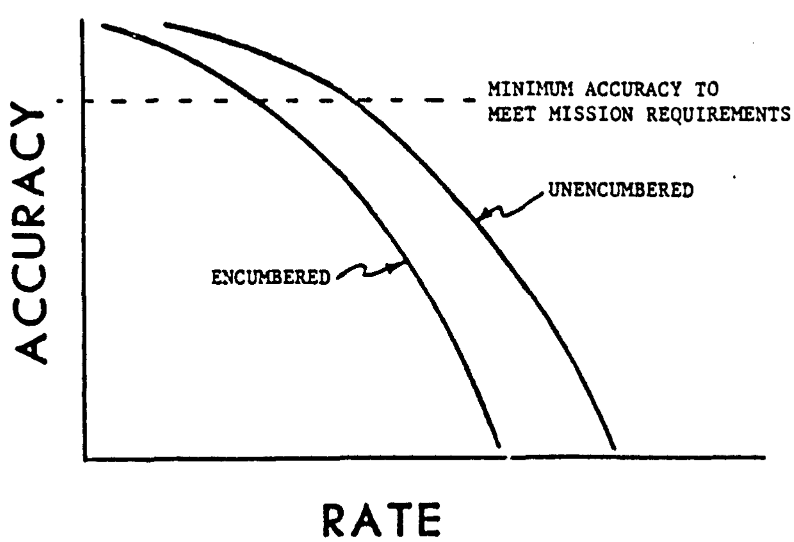


Figure 2-16. Accuracy Versus Rate

To remove this ambiguity, MOPP degradation studies normally use rate or time as the primary measure of performance. Task time is most useful in such studies due to its ease of measurement and because differences in time are readily comprehendable [65]. Accuracy measures vary widely in their impact upon task accomplishment and are more difficult to compare. In addition, several performance tests have reported that the quality (or accuracy) of performance did not differ significantly between MOPP levels [78,79]. However, these same tests reported significant differences associated with MOPP status when measures of rate/time were used. As a result, it is generally assumed that individuals maintain approximately the same level of accuracy whether degraded or not. However, the degraded individual can be expected to function at a lower rate in order to maintain this accuracy level.

It should be noted that the primary focus of this research is on individual performance. While it is recognized that many military tasks are collective in nature, a detailed analysis of the interaction effects associated with group performance is beyond the scope of what could reasonably be accomplished in this investigation.

The remainder of this section on human performance in protective clothing will provide a brief review of some of the more recent military studies and tests which have investigated this subject. Specific areas of interest include general military studies, developmental/operational equipment testing and field testing.

General Military Studies

AMSAA TR-313. This report, entitled "The Effects of Chemical Protective Clothing and Equipment on Combat Efficiency" [65], describes a methodology used to develop an initial task performance data base which can be used in computer simulations to assess degradation in a chemical environment. The data base is broken down by type and size of Army unit, the major tasks which the unit performs and the level of workload required to perform the tasks. Times to accomplish each function without protective clothing were based on the subjective judgements of officer personnel and subsequent tasks times in MOPP were obtained using work/rest ratios for avoiding heat casualties. Table 2-1 shows the performance degradation data for a company size maintenance unit.

One of the key limitations of this study is that the data base does not include time delays which occur from reduced mobility, dexterity or restricted visual acuity. It is questionable that, ignoring any mechanical degradation, increased task time due to heat stress considerations would typically be in the relm of a 100 percent increase at temperatures in the range 20 to 50 degrees Fahrenheit as reported. As will be shown later, there are a large number of recent studies which report significantly lower task-time performance degradation at moderate temperatures.

AFAMRL TR-84-063. This Air Force study, titled "Chemical Warfare Defense Operations: Field Study Methods and Results" [27], was aimed at developing a methodology for assessing Air Force Base performance in a CW environment and assisting in data base development.

Table 2-1. Performance Degradation for Maintenance Unit [65]

TYPE OF UNIT	MAJOR FUNCTION	DESCRIPTION	WORKLOAD	TIMES REQUIRED TO ACCOMPLISH FUNCTIONS			
				W/O PROTECTIVE CLOTHING*	WHILE IN MOPP 4(FULL PROTECTIVE ENSEMBLE)		
					@20°F(-7°C)	@50°F(10°C)	@85°F(29°C)
	Change power pack in M113 APC	w/ untrained 3-man team	Heavy	6 hrs	12 hrs	18 hrs	36 hrs
	Change cannon	155mm towed howitzer, untrained team (4)	Heavy	3-4 hrs	6-8 hrs	9-12 hrs	18-24 hrs
		w/trained team	Heavy	2-2.5 hrs	4-5 hrs	6-7.5 hrs	12-15 hrs
	Change recoil mechanism	155mm, towed howitzer,(5) untrained team	Heavy	8 hrs	16 hrs	24 hrs	48 hrs
Maintenance Unit company-size (124 people)	Establish a maintenance unit area	Includes placement of equipment and material, erection of maintenance facilities, and begin process for receiving supported equipment	Heavy	4.5 hrs	9.0 hrs	13.5 hrs	27 hrs
	Perform technical inspections	M60 series tank by 4 people	Moderate	1 hr max	1 hr max	1 hr max	3hr max
		M109 howitzer by 4 people	Moderate	1 hr max	1 hr max	1 hr max	3 hrs max
		M151A1 truck by 2 people	Moderate	30 min max	30 min max	30 min max	90 min max
	Perform direct support repairs	Replace transmission assembly, M60 series tank	Heavy	16.5 man hrs	33 man hrs	49.5 man hrs	99 man hrs
		Repair engine in M113 series tracked vehicle	Heavy	9.3 man hrs	18.6 man hrs	27.9 man hrs	55.8 man hrs
		Replace clutch disk and pressure plate, 5-ton M52A1 truck tractor	Heavy	7.8 man hrs	15.6 man hrs	23.4 man hrs	46.8 man hrs

*Assuming normal duty uniform and relatively ideal conditions of daylight, moderate weather, trained troops, etc.(unless otherwise specified).

Unobtrusive field team methods were used in observing a representative cross section of CW sensitive and mission critical activities. Such information was to be used to identify areas for more detailed study and to highlight choke points in maintaining a high state of operational readiness (sortie generation is typically the primary criteria).

Although most of the data was not quantified or validated, the study provided several interesting approaches and observations. As a part of the study, each major unit activity was broken down into specific tasks. These tasks were evaluated for their sensitivity to CW attack as shown by the example in Table 2-2. In addition, task performance degradation comments were obtained from exercise personnel at all

Table 2-2. Integrated Combat Turn Tasks Sensitive to CW [27]

Tasks (3 Teams)	Thermal Buildup	Limited FOV	Comm	Ensemble Damage	Requires Additional Training	Probable Time Increases
			PROBABLE ENSEMBLE EFFECTS			
General						
Standing						
Reaching		X				X
Walking	X			Boots (oil, wear)		
Writing						
Talking			X			X
Listening			X			X
Carrying	X			Gloves (oil, cuts, wear)	X	
Armorers Team						
Sitting (Forklift)						
Pushing	X			Gloves (wear)	X	X
Inserting						
Cutting				Gloves (cuts)	X	X
Holding Flashlight						
Aligning		X				
Inspecting						
Turning						
Twisting	X			Gloves (wear)	X	X
Bracing	X			Torso (wear)	X	X
Safetying		X			X	
Operating Forklift (Wheel, Lever)						
Climbing	X			Boots (oil, wear)	X	X
Balancing						
Handing						
Reading						
Signaling						
Threading				Gloves (wear)	X	X
Chaff Team						
Small Access Work	X	X		Gloves (wear)	X	X
Holding Flashlight		X				
Climbing	X				X	X
Overhead Work	X			Gloves (oil, cuts, wear)	X	X
Twisting	X					
Turning	X					
Inspecting		X				
Signaling						
Handing						
Refuel Team						
Pulling	X			Gloves (wear)		X
Screwing						
Kneeling	X			Legs (oil, wear)		
Dialing						
Aligning	X					X
Hoisting on Shoulder	X			Torso (oil, wear)		
Holding on Shoulder	X			Torso (oil, wear)		
Dragging	X			Gloves (oil, wear)		X

levels through interviews and questionnaires. The results, as shown in Table 2-3, are supportive of findings from other recent reports on CW degradation. Of particular interest was the following finding [27]

> . . . it was observed and subjective data was collected to support the conclusion that the more time spent actually training in the ensemble, the lesser the degree of performance degradation. . . Those personnel who appeared to have reduced the degrading effects of ensemble wear had either devised their own techniques to accomplish difficult tasks (commonly referred to as "work-arounds") or had learned techniques from more experienced co-workers.

Developmental/Operational Equipment Tests

Protective Gloves. The handwear of the soldier, which determines the degree of skill with which he can perform many critical battlefield tasks, constitutes one of the most important areas for research aimed at increasing the efficiency of the individual. Studies of the effects of chemical protective gloves on manual dexterity [41, 52,54] have revealed that wear of this portion of the protective ensemble yields a significant decrement in manual performance. All of the tests reviewed used standardized dexterity tests, the results of which are presented in Table 2-4. The common purpose of each test was to evaluate several different types of handwear, with bare hand performance as the baseline. In all laboratory tests, the current chemical/biological (CB) protective butyl rubber glove was one of the handwear types tested.

With the exception of the torque test, bare hand performance was best for all tasks. Although the amount of degradation and level of significance varied from test to test, the level of degradation that

Table 2-3. Ensemble Effects [27]

Degraded Performance	Exercise Personnel Comments
Thermal Buildup in Ensemble	Depends on climate/work area, may make mission success impossible.
	Slows work rates, introduces safety hazards.
	Published work cycle criteria for sedentary and active workers are unusable. Field data are needed that is job specific (USAF hospital commander comment).
Work Rates in Ensemble	Locomotion, manipulative task completion rates are increased.
	Dexterity tasks are much more difficult..
Communication	Present comm equipment is not well adapted to mask and hood wear. Manual communication is muffled but intelligible. ATC personnel need a microphone inside the mask.
Manual Tasks	Restriction to movement and heat buildup make physical exertion tasks much more difficult.
	Working with small tools or in tight areas is virtually impossible; however, with enough time can be accomplished.
Driving	Slow driving in warm climate increases thermal buildup.
	The CW mask severely limits peripheral vision forcing slower driving speeds.
Personnel Identity	Slows down assignments and job management. Need an AFSC (job) identity tag.
	Still a security problem.
Scenarios	Short scenarios are often not long enough to identify or examine actual unit capabilities.
Lack of Sufficient CWD Training	Slow ensemble donning/doffing rates and improper wear will kill a significant number of personnel.
	Filter change time can range from 5 minutes to an hour or more.
Glass Fogging in Ensemble	Decreased vision slows activities.
	Sweat increases fogging. Bending drops sweat on prescription lens inserts.
Speaking, Listening in Ensemble	Brick (handheld radio) communication introduces error and delays.
	Voice communication introduces error and delays.
	Landline telephones are difficult to use in CWD gear.
	Misinterpretation/missed alarms will kill many individuals.
Poor Fit of Mask	Mask fails to seal due to head size of personnel or due to sweat breaking seal.

Table 2-4. Dexterity Test Results

TEST TYPE	REPORT NUMBER	TASK EFF. *	SIGNIF. @α=.05
TORQUE TEST (angular force)	73-35	1.33	YES
MINNESOTA 2-HAND TURNING TEST (measures manual dexterity via manipulation of 1 1/2' × 1" blocks)	73-35 TR-81 TR-82	.75 .94 .79	YES N/A** NO
O'CONNOR FINE FINGER DEXTERITY TEST (designed to test the ability to assemble small mechanical parts)	73-35 TR-81 TR-82	.85 .71 .80	YES N/A** YES
CORD AND CYLINDER TEST (ability to handle soft, flexible materials)	73-35	.75	YES
BENNETT HAND TOOL TEST (proficiency in the use of wrenches and screw-drivers using nuts & bolts)	73-35 TR-81 TR-82	.90 .92 .94	YES N/A** NO
CRAWFORD PINS AND COLLARS TEST (manual dexterity using tweezers)	TR-81 TR-82	1.0 1.0	N/A** NO
CRAWFORD SCREWS TEST (fine finger dexterity in starting small screws and using screwdriver)	TR-81 TR-82	.74 .79	N/A** YES
PENNSYLVANIA DISASSEMBLY TEST (Nut & Bolt disassembly measuring finger dexteri-y, arm movement & hand/eye coordination)	TR-81 TR-82	.92 .94	N/A** NO
PENNSYLVANIA ASSEMBLY TEST (Nut & Bolt assembly measuring finger dexterity, arm movment & hand/eye coordination)	TR-81 TR-82	.74 .80	N/A** YES

*Task Effectiveness (barehand time/glove time). Soldiers were trained on the tasks (barehanded) prior to testing. For 73-35, degradations reported are those for trials 7 through 14 only.

**TR-81 did not report a level of significance for the difference between bare hand and gloved performance.

results from the use of protective gloves may be significantly smaller than the 300 percent increase in time used in the BRL degradation model [14], particularly where the use of hand tools are concerned. It was also noted that degradation was substantially reduced by practice with the gloves.

In a related test by McGinnis et al. [53], which tested handwear for cold/wet environmental protection, it was noted that tactile feedback loss at the fingertips is a primary source of decrement in manipulative performance. Thus, proper glove fit and reduction of airspace between the end of finger and the glove finger tip could improve performance. In addition, it was also noted that while gloves interfered with the handling of small nuts and washers on the Bennett Hand Tool Test, the protection provided by the gloves against the cold and scraping of the hands may aid performance on this test. This finding, along with the improved ability to apply angular force when wearing the rubber gloves, could confound degradation associated with maintenance tasks.

Protective Masks. Several references were found which discussed the performance of soldiers while wearing a protective mask. Three of these references [11,12,72] involve developmental tests for a new protective mask (XM30) in which this new mask is compared to the present M17/M17A1 protective mask. The results of these tests indicate that the primary types of degradation associated with the mask are limited field of vision, respiratory restriction and poor optical coupling with sighting devices. For most maintenance tasks, the degradation associated with these restrictions would not be expected to be a major contributor to increased task completion time. Although the restriction of field of view will require an individual to move his head more frequently and could cause some disorientation problems, the discomfort and psychological impacts of mask wear may overshadow these effects in maintenance tasks. Breathing resistance could be of importance in repair tasks with a high content of physical exertion.

Visual acuity, in terms of fine visual discrimination and short range depth perception, were not reported as major problems in any of these tests. Therefore, the high demand for visual acuity in maintenance tasks should not be a factor. Other factors such as mask fogging and heat buildup, are primarily environment and work load dependent. Table 2-5 provides a brief summary of some of the results for the referenced tests.

Overgarment/Overboots. The literature search conducted in support of this research did not reveal any references which dealt with the degradation associated with the overgarment and/or the overboots as individual components. Observations concerning these protective items were most often provided in human factors evaluations of the complete CB protective clothing system [2,76]. As a result, numerical estimates of degradation are confounded by the other clothing items.

The focus of data collection in these tests was on the wear of various protective overgarments in realistic military situations so that the garments could be examined for the degree of protection that remained after wear. In addition, individual comfort, heat stress levels and task performance were also evaluated. The most frequent degrading factors observed with the overgarments were related to the

Table 2-5. Mask Degradation

TEST	WITHOUT MASK	WITH MASK	TASK EFFICIENCY	KEY FACTORS
Obstacle Course (completion times)	4.22 min	5.14 min	.85	Breathing Resistance
Rifle Qualification (scores)	11.76	12.30	NS	Mask Bulk, Visual Distortion
Field of View (FOV)	87.7	77.0	.89	FOV
Optical Coupling				
M47 Dragon	6.1	3.2	.68	FOV
MGS CB Scope	5.7	1.7	.58	FOV
M19 Binoculars	6.9	3.7	.68	FOV
AN/PVS-5 Night Sight	40.0	26.5	.75	FOV
AN/TAS-6 Starlight Scope	7.0	6.8	.97	FOV
Visual Acuity (Ortho-rater Score)	5.5	5.5	NS	Visual Distortion
Depth Perception (Ortho-rater Score)	10.0	10.3	NS	Depth of Field

note: NS = Difference Not Significant

limited range of movement and bulkiness of the clothing. Exaggerated body movements to perform tasks requiring full extension of the limbs increases fatigue. In addition, the bulk of the overgarment makes maneuver in confined spaces or touching objects in tight access areas difficult due to clothing, catching on protruding objects. However, no quantitative estimates of additional time required to perform such tasks were available.

It should be noted that overgarments must be worn in conjunction with other items of field clothing and equipment (e.g. field jackets, load bearing equipment). Two studies by the U.S. Army Human Engineering Laboratory [19,20] report that range of movement is further degraded with additional field gear wear. Bauldauf and Klopcic [14] also noted that the length of step for individuals can be reduced by as much as 50 percent due to the overgarment pants and overboot combination.

Military Field Tests

For the purpose of this research, the term field test includes experiments in which soldiers were tested individually or as a unit in the performance of a combat mission. They differ from the developmental and operational equipment tests in that their primary emphasis is on evaluating mission performance rather than equipment suitability. There have been a number of recent literature reviews which have analyzed military field testing [19,20,60,79]. The principle observations from these reviews were that past tests have lacked uniformity of structure and purpose, experimental design/control was often weak and most of the older tests involved equipment and doctrine which is currently obsolete. With the exception of some of the testing done within the last five years, the vast majority of experimentation has not dealt with the mechanical degradation due to MOPP. The primary emphasis of most testing has been on heat-induced casualties and mission degradation due to the auxiliary tasks required in a chemical environment (e.g. decontamination, chemical reconnaissance, casualty care).

A wide variety of mission performance tests involving both U.S. and NATO Forces were reviewed in the conduct of this research. However, due to the limitations mentioned above and the focus on mechanical degradation, only eight of the more recent studies will be reported in this section. Tables 2-6 and 2-7 highlight the key findings of these tests that are pertinent to this investigation. The first four tests are primarily maintenance task oriented with the remainder covering a wider range of military missions.

In reviewing these tables, several recurrent themes become evident.

1. Task Effectivenes Range. Task effectiveness levels reported in these tests were normally between .5 and 1.0 (task time without protective clothing divided by task time in MOPP). This is consistent with the experience of a variety of U.S Army and Air Force experimenters interviewed as a part of this investigation.
2. Sources of Degradation. The protective gloves and mask are most frequently reported as the primary contributors to task-time degradation. For tasks requiring manual dexterity, the gloves presented the biggest problem.
3. Learning Effects. With very few exceptions, major learning effects were observed by the researchers and were reflected in the data. In many cases, learning effects associated with the task itself were confounded with those associated with becoming familiar with performing the task in protective clothing. In those cases where they were not confounded, the rates of learning appeared to differ. By the end of the second or third trial in MOPP, the majority of improvement had been obtained in most cases.

Table 2-6. Maintenance-oriented Field Tests

REPORT DESCRIPTION			TASKS PERFORMED		OBSERVATIONS FROM TEST		COMMENTS ON TEST DESIGN	REMARKS
DATE	TITLE	AGENCY	DESCRIPTION	DEGR	HUMAN FACTORS	EQUIPMENT		
1981	Ground Crew CDE Performance (Task-Time Degradation Test) [77]	U.S. Air Force Aeronautical Systems Div.	Complete Combat Turn, F4 Aircraft -Refuel Aircraft -Safe Gun Task -Stray Voltage Ck. -Ammo Loading -Install Ext. Tank -AIM9 Missile Load -AIM7 Missile Load	.73 .78 .70 .72 .71 .66 .79 .66	-manual dexterity can be degraded by as much as 100% -critical events in turns can produce an occasional high turn time -correction of problem more difficult in CDE	-mask & gloves have the greatest effect on task-time degradation -gloves: sense of feel important to safe gun task, bulk of gloves a problem with tank installation	-crews were experienced in combat turns but not familiar with CDE -two crews used, 7 MOPP & 2 shirtsleeve trials	-significant learning effects noted after 2 trials in CDE for both crews -turns were also performed using leather gloves over butyl rubber gloves which further degraded some manual dexterity tasks -test was video taped
1982	Aviation Supply Class III/V Field Test [46]	U.S. Army Human Engineering Laboratory	Rearm & Refuel Apache Helicopter	.86	-degradation of 5 man crew roughly 1/2 that of normal 3 man crew	-mask: when looking downward, mask/eyelens tended to rise up	-subjects were pretrained prior to test -randomized design with 12 trials per condition	-tasks were largely gross body & hand movement (limited need for finger dexterity) -test was filmed
1982	Tactical Air Control System CW Defense Equipment Task Validation Special Project [34]	U.S. Air Force Tactical Air Command	Maintenance of Electronic Equip.	.91 to .66	-95% reported slight to moderate reduction in performance -additional individual facilitates task -perseverance in over-coming frustration with CDE is pivotal -more errors in CDE	-gloves: forced more use of tools (pliers, tweezers & magnets) -mask: reduced field of vision caused bumping into equipment/people, meters difficult to read	-subjective scale used to evaluate CDE degradation (no time line analysis) -no indication that subjects were familiar with doing tasks in CDE	-even though maintenance tasks were degraded more than operational tasks, maintenance is perceived to have less impact upon overall mission accomplishment
1984	Missile Component Repair While Wearing NBC Protective Clothing [63]	U.S. Army Human Engineering Laboratory	TOW Missile Repair Dragon Missile Repair	1.0 .69	-difficulties reported most often; repeated minor mistakes, frustration & tendency to rush or become careless -procedural/diagnostic work not degraded	-mask/hood & gloves found to contribute equally to the degradation reported in MOPP 4 (18% for each)	-3 replications under each of 4 protective conditions -30 min. acclimatization period allowed before the test -excellent test design	-TOW repair task: mainly knob & switch activation, meter reading & a small amount of manual dexterity -Dragon repair task: mainly fine hand/eye coordination & finger control of small parts -no significant learning effect after second trial -test was filmed

Table 2-7. General Field Tests

REPORT DESCRIPTION			TASKS PERFORMED		OBSERVATIONS FROM TEST		COMMENTS ON TEST DESIGN	REMARKS
DATE	TITLE	AGENCY	DESCRIPTION	DEGR	HUMAN FACTORS	EQUIPMENT		
1981	Chemical Warfare Protective Posture Performance Test (CWP3) [26]	U.S. Army Combat Developments Command	Road March Cross Country Tra Barrier Maneuver Tgt Detect Time Tgt Identify Time Time to Engage Tgt	.86 .80 .79 .47 .48 .45	-walking outside the tank & grasping objects was difficult in wet weather -degradation values are for "buttoned up" condition (worst case)	-mask: restricted use of weapons optics to acquire & engage tgts., glare on mask lens a problem when facing sun -gloves: difficulty using switches, knobs & tools	-significant difference between test loops limits usability of data	-no statistical difference between the 17 crews -CWP3 designed to be only an initial investigation, further experimentation recommended
1982	Patient Care in a Chemical Environment [64]	U.S. Army Health Services Command	CW Casualty Treat. Immobilize Fract. Apply Splint Initiate Med. Care Apply Dressing Apply Tourniquet Administer Morph. Treat Chest Wound Intravenous Infus.	.79 .64 .61 .71 .70 .68 .60 .52 .65	-bulk of learning effects obtained by 3rd trial in MOPP & by 2nd trial in BDU	-use of special tactile glove resulted in a significant decrease in degradation over std. glove (.65 vs .77) -gloves: problems with tying, handling needles scissors use & writing	-random assignment of treatments, 6 trials for each condition -9 subjects used, unknown training/skill level -good test design	-tactile glove found to be highly susceptible to damage
1983	Evaluation of Combat Vehicle Gunner Performance with Various Combinations of NBC Apparel [48]	U.S. Army Human Engineering Laboratory	Target Tracking & Hits (yoke control) Target Tracking & Hits (isometric & control)	1.0 .88	-once subjects were proficient in MOPP they performed equally well with or without the clothing (1 hour of training)	-mask: provided some protection from recoil, improving performance in some cases (buffer) -gloves: air space in finger tips a problem with pressure sensitve isometric control	-completely randomized design -performance measures included time (time to first hit) and accuracy (% hits, no. of hits)	-"degradation in NBC gear not as severe as anticipated" -study recommends others tests on a wide variety of tasks
1984	Combined Arms in a Nuclear/ Chemical Environment [83]	U.S. Army Combat Developments Command	Hasty Attack * Day Defense * Night Defense * (based on ave. movement times)	.77 .96 1.0	-key problems noted were mobility & firepower degradation	-principle stressors were breathing load of mask, heat stress an inability to satisfy personal needs due to encapsulation	-test conduct was weak -usability of data is extremely limited, best information obtained from general observations	* test attempted to measure a wide variety of performance measures within these and other major misions - degradation values shown here came from [75]

4. Task Time Variability. Although not reflected in Tables 2-6 and 2-7, a general review of field test data indicates occasional MOPP task times much higher than the average. Although this could sometimes be attributed to differences between subjects, the occurance of this phenomena in different trials for the same subject tends to support the conclusion that MOPP tasks times were more variable than unencumbered task times, although not conclusively supported.

5. Video Tape Usage. In comparison to earlier testing efforts, a significant number of tests were filmed for later analysis. If this trend continues, the quality and quantity of data available for future analysis may improve.

In concluding this section, it should be noted that the data base used for this research was obtained from a field test jointly sponsored by the Ballistic Research Laboratory and Dugway Proving Ground. This test, entitled "Maintenance Operations in Mission Oriented Protective Posture Level IV (MOPP IV)" [85] will be discussed in the next chapter in conjunction with the data analysis.

CHAPTER III

MODELING OF PERFORMANCE DEGRADATION

Overview

As highlighted in the introductory chapter, the modeling and simulation of performance degradation plays a key role in the development of combat doctrine, training and equipment. A review of chemical threat/target vulnerability models indicates that the area of personnel degradation, represented by the area within the dotted line in Figure 3-1, has not been extensively developed. Many of the combat models designed to include CW have tended to concentrate on the simulation of chemical agent behavior and casualty prediction. A closer look at those models which do simulate performance degradation indicates very rudimentary approach, often concentrating heavily upon the prediction of heat casualties and modification of work/rest rates to compensate for environmental and mission constraints. The mechanical degradation that results from the protective ensemble itself has been largely ignored.

The following sections provide a brief review of three models which are specifically designed to incorporate chemical degradation effects into combat simulations. These three models represent the most comprehensive methodologies for describing the mechanical degradation due to chemical protective clothing that were found during the literature search. However, it must be noted that several classified models are known to exist and were not available for analysis.

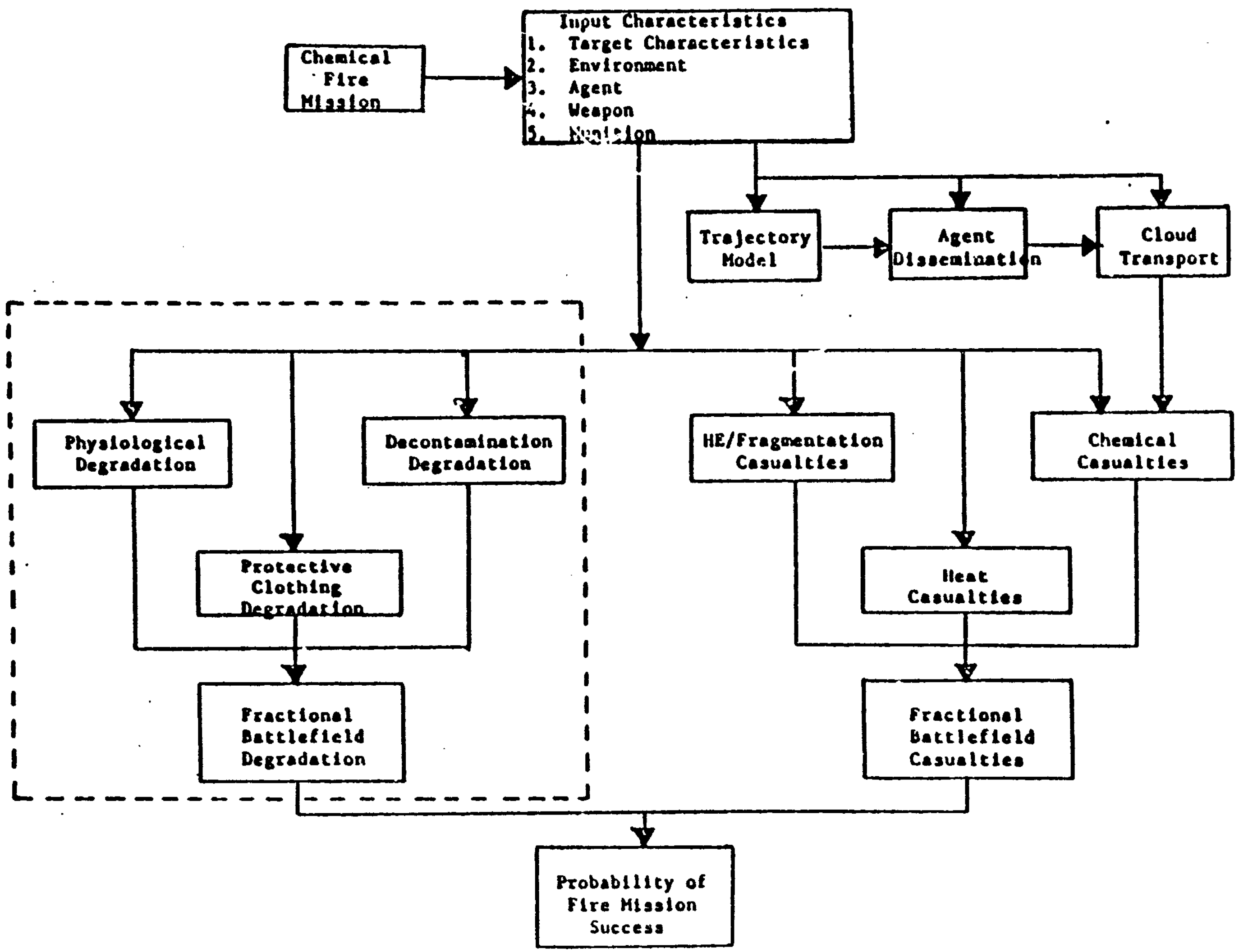


Figure 3-1. CW Modeling

Personnel Degradation Model

The purpose of the Personnel Degradation Model [23], PDGRAM, is to assess an individual's ability to perform his tactical mission when engaged in chemical warfare. The method of assessment involves dividing the soldier's task into several different skills, calculating the efficiency level for each skill, then combining the skill levels into an overall efficiency factor.

PDGRAM calculates a value for each of five skills as a function of the environmental conditions, training, protective posture, and the fatigue of the unit. The five skills are denoted as visual, manual dexterity, aural, mental (a measure of psychological well being), and the work-rest ratio. Actually, two values are broken out for each skill, an efficiency related to effects of the protective posture and an efficiency related to chemical contamination received by the unit. The overall skill factor is a product of these two levels.

The five skill efficiency levels are used to calculate three factors; fire power, mobility, and C3 (command, control, and communications). The three factors are, in turn, combined to produce the unit efficiency. This is done by computing a weighted average of the three factors. The weights are assigned as input parameters and represent the relative importance of each factor to the unit's performance of its tactical objective. Output from PDGRAM includes the average skill efficiency level for each skill, the factor values for firepower, mobility and C3 and the overall unit efficiency.

Model limitations center around the formulation of skill efficiency levels. In general terms, the formulas used are an attempt to account for factors that affect skill efficiency in a single equation. The factors incorporated are known to have an effect in a qualitative sense but a reliable data base is not available to support quantitative formulation. As a result, skill paramters were estimated based on input from three field tests conducted during the 1969 to 1976 time frame. The relative efficiencies for soldiers in full MOPP used in PDGRAM are shown in Figure 3-2. Although the reports describing these tests were classified and could not be reviewed, the applicability of the outdated doctrine and equipment employed in these experiments is questionable. In terms of mechanical degradation due to protective clothing, PDGRAM is limited in that only one factor is used to describe this source of degradation. Therefore, this model does not differentiate between a task which requires a high degree of fine finger dexterity from another task involving only gross body movement. However, beyond those limitations discussed, PDGRAM represents one of the first comprehensive approaches to describing the key factors which contribute to performance degradation.

MANUAL:	70%
VISUAL:	45%
AURAL :	80%
MENTAL:	93%

Figure 3-2. PDGRAM Skill Efficiency at MOPP IV

Multiple Aggregated Groups Integrated Conceptually

The Multiple Aggregated Groups Integrated Conceptually (MAGIC) methodology [22] provides a means of incorporating task-time degradation of maintenance tasks into the U.S. Air Force's Chemical Warfare Theater Simulation Airbase Resources (CWTSAR) model. CWTSAR traces individual pieces of equipment and personnel in an event simulation designed to evaluate the effectiveness of critical airbase operations in different threat scenarios. As input to CWTSAR, MAGIC is unique among degradation models in that it breaks down key tasks, identified by Work Unit Codes (WUC), into major skill areas. Five skill areas were selected as representative of most aircraft maintenance tasks; mechanical, electrical, pneudraulics, structural and buildup/tear down. Given this breakdown, the percentage each skill contributes to task accomplishment is then estimated by qualified maintenance personnel.

Within a given personnel skill area, the physical ability requirements for completing the task are then evaluated. Exertion, dexterity, accessibility and visual factors for each skill are subjectively evaluated on a scale of one to three, representing increasing demand for a given factor. Using the procedure shown in Table 3-1, individual demand factor ratings are summed for each skill (minimum of 4, maximum of 12). This provides an overall demand level which is used to determine the degradation factor associated with that skill.

Using field data, a scatterplot of reported degradations for events within a skill area was constructed and a scale of 4 to 12 was superimposed for assessing skill degradation (see Figure 3-3). Given a

Table 3-1. Sample Task Analysis with MAGIC

WUC = 13B MAIN LANDING GEAR	STRUCTURAL	ELECTRICAL	MECHANICAL	PNEU-DRAULICS	BUILD UP TEAR DOWN
EXERTION	2	3	3	2	3
DEXTERITY	3	2	2	3	2
ACCESSIBILITY	1	2	1	2	2
VISION	1	1	2	2	2
TOTAL COLUMN DEMAND	7	7	8	9	8
DEGRAD. FACTOR *	1.25	1.25	1.50	1.50	1.75
COLUMN % OF WUC	10	10	45	20	15
COLUMN CONTRIBUTION	.125	.125	.675	.300	.262

TOTAL DEGRADATION = .125 + .125 + .675 + .300 + .262 = 1.478

*See Figure 3-3

degradation factor and relative contribution for each skill area, a weighted average is then used to compute the overall degradation factor associated with a particular WUC. This degradation factor, as defined here, is the factor by which one multiplies the normal unencumbered task time by to obtain the time required in MOPP.

MAGIC is primarily limited by the data base it is designed to utilize and by the underlying assumption that subtasks within a given skill area share common characteristics which differentiate their degradation from the degradation associated with the other skills. This particular skill breakdown (mechanical, electrical, etc.) was

STRUCTURAL

TOTAL DEMAND	4 5	6 7	8 9 10	11 12
DEGRAD. FACTOR	1.0	1.25	1.50	2.0

ELECTRICAL

TOTAL DEMAND	4	5 6 7	8 9	10 11	12
DEGRAD. FACTOR	1.0	1.25	1.50	1.75	2.0

MECHANICAL

TOTAL DEMAND	4 5	6 7	8 9 10	11 12
DEGRAD. FACTOR	1.0	1.25	1.50	1.75

PNEUDRAULICS

TOTAL DEMAND	4 5	6 7 8 9 10 11 12
DEGRAD. FACTOR	1.0	1.50

BUILDUP/TEARDOWN

TOTAL DEMAND	4 5	6 7	8 9 10	11 12
DEGRAD. FACTOR	1.0	1.50	1.75	2.0

Figure 3-3. Degradation Factor Scales.

selected because of its compatibility with the existing Air Force Logistics Command (LCOM) data base, which maintains repair records for these categories. The advantages for Air Force use are obvious but application to other, non-aviation repair tasks may be limited. In addition, no theoretical evidence was given to support the assumption that such a functional breakdown captures the majority of degradation associated with a given task. However, the overall approach is intuitively attractive and initial results with this relatively new methodology have been reasonably accurate.

BRL Chemical Protection Degradation Model

The Ballistic Research Laboratory (BRL) recognized a need for a methodology which could provide a quantitative assessment of degraded effectiveness due to MOPP as input to their Army Unit Resiliency Analysis (AURA) model. As described by Klopcic and Roach [47], AURA is ". . . an amalgamation of analysis techniques, algorithms and data sources gathered from the laboratories that specialize in the various areas which impact upon the resiliency of a military unit."

The creators of this model have attempted to adapt state-of-the-art modules into a single model which will evaluate unit effectiveness in a variety of threat environments, including chemical warfare. AURA describes a unit both physically, in terms of its organic equipment and personnel, and functionally by explicitly describing the tasks that are required to accomplish unit missions and the relationships between these tasks.

As with PDGRAM, the BRL degradation model [14] is based on the premise that the ability to perform a task in MOPP is dependent upon the demand for certain physiological factors. Seven such factors were identified as defined in Figure 3-4. It is assumed that these factors are independent of each other to the extent that the use of one factor does not imply the use of any other.

In developing a MOPP degradation algorithm, Bauldauf and Klopcic identified four characteristics of the problem which should be captured by the mathematical behavior of the algorithm [21] as follows:

1. If any one or more factors is completely degraded, the job is completely degraded.

NEAR VISUAL ACUITY	- ability to see in the near range of vision and detect fine detail
FAR VISUAL ACUITY	- ability to detect, recognize and discern size and movement of objects in the far range of vision
AURAL/ORAL	- ability to understand communication received by the ear and to send communications by voice
MANUAL DEXTERITY	- ability to perform fine motor skills involving the hands and fingers only
MOBILITY ENCUMBRANCE	- ability to perform gross motor skills such as walking, bending and other non-dexterious body movements
PSYCHOLOGICAL FACTORS	- ability to concentrate on assigned tasks as affected by the confining and isolating nature of protective clothing
HEAT BUILDUP	- amount of energy per unit time an individual can expend at a given MOPP level and temperature without risk of becoming a heat casualty

Figure 3-4. BRL Degradation Factors

2. If no factor is degraded, the job is not degraded.
3. The job degradation is at least as severe as the most degraded factor.
4. There is a tendency for automatic compensation. By compensating for factor A one automatically has partially compensated for factor B.

The mathematical formulation of the BRL degradation algorithm is based on two variables, Demand and Degraded Ability. Demand, DM_{JI}, for physiological factor I in job J is defined as

$$DM_{JI} = \frac{\text{Rate of Performance of I for 100\% in Job J}}{\text{Maximum Rate of Performance of I}} \qquad (1)$$

In other words, DM_{JI} provides an estimate of how difficult the task is based on what is needed to achieve the desired results compared to the maximum possible application of that physiologicl factor. If the expected rate of performance is fairly low in comparison to the maximum possible, the additional time required when performing in MOPP can be reduced or eliminated by increasing performance rate (without loss of accuracy).

Degraded Ability, $DA_{IM}(t)$, to perform physiological factor I in MOPP M at temperature t is defined as

$$DA_{IM}(t) = \frac{\text{Rate of Performance in MOPP}}{\text{Normal Rate of Performance (unencumbered)}}$$

$$= \frac{\text{Normal Task Time}}{\text{MOPP Task Time}} \qquad (2)$$

Using a variety of data sources ranging from field tests to laboratory studies, a matrix of degrdaded abilities was developed as shown in Table 3-2. A value of 1.0 indicates no degradation while a value of 0 would indicate complete degradation (e.g. task could not be accomplished in MOPP).

Given appropriate values of DM_{JI} and $DA_{IM}(t)$, the degradation factor for job J due to physiological factor I in MOPP M at temperature t is defined by

$$F_{JIM}(t) = \begin{cases} 0 & : \; DA_{IM}(T) > DM_{JI} \\ \dfrac{DM_{JI} - DA_{IM}(t)}{DM_{JI}} & : \; DA_{IM}(t) < DM_{JI} \end{cases} \qquad (3)$$

Table 3-2. Degraded Ability Matrix

PHYSIOLOGICAL FACTOR	MOPP LEVEL 0	I	II	III	IV
Near Visual Acuity	1.0	1.0	1.0	0.5	0.4
Far Visual Acuity	1.0	1.0	1.0	0.4	0.3
Oral/Aural	1.0	1.0	1.0	0.5	0.3
Manual Dexterity	1.0	1.0	1.0	1.0	0.3
Psychological	1.0	.95	.90	.85	.80
Mobility Encumbrance	1.0	0.9	0.6	0.5	0.5
Heat Buildup 0°C	1.0	1.0	1.0	1.0	1.0
10°C	1.0	0.9	0.9	0.9	0.9
20°C	1.0	0.9	0.9	0.7	0.6
30°C (low/high humid)	1/.9	.8/.65	.8/.65	.7/.55	.6/.4
40°C (low/high humid)	8/.3	.5/.15	.5/.15	.4/.10	.3/.05

As can be seen, F_{JIM} is a function which is zero when no degradation exists and rises to one as ability goes to zero. The degradation factors of each physiological area are ordered from largest to smallest and then combined to obtain an overall degraded effectiveness for the job. By designating the reordered factors as

$$F_{JKM}(t) = F_{J1M} > F_{J2M} > \ldots F_{JKM} > \ldots F_{JNM} \qquad (4)$$

the Degraded Effectiveness, $ED_{JM}(t)$, can then be given by

$$ED_{JM}(t) = \prod_{K=1}^{N} \left(1 - F_{JKM}^{K}(t)\right) \qquad (5)$$

As noted by Bauldauf and Klopcic [14], any increasing function of K which is always greater than one could be used as the exponent of F_{JKM} and still satisfy the desired characteristics. However, this particular function was selected based on its agreement with available data.

As with PDGRAM, the limited data base from which to draw reliable degraded abilities currently restricts the application of the BRL methodology. Judging from the numerical values of near vision, manual dexterity and mobility encumbrance in the degraded ability matrix, it appears that mechanical degradation may be overestimated in this model. In addition, the ability to separate the near visual component from manual operations, in order to obtain two distinct degraded abilities, is questionable. A further contributor to overestimation is contained in the mathematical algorithm. Specifically, the BRL model does not differentiate between the relative contribution each physiological factor makes to task accomplishment. For example, a task in which 70 percent of the total task time is spent on operations requiring manual dexterity is degraded by the same amount as a task which requires only 10 percent of the time be spent using manual dexterity (assuming the other physiological components are identical).

In summary, all three degradation models reviewed have the common problem of a limited data base for estimating degradation parameters. In most cases, subjective estimates or inference from a small number of field tests was used to obtain the parameter values currently used in these models. MAGIC suffers to a lesser extent in this respect but is restricted to aircraft maintenance tasks. PDGRAM and the BRL model are generic methodologies and are somewhat similar in their physiological approach. However, for the purposes of evaluating individual tasks, the BRL model has the advantage in its ability to compensate for the effect of multiple degradation factors and account for the demand associated with them.

CHAPTER IV

DEGRADATION ANALYSIS METHODOLOGY FOR MAINTENANCE (DAMM)

General

In this chapter, a methodology for the analysis of maintenance task degradation will be developed. DAMM draws upon much of the information described in the two previous chapters and is designed to be compatible with the BRL degradation model. To aid in this effort, six desired characteristics were identified as shown in Figure 4-1. Where tradeoffs are necessary between these goals, justification for the approach will be discussed. The following sections will address taxonomy development, the determination of movement degradation factors and the calculation of degraded effectiveness.

UNIDIMENSIONAL	- each movement class must be unique and readily identifiable.
VALIDITY	- methodology must be based on relevant work measurement principles and known characteristics of performance degradation.
COMPATIBILITY	- method should be fully compatible with U.S. Army maintenance doctrine and with the BRL degradation model.
SIMPLICITY	- scheme should be easy to apply and interpret.
RELIABILITY	- classifications should capture the majority of task-time degradation.
GENERALITY	- taxonomy should be applicable to a full range of maintenance tasks.

Figure 4-1. Desired Characteristics

Taxonomy Development

Task Description

To facilitate task description, it is useful to break each job down into subtasks or task elements. Karger and Bayha [44] have defined three types of task elements; constant, foreign and variable as defined in Figure 4-2. Although variable elements occur in many maintenance tasks, the necessity to establish specific degradation values for each element will require all subtasks to be treated as constant. However, the impact of this simplification will be partially addressed in the classification of task elements. Foreign elements are not pertinent to the objective at hand but could be incorporated as random events as part of a simulation model if desired.

CONSTANT ELEMENT	- A job or task element without significant variation in its work content or performance time.
FOREIGN ELEMENT	- An element with a random, usually unpredictable, frequency of occurrence, not part of normal method.
VARIABLE ELEMENT	- An element whose normal time varies significantly from cycle to cycle as a function of one or more job variables.

Figure 4-2. Task Elements

For Army maintenance tasks, technical manuals (TM) provide the logical vehicle for job breakdown. Using a TM listing of task steps, a job can be readily described as a sequence of relatively short, easily identifiable elements. Of particular interest in degradation analysis, TMs provide insight as to what is handled and how it is handled. The size and shape of most components can be determined from illustrations and the tools required for assembly/disassembly are identified. However, it will be necessary to further subdivide TM steps to distinguish starting an operation with the fingers from completing it with a hand tool. The importance of this modification will be come apparent in the following sections.

Classification of Task Elements

General. Of the seven degradation factors identified for use in the BRL model, the effects associated with manual dexterity, mobility and near vision are directly applicable to mechanical degradation of maintenance tasks. These three factors differ from task to task in their impact upon task time and will be the focus of further research. Although aural/oral capability is sometimes required for maintenance operations involving teams, the close proximity of work rarely causes this factor to be of significance. Since far vision is not applicable in repair tasks, only psychological factors and heat stress remain as possible sources of degradation. As mentioned previously, heat stress is largely a function of climatic conditions and work load, both of which are assumed to be of limited impact for relatively short, anerobic tasks performed at moderate temperatures.

Assumptions. Before proceding with a description of the proposed taxonomy, it is appropriate to state those assumptions required in the development of movement categories for task elements.

1. MOPP degradation is related to specific body movements which are characteristic of a given task element.

2. The percentage of total task time that a movement category requires without protective clothing is different from that in MOPP.

3. Although the order of task element accomplishment can differ, the procedures used are standardized and relatively insensitive to protective posture changes.

The third assumption warrants some additional explanation. The method of task accomplishment is often a function of training. Barnes [13] noted that "If a careful analysis were made of an operation, it would generally be found that a skilled person uses a different method from the one used when he or she was less skilled on the job." As a result, this assumption implies that a plateau of task learning has been achieved. In addition, foreign elements associated with incorrect procedures or the use of unauthorized tools are not covered in this methodology.

The following sections describe the development of a taxonomy for maintenance task analysis, as depicted in Figure 4-3. Each level of classification, indicated by the vertical dotted lines, will be described and supported in the following sections.

Element Type

In classifying task elements by type, it is necessary to consider the characteristics most often associated with maintenance tasks. Typically, repair jobs involve the removal and installation of components through a series of manual operations. Although this type of breakdown will not account for all manual motions applicable to

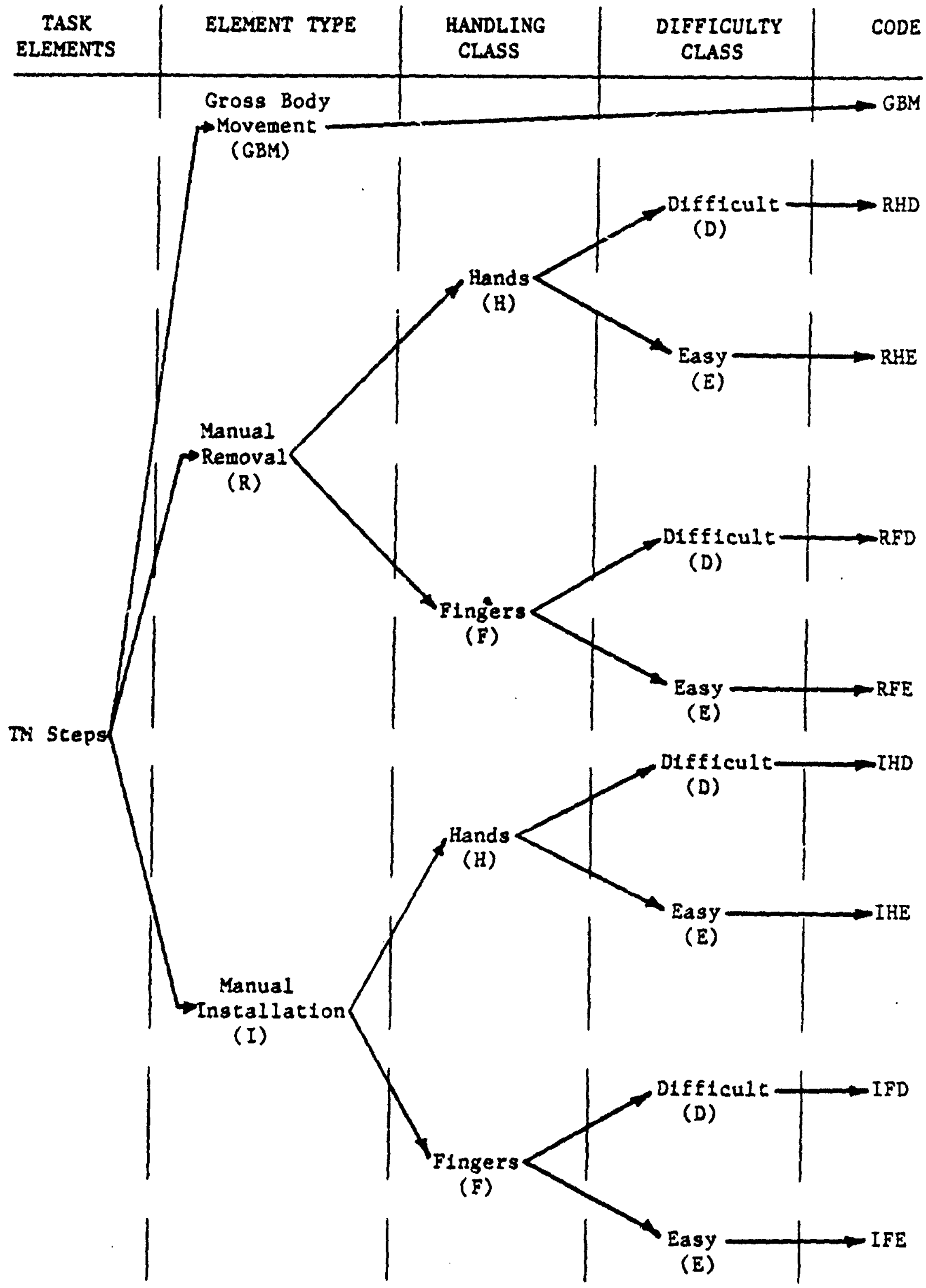


Figure 4-3. Taxonomy for Maintenance Task Analysis

maintenance tasks, the overall goal is to account for the majority of task-time degradation not the total task time. As described earlier, Data Block Synthesis differentiates task elements in this manner.

The decision to describe task elements according to their assembly or disassembly purpose is based on several observations which are essential to degradation issues. The contribution of near visual requirements to manual dexterity operations, as required by the current BRL methodology, is difficult to determine when two separate degradation factors are used. However, removal and installation classifications can help distinguish between those manual motions which are largely guided by near vision and those that are not. Installation task elements involve finger/hand and eye coordination in a blending of movements to align, orient or engage parts. In work measurement terminology, this is typically referred to as a positioning requirement [44]. It is assumed that need for visual acuity is greater for assembly tasks and that there is a significant difference in the MOPP degradation between installation and removal operations. The results of the Pennsylvania Assembly and Disassembly tests, as shown in Figure 2-21, support this assumption. It should also be noted that positioning of components and tools are critical to many assembly tasks and work measurement studies have found larger time variation in task elements of this type [40].

Recognition that the demand for vision in directing physical movement should not be accounted for separately is consistent with common work measurement techniques. According to Karger and Bayha [44],

> Eye time is allowed only when it occurs during a complete lapse of other operator motions or limits out other simultaneous motions, with the specific provision that the eye motions in question are necessary for the worker to complete his task or before the next manual motion can be performed.

Task elements which typically fall into such a category would involve the perception of data from measuring devices (gauges, rulers, etc.) and reading printed instructions. However, these task elements have not been shown to be degraded at moderate temperatures and work rates (e.g. mask lenses not subject to fogging).

In addition to removal and installation operations, maintenance tasks occasionally require what will be termed gross body movement. As an operational definition, gross body movement will refer to those body, leg and foot motions which are used either to locate the hands and arms to perform or directly perform the majority of a task element. The latter portion of this definition allows for the situation in which control of an item is exercised by the large body muscles. Gross motions are often required to gain access to a piece of equipment or to manipulate large, heavy objects. Such movements are typically aggregated in most work measurement techniques and are normally affected by fewer variables than manual motions [44].

It should be noted that gross body motions that are performed simultaneously with manual motions are considered to be "limited out." If gross body motions overlap manual motions, the manual assembly or disassembly operation will be considered as the one causing the greatest amount of time degradation, or the limiting element type. This approach represents an adaptation of the limiting principle used in most work measurement techniques [44]. Fortunately, such simultaneous motions have be found infrequently in maintenance tasks [86].

Handling Classification

Work classification/measurement techniques oriented toward maintenance tasks are typically based on what items are handled and how they are handled. MEK and Data Block Synthesis are good examples of this approach. Based on the large demand for manual dexterity in such tasks and the significant degradation associated with it, a finer breakdown of assembly and disassembly tasks was deemed appropriate. Because of the relative ease of differentiating between parts/tools handling using the hands from those requiring finger control, a handling classification approach based on this breakdown appeared logical. More importantly, many of the reports on human performance, as discussed in Chapter II, indicated a significant amount of degradation associated with fine finger dexterity as compared to hand manipulation. Included in either handling class are those hand and arm motions necessary to gain control of a component or tool and to use it for a given operation. Replacement of a tool or component, if required, is also included in the handling of an item.

Hand Dexterity. This handling class refers to those objects that can be grasped and controlled by simple closure of the fingers and hand/arm movements. As shown in Figure 4-4, the initial grasping of an item in this category does not require fine finger dexterity. Hand manipulation involves objects large enough to be held in the palm of the hand with minimal reliance on the fingers for grasping, positioning and use. For repair tasks, hand activity is often found in elements requiring the loosening or tightening of a component fastener with a tool such as a large wrench or hammer.

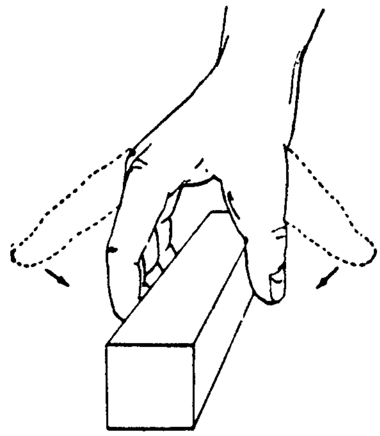


Figure 4-4. Handling Class: Hand

Hand manipulation can be accomplished with one or both hands. However, the majority of maintenance operations involve directing a component or tool to a fixed destination [45]. As such, one hand typically dominates the action while the other is used to hold or steady the item involved. For this reason and for ease of application, this taxonomy will not distinguish between two-handed and one-handed operations. Inherent in this approach is the simplifying assumption that there is no significant difference between degradations associated with either type of movement. As with overlapping element types, simultaneous hand movements are considered to be limited out by the dominant hand.

Finger Dexterity. Handling an object with the fingers implies that active use of two or more fingers is required to gain control and use an object. As illustrated in Figure 4-5, an item of small size or a thin object which lies flat on a supporting surface requires accurate control and fine finger manipulation to grasp and use. However, it should be noted that while the size and shape of the object is a key variable which helps to determine how an object is handled, the primary criteria for specifying either hand or finger handling lies in how the object is used. For example, picking up a screwdriver could be considered a hand dexterity task element. However, except for the initial loosening of a screw, a screwdriver is usually manipulated by the fingers, particularly if the screw is fairly long. The analyst using this taxonomy would have to make a subjective judgement based on work content in order to classify such borderline cases. The sensitivity of the taxonomy to such judgement calls will be discussed in a later section.

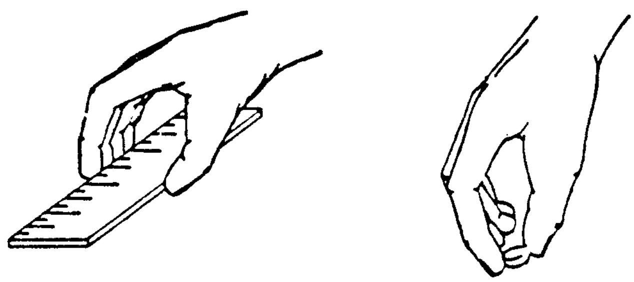


Figure 4-5. Handling Class: Fingers

As with the hand classification, finger manipulation can involve both hands. Again, the use of a screwdriver is a good example. However, based on direct observation of maintenance tasks being performed, it appears that finger use tends to alternate from hand to hand. This poses a potential problem with respect to task-time degradation of jobs requiring finger manipulation of a small item. Because of the bulk of the gloves, which restricts the ability to maintain two-hand contact in close proximity to each other, the degradation associated with one and two-hand finger manipulation may differ. However, no experimental evidence exists to support this conjecture. As such, no distinction will be made between one and two-hand use.

Difficulty Classification

The lowest level of task element classification is based on the premise that a task which is difficult to accomplish when unencumbered will be more highly degraded when protective clothing is required than an easier task. In order for this approach to be feasible, the method used to establish task element difficulty must relate well to movements that are highly degraded. Bailey and Presgrave [10] identified four characteristics which influence task difficulty; force, visual control, precision, and distance. For degradation analysis, the first three are of primary interest. Except for very small items, the amount of angular force that can be applied to an object can actually increase when rubber gloves are used. However, there is little reason to expect that other types of force are affected by the use of protective clothing at moderate work rates. There is ample evidence that visual control and precision can have a major impact upon task-time degradation, particularly for fine finger manipulation. In particular, MAGIC was specifically designed to account for the level of demand associated with task element characteristics. It is interesting to note that three of the four demand factors used in MAGIC, namely dexterity, accessability and visual requirements, relate to visual control and precision.

Levels of Difficulty. Given this background, two difficulty classifications were selected. A "difficult" task element is characterized by an operation which involves removal or installation (either by hands or fingers) of an item having a fine likage or matchup with another component. This can include the use of a tool which requires precise positioning be maintained (e.g. spanner wrench, screwdriver) or the mating of two components which involve a high degree of manual dexterity for careful alignment or orientation. A task element can also be classified as difficult due to restricted vision or access involved with an operation. Specifically, a job can be highly degraded if the mechanic cannot adequately see or gain proper access to the components involved, even for relatively coarse linkages. This is an explicit recognition of problems associated with the bulk of the mask and overgarment, which restricts access, and the loss of tactile sense due to glove wear. Additionally, correction or repositioning time has been noted as being highly degraded in MOPP. A task component which does not exhibit such characteristics would be classified as "easy."

Task elements which are "difficult" often involve the handling of small screws or nuts which typically have fine linkages and are difficult to manipulate. Although an exact break point in this case cannot be empirically established, available references and observations suggest that small items less than 1/4" × 1/4" and thin items less than 1/8" should be classified as difficult to handle [66,76,81].

From another standpoint, handling small items with the fingers also adds to visual obstruction, particularly when bulky gloves are worn.

Subjectivity. Unlike the other levels of this taxonomy, the difficulty classification is largely subjective and depends upon the experience of the task analyst. Although some subjectivity is associated with all highly aggregated work classification/measurement techniques, it was hoped that limiting the number of difficulty classes would simplify this decision. In addition, maintaining difficulty classification consistency between removal and installation of the same item can assist in this decision. For example, if a task element is classified as difficult for installation, it should also be classified as difficult for removal unless the procedures are significantly different. This issue will be addressed further in the demonstration and evaluation of this methodology.

Alternative Approach

Obviously, certain tradeoffs had to be made in terms of taxonomy accuracy and simplicity. Of particular concern was the number of movement categories associated with the taxonomy (taxonomy level). As discussed previously, a more detailed approach has the advantage of increased accuracy and applicability but sacrifices case of use. In this research, the taxonomy level was dictated by the known characteristics of MOPP degradation and the need to establish a proportional breakdown of movement category contributions to total task time without formal testing.

As an example, an alternate classification method was originally attempted using a modified Data Block Synthesis approach. Using a primary classification of threaded and non-threaded fastening and gross body movement, two different tasks were classified according to the method of handling (fingers, one hand or two hands) and further broken down as aided (performed with tool) or unaided. The resulting taxonomy had 14 different classifications. In addition to being difficult to apply, little experimental evidence was found to support the assumption that the degradation associated with threaded fasteners was substantially different from non-threaded fasteners. Using available data, little significant difference was noted between degradation factors for most classes. The failure of the system to account for significant differences between positioning requirements for installation versus removal could have been a major factor in this result.

Decision Model

To assist in the application of this taxonomy for maintenance task analysis, a decision model was developed. This model, shown in Figure 4-6, is a consolidation of many of the ideas presented in this section. To aid in the interpretation of some of the terms used in this model, selected definitions are provided in Figure 4-7. The general approach is as follows:

1. Using the appropriate technical manual, divide the job into a distinct series of steps (task elements). Task elements which involve both manual starting/removal and tightening

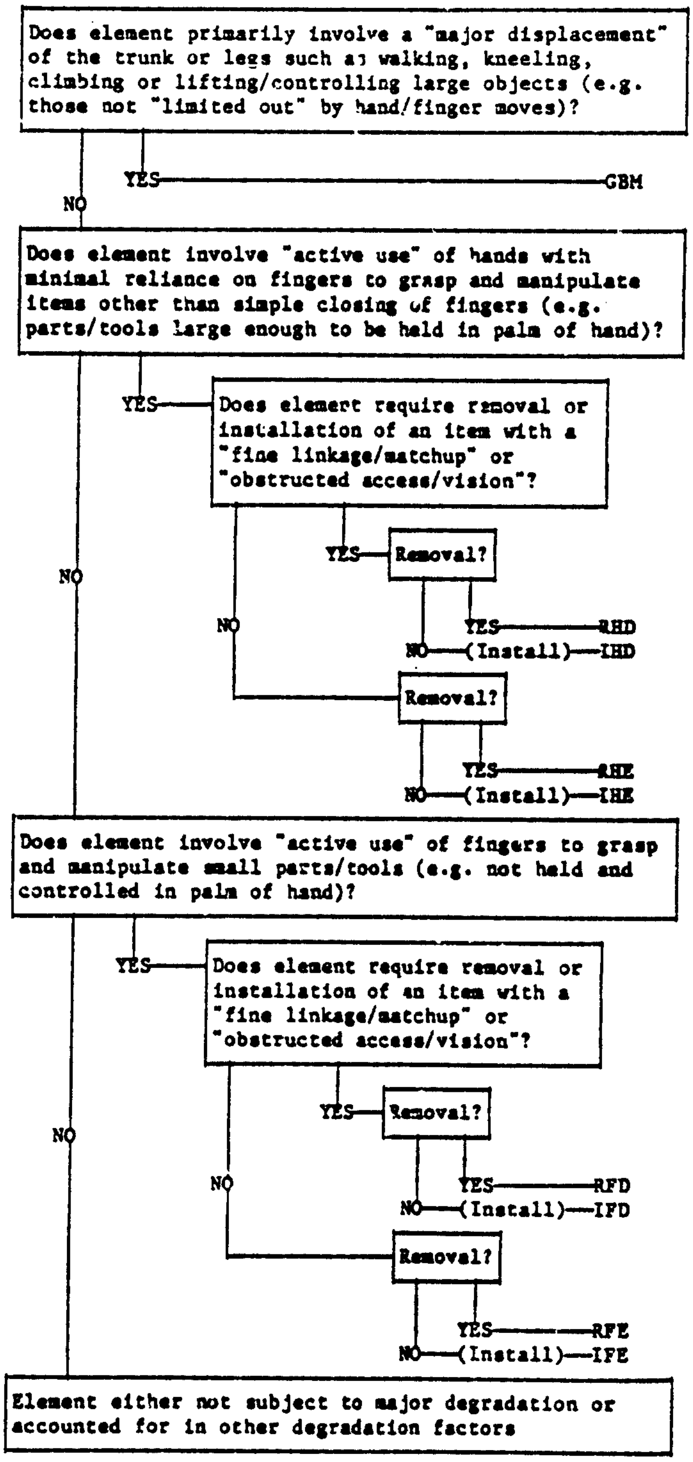


Figure 4-6. Decision Model for Mechanical Degradation

MAJOR DISPLACEMENT	- Refers to full body movements which involve more than two seconds to perform and are required to complete the task (unavoidable). For example, bending, turning or stepping toward a location to pick up or set down a tool is not considered a major displacement and is "limited out" by subsequent use of the tool.
LIMITED OUT	- Degradation associated with body assisted manual motion is considerd to be limited by the manual dexterity requirement rather than the gross body movement.
ACTIVE USE	- Application of pressure sufficient to gain control of a part/tool with hands or fingers requiring little use of trunk or leg muscles.
OBSTRUCTED ACCESS/VISION	- Difficulty experienced in viewing or touching items being removed or installed. Access and vision can be obstructed by the bulk of protective clothing when in confined spaces or due to the small size of objects being handled (e.g. items less than 1/4" held in fingers cannot be easily viewed or controlled when wearing gloves).
FINE MATCH UP/LINKAGE	- Accurate positioning is required for aligning/orienting two or more objects for the purpose of fastening or mating them together (e.g. fine threads, small clearances, tools which are difficult to position and use).

Figure 4-7. Definition of Terms

or loosening with a tool should be listed as separate elements.

2. Based on the parts or tools to be handled and the task element description, classify each element using the decision model. Adjacent task steps that receive the same movement classification can be combined to facilitate analysis.

The remaining actions necessary to obtain an estimate of degradation for a given task will be described in the following sections.

Movement Degradation Factors

In order to establish the level of degradation for a given maintenance task, degradation factors for each movement class must be estimated. Ideally, a large cross-section of repair tasks should be classified according to the proposed taxonomy and the degradation for each movement class determined from field test data. Unfortunately, there are no degradation data bases of sufficient detail to support an approach of this nature. However, it is possible to use video tapes of MOPP degradation tests to obtain the data required. The following sections will demonstrate a possible approach to accomplishing this goal.

DO-49 Maintenance Operations Test

As a result of the need for personnel degradation data, a portion of an extensive Department of Defense study program, called DO-49, was directed at quantifying the effect of MOPP IV on the performance of selected military tasks. Conducted by Dugway Proving Ground with the participation of the U.S. Army Ballistic Research Laboratory's Vulnerability/Lethality Division, this program includes five specific MOPP IV programs, with emphasis on operations in cold, moderate and hot temperatures as shown in Figure 4-8.

The maintenance operations test [85], conducted during April and May 1984, at moderate temperatures (39-68F), was the first of these

- MAINTENANCE OPERATIONS
- ARMOR OPERATIONS
- SIGNAL OPERATIONS
- MISSILE OPERATIONS
- NIGHT RECONNAISSANCE OPERATIONS

Figure 4-8. DO-49 MOPP IV Programs

investigative efforts. Video tapes from this test provided an excellent vehicle for analysis. Seven maintenance oriented tasks (Figure 4-9), representing a wide range of physiological demands on the individual soldier, were tested in Battle Dress Uniform (BDU) and in full protective posture (MOPP IV). Five teams/subjects were used for each task but the number of replications for each level of protection varied from one to eight depending upon the length of the job. Each task was divided into several events (an aggregation of task elements) and the time to complete each event was recorded. The schedule of treatments

Remove/Replace M60A3 Power Pack

Remove/Replace M60A3 Transmission

M109 Breech Block Repair

M60A3 Vehicle Recovery

M60 Machine Gun Repair

M901 ITV Traverse Mechanism Repair

FADAC Circuit Board Repair

Figure 4-9. Maintenance Operations Tasks (e.g. BDU and MOPP) was randomized. It is important to note that the individuals used in the test were trained in the appropriate Military Occupational Specialty (MOS) but were not provided the opportunity to perform the task prior to being tested for record.

Because of the wide variation of tasks and replications involved, it was necessary to select those tasks which could provide reasonably reliable data based on the criteria listed in Figure 4-10. Of

MINIMIZE TASK LEARNING EFFECTS

- use trials in which subject/team already performed the task at least twice (in MOPP or BDU)

GOOD VIDEO TAPE QUALITY

- consistent camera angles from trial to trial
- sufficient picture detail to observe manual motions

MINIMIZE GROUP INTERACTION EFFECTS

- individual tasks preferred
- two-man tasks which consist primarily of sequential steps performed by one individual with assistance from the other team member are acceptable

APPROPRIATE LEVEL OF MAINTENANCE

- unit or intermediate direct support maintenance only

CONSISTENT EXPERIMENTAL PROCEDURES

- procedures used to perform task consistent from trial to trial
- Experimental conditions the same for all trials

Figure 4-10. Task Selection Criteria

particular concern was the need to minimize learning effects and the ability to closely observe the manual operations being performed by the same person in each protective posture. Using this criteria, two tasks were found to have sufficient replications and good enough video quality to support analysis; M109 Breech Block Repair and the M60 Machine Gun Repair. A third task, the M901 ITV Traverse Mechanism Repair, met most of the criteria but the video tape did not provide sufficient detail for direct analysis. However, this task provided sufficient information for methodology demonstration and evaluation as will be discussed in the next chapter.

M109 Breech Block Repair. This task involved the removal and replacement of the breech block from a M109 Self-Propelled Howitzer (155mm artillery system). Although a two-man crew was used for this task, only the actual removal and subsequent replacement of the breech block itself required two individuals (2 out of 25 task elements). The remainder of the task was performed by one individual with the assistance of the other.

This repair job involved a wide range of physical activity ranging from gross body movement (GBM) to the precise removal/installation of components requiring fine finger dexterity (RFD and IFD). A detailed description of the steps involved in this task, obtained from the appropriate TM [7], is provided in Appendix B. Figure 4-11 shows a task element being performed in MOPP IV.

M60 Machine Gun Repair. This one-man task simulates the field repair of the 7.62 MM machine gun found in virtually all Army combat

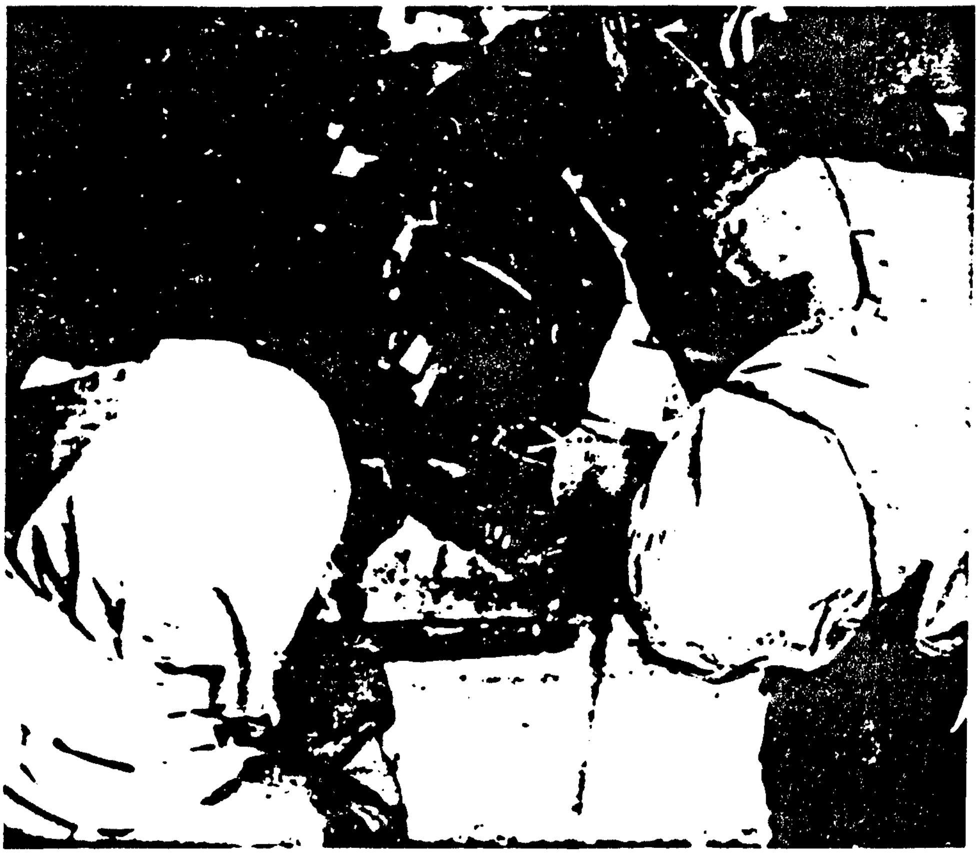


Figure 4-11. M109 Breech Block Repair in MOPP IV.

units. The procedure used for this job can be performed by the operator of the weapon and requires no specialized maintenance skill other than those specified in the operator's TM [6].

The task requires varying degrees of manual and fine finger dexerity but does not involve gross body movement. The assembly of the trigger group, which requires the alignment of several small parts, is a particularly difficult task element (see Figure 4-12). A full task description is provided in Appendix C.

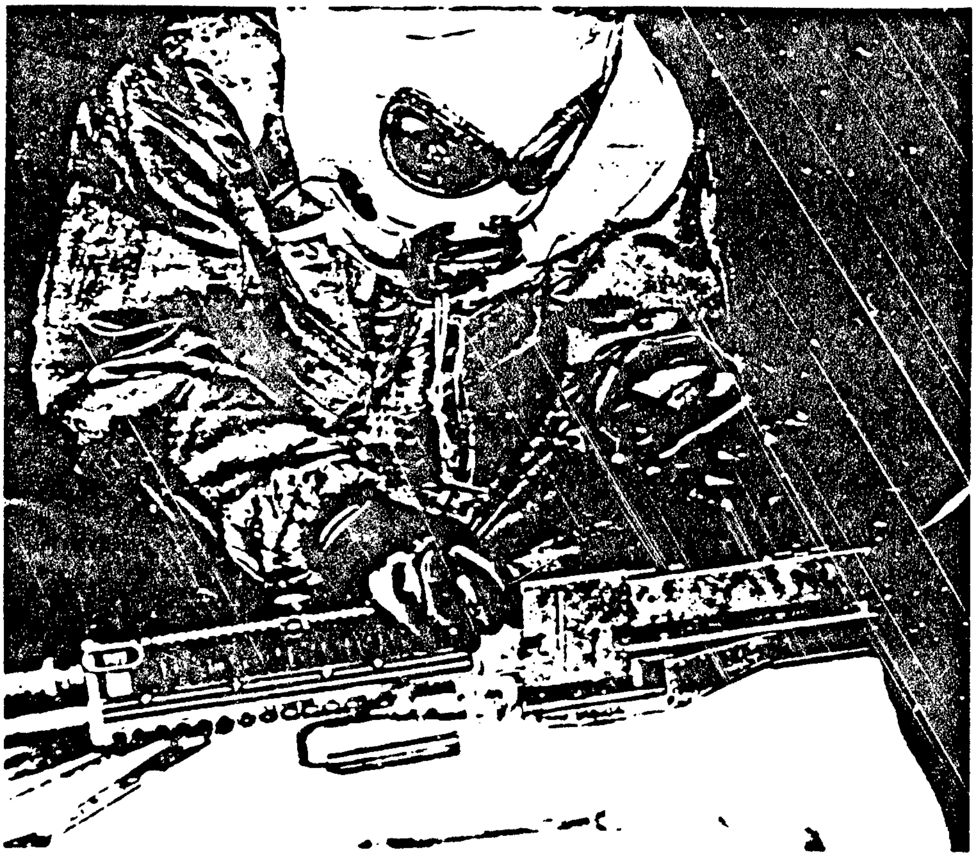


Figure 4-12. M60 Machine Gun Repair in MOPP IV.

Task Analysis

Using the appropriate technical manual, some basic knowledge of the task gained from an initial review of the video tapes and the proposed task taxonomy, each job was divided into task elements with a specific movement code. As recommended by Regalbuto [66], both audio and visual cues were used to assist in establishing the start and stop points for task elements. Task analysis data sheets, Figures 4-13 and 4-14, were developed for each task to be reviewed.

TASK: M109 BREECH BLOCK REPAIR TRIAL NUMBER:

ELEMENT NO.	CODE	ELEMENT DESCRIPTION	PARTS/TOOL HANDLED	BODY TIME	REMOVE		INSTALL		HANDLING		REMARKS
					DIFF	TIME	DIFF	TIME	F	A	
101	RFE	Remove Firing Mechanism	Firing Mechanism								
102	RHE	Remove Catch Plate & Spring	Plate & Spring Hammer								
103	RHD	Loosen Adjustor	Cresent Wrench								
104	RHE	Release Cam Tension	Cresent Wrench								
105	RHE	Remove Cam Damper	Cam Damper								
106	IFD	Secure Cam	Cam & Strap								
107	GBM	Open Breech Block	Operating Handle & Block								
108	GBM	Lock Breech Block	Breech Block								
109	RFD	Remove Plunger Group	Plunger Group & 2 Screws/Screwdriver								
110	RHD	Remove Firing Mechanism Housing	Housing Spanner Wrench								
111	RHE	Remove Obturator	Obturator								
112	GBM	Remove Breech Block	Breech Block Cleaning Staff								
113	GBM	Install Breech Block	Breech Block Cleaning Staff								
114	IHE	Install Obturator	Obturator								
115	IFD	Install Firing Mechanism Housing	Housing								
116	IHD	Tighten Firing Mechanism Housing	Spanner Wrench								
117	IFD	Install Plunger Group	Plunger Group & 2 Screws/Screwdriver								
118	GBM	Unlock Breech Block	Breech Block								
119	GBM	Close Breech Block	Breech Block								
120	RFD	Release Cam	Cam Cam Strap								
121	IHD	Install Cam Damper	Cam Damper								
122	IHE	Tighten Cam Tension	Cresent Wrench								
123	IHD	Tighten Adjustor	Cresent Wrench								
124	IHE	Install Catch Plate	Plate & Spring Hammer								
125	IFE	Install Firing Mechanism	Firing Mechanism								

Figure 4-13. M109 Breech Block Task Analysis Data Sheet (Task 1)

TASK: M60 MACHINE GUN REPAIR TRIAL NUMBER:

ELEMENT NO.	CODE	ELEMENT DESCRIPTION	PARTS/TOOL HANDLED	BODY TIME	REMOVE		INSTALL		HANDLING		REMARKS
					DIFF	TIME	DIFF	TIME	F	H	
201	RHE	Clear weapon	Cocking Handle								
202	RHD	Remove Barrel	Spring Detent, Latch & Barrel								
203	RHE	Loosen Gas Cylinder Nut	Open End Wrench								
204	RFE	Remove Gas Cylinder Nut & Piston	Nut & Piston								
205	RHE	Loosen Extension	Open End Wrench								
206	RFE	Remove Extension	Extension								
207	RHE	Loosen Gas Cylinder Plug	Box Wrench								
208	RFE	Remove Gas Cylinder Plug	Plug								
209	IFE	Install Extension	Extension								
210	IHE	Tighten Extension	Open End Wrench								
211	IFE	Install Gas Cylinder Nut & Piston	Nut & Piston								
212	IHE	Tighten Gas Cylinder Nut	Open End Wrench								
213	IFE	Install Gas Cylinder Plug	Plug								
214	IHE	Tighten Gas Cylinder Plug	Box Wrench								
215	IHD	Install Barrel	Barrel & Latch								
216	RFE	Remove Leaf Spring	Leaf Spring Screwdriver								
217	RFD	Remove Trigger Group	Trigger Group & Pin								
218	RFD	Remove Sear & Trigger	Sear, Sear Pin & Trigger								
219	IFD	Install Sear & Trigger	Sear, Sear Pin & Trigger								
220	IFD	Install Trigger Group	Trigger Group & Pin								
221	IFD	Install Leaf Spring	Leaf Spring Screwdriver								

Figure 4-14. M60 Machine Gun Task Analysis Data Sheet (Task 2)

In conducting the actual time-line analysis, a repetitive timing approach was used [44]. This approach, commonly referred to as the snapback method, involves timing each individual element and reseting the stopwatch. The method has the advantage of allowing direct time recording for each time element and provides a capability to eliminate foreign elements (incorrect procedures, unnecessary actions, etc.). Timing accuracy was facilitated by the pause and rewind features available on the video cassette recorder (VCR). Practice runs for each task were conducted until timing proficiency in the range of ± 1 second was obtained. Task elements which did not have well-defined start/stop points typically required several tries to obtain a consistent time value.

During the data collection process, problems were encountered with some of the trials. In several instances, two different task elements were performed simultaneously, either by two individuals or by a single individual attempting to do different elements with each hand. Since these occurrences were relatively few in number, the simultaneous actions were timed separately and recorded as sequential events with the appropriate comment in the remarks section of the data sheet. Additional problems were noted with subject errors and pauses (e.g. waiting to be told to proceed with the next step). These occurrences were considered foreign elements and not included in the data. In the case of subject error causing a task element to be redone, the point at which the correct sequence of events resumed was used as the element time. However, it should be stressed that difficulties encountered with correct procedures are inherent in many maintenance tasks and no attempt was made to eliminate the effect of this from the data. As a result, some task elements proved to be highly variable.

In addition to the time-line analysis, a procedural analysis was performed for each task. Specific areas of interest included the identification of procedural changes forced by the protective ensemble and the use of work arounds to facilitate task accomplishment in MOPP.

Descriptive Statistics

Prior to any formal analysis of movement classes, descriptive statistics were obtained on BDU and MOPP trials for both tasks using the BMDP1D (simple data description) software package [28]. To retain information concerning specific trials, case labels were assigned according to the scheme shown in Figure 4-15. A complete listing of all data and descriptive statistics for each task element are provided in Appendix D. All times are in units of seconds.

M = Treatment Type: B = BDU, M = MOPP, D = DECON*

2 = Team/Subject number

5 = Task replication number (number of times team/subject had done task)

2 = Treatment replication number (number of times team/subject had done task under the current treatment type

*DECON trials were used as estimates of MOPP performance where MOPP trials were limited (thin layer of clothing used over overgarment/gloves to detect chemical contact).

Figure 4-15. Case Labeling System

Since mean element completion times ranged from a low of 4.30 seconds to a high of 98.64 seconds, the coefficient of variation (CV) proved to be useful as a measure of element variability. It was expected that, in general, MOPP trials would have higher CV values than BDU trials and that task elements classified as "difficult" would represent the majority of this increase. A brief review of the data, as shown in Table 4-1, did not fully support these expectations. Although the more dexterous machine gun task showed an increase in variability for MOPP performance, the breech block repair job showed little change.

Fairly good consistency was noted between the variability of a given movement class between BDU and MOPP trials, particularly in the M60 task. If a task element was highly variable in BDUs, it normally showed up as highly variable in the MOPP trials as well. In addition, a comparison of movement classes indicated a few more "difficult" task

Table 4-1. Task Time Variation

TRIAL	% of Task Elements with CV > .35	Movement Categories with CV > .35
M60 Machine Gun (BDU)	27%	RHE(3), PFE(1), IHE(1), IFD(1)
M60 Machine Gun (MOPP)	50%	RHE(3), RFE(1), IHE(2), IFD(2), RFD(1), IFE(1)
M109 Breech Block (BDU)	24%	RHE(1), RHD(1) IHD(1), GBY(2) IFE(1)
M109 Breech Block (MOPP)	20%	RHE(2), RHD(1) IHD(1), RFD(1)

elements were reported as variable for MOPP trials than for BDU. Although neither of these observations are considered significant enough to support any strong conclusions, it does appear that the use of protective clothing may increase the variability of task times for some tasks.

Movement Category Analysis

For the analysis of the nine movement categories established, three major objectives were identified. First, it was necessary to discover if any significant differences existed between task element degradations in the same category. Major problems in this area could indicate that the taxonomy does not establish a meaningful relationship between physiological movements and task degradation. Secondly, the analysis was to be used in highlighting inconsistencies in the taxonomy or decision model which may be contributing to problems associated with the first objective. Estimation of movement category degradation factors represents the third objective.

Regression analysis, with indicator variables representing each task element within a given movement category, was used to meet the stated objectives. This approach represents a general method of analysis of variance and provides a direct indication of the contribution of each task element to the regression, assuming the other variables are in the model. Because the subjects performing the two tasks were not the same, it was not possible to test for subject differences. Although the small number of individuals/teams used in these two tasks could be expected to contribute to data variability, it is generally accepted that subject differences would be small given a larger sample

[44]. With recognition of this limitation, the following sections will demonstrate an approach to analyzing movement categories and obtaining the desired degradation factors.

Regression Models. Two linear regression models were used; a ratio model and a difference model. In the ratio model, the response variable, Y_{ij} was defined as the average BDU time for subject i and task element j divided by the average MOPP time for the same subject and task element. By defining Y_{ij} in this manner, it was hoped that some of the error associated with subject differences could be eliminated. The difference model defined the response variable as the difference between the average MOPP and BDU times for each individual and task element. This model, if deemed suitable, would have an advantage in that more is known about the distribution of the difference between two random variables than for a ratio of variables.

Nine models of each type were constructed, two for each movement class. Because there was no reason to suspect any interaction between task elements within a given class, no interaction terms were included in these models. The general ratio model:

$$Y_{ij} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots B_K X_K + \varepsilon \quad (6)$$

where

$$Y_{ij} = \frac{\text{mean BDU time, subject i, element j (sec)}}{\text{mean MOPP time, subject i, element j (sec)}}$$

β_0 = intercept

β_K = regression coefficients

K = number of task elements included in movement class minus one

X_K = indicator variables which identify specific task elements

ε = error term

is the same as the difference model except for the redefinition of the response variable. It should be noted that the number of indicator variables is one less than the number task elements included in the model. Inclusion of one variable for each task element would render the least squares normal equations unsolvable since the Kth variable would be completely determined by the first K-1 variables entered into the regression equation. The excluded task element is often referred to as the reference category [57].

To illustrate this procedure, the movement category IFE will be used. Using the task element classifications shown in Figures 4-13 and 4-14, four IFE elements are available for estimating the degradation associated with this movement class (one from Task 1, three from Task 2). Using a ratio model given by:

$$Y_{ij} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 \qquad (7)$$

each task element is defined by the variables shown in Table 4-2. In this case, task element 213 has been used as the reference category. This figure also indicates the expected degradation values for each element, given a multiple regression solution.

For illustration purposes, selected results from the IFE ratio model run are provided in Figure 4-16. With the possible exception of

Table 4-2. IFE Indicator Variables.

TASK ELEMENT	INDICATOR VARIABLES X1	X2	X3	PREDICTED DEGRADATION (Y')
125	1	0	0	$\beta_0 + \beta_1$
209	0	1	0	$\beta_0 + \beta_2$
211	0	0	1	$\beta_0 + \beta_3$
213	0	0	0	β_0

REGRESSION TITLE IS
IFE RATIO

DEPENDENT VARIABLE. . . . . 7 Y
TOLERANCE .0100
ALL DATA CONSIDERED AS A SINGLE GROUP
MULTIPLE R .1707 STD. ERROR OF EST. .2151
MULTIPLE R-SQUARE .0291

ANALYSIS OF VARIANCE

	SUM OF SQUARES	DF	MEAN SQUARE	F RATIO	P(TAIL)
REGRESSION	.0139	3	.0046	.100	.9582
RESIDUAL	.4627	10	.0463		

VARIABLE		COEFFICIENT	STD. ERROR	STD. REG COEFF	T	P(2 TAIL)	TOLERANCE
INTERCEPT		.82324					
X1	4	-.07417	.15709	-.193	-.472	.6469	.58333
X2	5	-.08606	.17563	-.191	-.490	.6347	.63636
X3	6	-.04967	.17563	-.110	-.283	.7831	.63636

Figure 4-16. IFE Ratio Model Results.

213, there is fairly close agreement between the degradations for each task element. In addition, the lack of any significance of regression or individual coefficient contribution leads to the conclusion that the degradation values associated with each task element included in IFE are not significantly different at the .10 level. Further analysis of the complete BMDP1R [28] IFE regression output used to obtain this data, provided in Appendix E, indicates no significant problems with the assumptions of non-constant error variance or normality and a high positive correlation between BDU and MOPP times was found as expected.

Similar analyses of the remaining ratio and difference models were performed as summarized in Table 4-3. While the ratio models did not show inconsistencies with any of the movement categories, the difference models produced a number of significant effects. On closer analysis, the task elements indicated as highly significant contributors to the regression were also the three most time consuming elements to perform. With the response variable defined as the difference between the MOPP and BDU task element times, this result is not surprising. This suggests that the ratio model is the appropriate model to use in this situation.

In conducting the residual analysis for each model, particular attention was given to the identification of possible outliers. The majority of the points that were two standard deviations or more away from the mean occurred when only one MOPP and/or BDU trial was available for a given subject. Under this circumstance, it is not unrealistic to expect an uncharacteristically low or high time value. To reduce this source of variation would involve discarding a complete

Table 4-3. Regression Results

Code	Ratio Model			Difference Model		
	Regr. Signif. (α=.10)	Coefficients Significant (element #s)	Resid. Plots *	Regr. Signif. (α=.10)	Coefficients Significant (element #s)	Resid. Plots *
GBM	no	none	ok	no	none	ok
RHE	no	none	resid.	no	#103 **	ok
RHD	no	none	norm	no	none	norm
IHE	no	none	norm	yes	#122 **	ok
IHD	no	none	ok	no	none	norm
RFE	no	none	ok	no	#204,206 ***	ok
RFD	no	none	ok	no	#120,217 ***	ok
IFE	no	none	ok	no	none	ok
IFD	no	none	ok	yes	#219 **	ok

* Resid = weak trend in residual plot
Norm = weak normal plot
** Highly significant contributors to regression
*** Would not contribute significantly at α = .05

series of MOPP and BDU trials, further reducing an already small sample size. Without any strong evidence that these trials were true outliers, the cost of discarding this data in terms of statistical significance would likely exceed the gain in reduced variability.

In conclusion, the lack of any significant contribution of either the partial regression coefficients or the regression models a whole, seems to indicate the taxonomy succeeds in classifying task elements according to their level of degradation. However, the high variability of the data makes the lack of any significant difference in task element degradation within classes a weak conclusion. To put this result in perspective, the best that can be said at this point is that no serious problems appear to exist with the taxonomy.

Estimation of Degradation Factors

As a data consistency check, degradation factors for each category of movement were calculated in two ways. Using an average of the predicted degradations for each task element obtained from the regression output, an estimate was obtained which partially accounted for performance differences between individuals (ratio model). The alternate method, which assumes no differences between subjects, involved a simple average of all BDU task element times divided by the average of all MOPP times.

The results of these calculations are displayed in Table 4-4. For roughly 85 percent of the task elements (7 of 46), the two degradation values were within ± .10 of each other and within ± .05 over 60 percent of the time. This agreement was further reflected in the average degradation values for each movement class and their relative rank as shown in the table. Because the estimates obtained from the regression models have a slight advantage in terms of smaller standard deviations for the majority of movement classes, these values were selected for further analysis as described in this next section.

Degradation Factor Analysis

While the previous section provided some insight as to the

Table 4-4. Movement Degradation Values.

ELEM NO.	ELEMENT DESCRIPTION \ MOVEMENT CODE & DEGR.	IFD .67	IFE .77	RFD .74	RFE .84	IHD .70
106	Secure Can	.707 (.711)				
115	Install F.M. Housing	.715 (.678)				
117	Install Plunger Group	.766 (.734)				
219	Install Sear & Trigger	.609 (.581)				
220	Install Trigger Group	.661 (.735)				
221	Install Leaf Spring	.568 (.491)				
125	Install Firing Mech.		.749 (.726)			
209	Install Extension		.737 (.736)			
211	Install G.C.Nut & Pist.		.774 (.684)			
213	Install G.C. Plug		.823 (.633)			
109	Remove Plunger Group			.740 (.701)		
120	Release Can			.727 (.679)		
217	Remove Trigger Group			.859 (.634)		
218	Remove Sear & Trigger			.617 (.562)		
101	Remove Firing Mech.				.847 (.790)	
204	Remove G.C. Nut & Pist.				.783 (.744)	
206	Remove Extension				.845 (.791)	
208	Remove G.C. Plug				.783 (.757)	
216	Remove Leaf Spring				.955 (.860)	
116	Tighten F.M. Housing					.869 (.721)
121	Install Can Damper					.643 (.621)
123	Tighten Adjustor					.677 (.718)
215	Install Barrel					.591 (.658)
	MEAN DEGRADATION	.671(.655)	.771(.695)	.736(.644)	.843(.788)	.695(.680)
	STANDARD DEVIATION	.073(.097)	.038(.047)	.099(.061)	.070(.045)	.121(.049)
	DEGRADATION RANK	1 (2)	4	3 (1)	6 (5)	2 (3)

ELEM NO.	ELEMENT DESCRIPTION \ MOVEMENT CODE & DEGR.	IHE .82	RHD .88	RHE .93	GBM .89
114	Install Obturator	.870 (.823)			
122	Tighten Can Tension	.983 (.985)			
124	Install Catch Plate	.875 (.881)			
210	Tighten Extension	.707 (.750)			
212	Tighten G.C. Nut	.705 (.700)			
214	Tighten G.C. Plug	.776 (.760)			
103	Loosen Adjustor		.844 (.789)		
110	Remove F.M. Housing		.868 (.806)		
202	Remove Barrel		.940 (.978)		
102	Remove Catch Plate			.924 (.866)	
104	Release Can Tension			.885 (.855)	
105	Remove Can Damper			1.031 (.932)	
111	Remove Obturator			.840 (.819)	
201	Clear Weapon			.846 (.833)	
203	Loosen G.C. Nut			.849 (.867)	
205	Loosen Extension			.951 (.813)	
207	Loosen G.C. Plug			1.073 (.935)	
107	Open Breech Block				.879 (.796)
108	Lock Breech Block				.926 (.930)
112	Remove Breech Block				.854 (.831)
113	Install Breech Block				.971 (.956)
118	Unlock Breech Block				.880 (.992)
119	Close Breech Block				.835 (.824)
	MEAN DEGRADATION	.819(.817)	.884(.858)	.925(.865)	.891(.880)
	STANDARD DEVIATION	.110(.104)	.050(.105)	.088(.047)	.050(.081)
	DEGRADATION RANK	5 (6)	7	9 (8)	8 (9)

Numbers in parenthesis are the sum of all BDU trials divided by the sum of all MOPP trials.
Numbers prior to parenthesis are the average of degradations predicted using regression.

validity within each movement category, this discussion will center on the ability to distinguish between categories. Ideally, it would be desirable to consolidate some of the categories if this could be done without significant loss of accuracy or generality. Three specific questions need to be answered here in terms of degradation.

1. Is there a significant difference between handling classes (finger verses hands)?
2. Given an element type and handling class, is there a significant difference between difficulty classifications?
3. Given a handling and difficulty class, is there a substantial difference between element types (removal versus installation)?

If there was reason to expect that the distribution of the ratio of BDU to MOPP task times was normal, the answers to these questions would be easy to obtain. Unfortunately, this distribution is unknown. In an effort to account for this uncertainty, both parametric and non-parametric tests were done on the data.

T-Test. If the populations associated with two movement categories can be assumed to be normal and independent, a t-test can be used to test the hypothesis:

$$H_0: \mu_1 = \mu_2$$
$$H_1: \mu_1 \neq \mu_2$$

Using BMDP3D [41], two-sample t-tests, with and without the assumption of equality of variances, were made. In addition, Levene's test for equality of variances was also computed. This test has been shown to be less sensitive to departures from normality but must be used with caution for small sample sizes [17].

Kruskal-Wallis Test. This non-parametric test is an extension of the Mann-Whitney test for two independent samples and investigates the hypothesis [25]:

H_0: All of the K population distribution functions are identical.

H_1: At least one of the populations tends to yield larger observations than at least one of the other populations.

In addition to requiring the assumptions of independence within and between samples, this test also assumes that all samples are random [25]. Although there is little reason to question their independence, the selection process used to determine which trials would be used for analysis (e.g. to eliminate learning effects) leaves the randomness assumption open to question. However, the ability of this test to use more of the information available than some other commonly used tests and common reliance on the randomness of samples led to the decision to use the Kruskal-Wallis Test. BMDP3S [28] was used for this test.

Test Results. Tables 4-5 and 4-6 summarize the t-test and Kruskal-Wallis test results. In the case of the non-parametric test, initial computer runs were made using all four movement categories within a given handling class (e.g. fingers and hands) as a check to insure that at least one of the four categories were different from the other three. Significant differences were noted for both handling

Table 4-5. Finger Degradation Tests

	IFD .671 6	IFE .771 4	RFD .736 4
IFD .671 6			
IFE .771 4	YES (.60) YES		
RFD .736 4	NO (.25) MARG		
RFE .843 5		YES (.40) YES	MARG (.50) MARG

KEY:

IFE	Movement Code
.768	Degradation
4	No. of Observations
YES	T-Test Results
(.60)	Approx. Power of T-Test
YES	Kruskal-Wallis Results

YES = significant at $\alpha = .10$
MARG = significant at $.10 < \alpha < .20$
NO = not significant at $\alpha = .20$

classifications, although the fingers showed a much higher degree of significance (.0093 versus .0994). It should also be noted that a comparison of finger versus hand degradation was also highly significant ($\alpha = .0036$).

Based on the objectives stated at the beginning of this section, tests of selected category pairings were conducted as shown in the

Table 4-6. Hand Degradation Tests

	IHD .695 4	IHE .819 6	RHD .884 3
IHD .695 4			
IHE .819 6	MARG (.25) MARG		
RHD .884 3	YES (.60) MARG		
RHE .925 8		YES (.70) YES	NO (.10) NO

KEY:

RHD	Movement Code
.884	Degradation
3	No. of Observations
YES	T-Test Results
(.60)	Approx. Power of T-Test
YES	Kruskal-Wallis Results

YES = significant at $\alpha = .10$
MARG = significant at $.10 < \alpha < .20$
NO = not significant at $\alpha = .20$

tables provided. Good test result consistency was noted between the Kruskal-Wallis and t-tests. This tends to reinforce the conclusion that, in the absence of distributional information, the majority of comparable movement classes do differ. However, the lack of significant difference between RFD and IFD was surprising. It was expected that the difference between installation and removal in a situaton results must be considered when reviewing this information. A brief discussion will be provided in the last chapter which will address future test design considerations to limit the need for some of these assumptions.

Procedural Analysis

The analysis of task procedures was aimed at identifying changes in the method used to perform task elements (workarounds). Specifically, it was necessary to know how the use of protective clothing influenced maintenance procedures and to estimate the potential effect procedural changes might have on estimating task degradation.

Although there are a number of instances in the literature in which the use of MOPP forced changes in procedure, insufficient information is available concerning the frequency and effect of workarounds. Based on a detailed analysis of the two tasks previously discussed and a brief review of the remaining DO-49 video tapes, very few procedural changes were observed. Of those changes noted (see Table 4-7), the majority would simply be reflected as task-time increases and are not expected influence the proposed analysis methodology. However, the finger installation of nuts, or similar threaded fasteners, and subsequent wrench tightening bears a closer analysis.

As described in Table 4-7, there is a tendency to do more finger tightening of nuts when doing so against increasing resistance. It is suspected that the increased ability to apply angular force and protective effect of the gloves (e.g. against scraping of fingers/hands) influences subjects to spend more time on this activity, causing it to

Table 4-7. Procedural Changes

TYPE OF CHANGE	DESCRIPTION OF CHANGE	EXAMPLE	EFFECT ON METHODOLOGY
Tool Usage	Increased incidental use of tool to assist in action done primarily with hands or fingers	Punch used to disassemble M60 Trigger Group	None, limited only by finger manipulation without tool
Tool Usage	Use of tool in MOPP when not required in BDU to replace bare finger manipulation	Pliers used to pick up thin washers/snap rings	None, pliers primarily manipulated by fingers (no change in movement category)
Disorientation	More time spent trying to figure out what to do next (even after many trials)	General Observation	None, accounted for in Psychological Degradation Factor (not part of mechanical degr.)
Deliberate Movement	More deliberate pick-up and return of tools or parts	General Observation	None, accounted for in all movement degradation factors
Finger Tightening	Against increasing resistance, tendency to tighten nuts w/o tool more in MOPP which decreases wrench tightening time	Installation of Cam Damper on Breech Block	Change of movement difficulty class required

be highly degraded in terms of task time. As a result, the subsequent time required for wrench tightening shows little or no degradation. To adapt the decision model for this circumstance, it was necessary to change the classification of tightening the cam damper from "difficult" to an "easy" classification (initial installation was classified as difficult). If the installation had been classified as easy, it would have been necessary to change it to a difficult class. In other words, related operations must be of different difficulty levels in this situation.

In an attempt to verify this effect, a separate experiment, described in Appendix G, was designed and executed by another researcher [76]. Although the actual degradation values differed by 15 to 20 percent as compared to those from DO-49 maintenance tasks, the difference in degradation was clearly reflected in the data and the comments of the subjects. Without exception, the time required to wrench tighten a nut actually decreased when in MOPP while finger tightening the nut was highly degraded (average degradation was .55 for IFD).

Degraded Effectiveness

To complete the Degradation Analysis Methodology for Maintenance (DAMM), it will be necessary to translate the degradation of movement categories into a "mechanical degraded ability" for a complete task. Then, through a modification to the current BRL Performance Degradation Model, this mechanical degradation can be combined with other degradation factors (e.g. heat build-up, psychological) to produce an estimate of degraded effectiveness for maintenance tasks.

Mechanical Degraded Ability

To estimate the mechanical degradation associated with a given task, an estimate of the relative contribution of each movement category to total task time is required. This can be accomplished either indirectly, through a subjective estimate made by a person familiar with the task or directly, by timing a qualified mechanic while he performs each task element. Although the direct approach is obviously more accurate, the taxonomy was designed to facilitate subjective estimates. By first breaking down the job into element types, the percentage of time spent on removal, installation and gross body movement (if any) can be estimated. With this initial partitioning, removal and installation can each be further subdivided by the contribution the handling/difficulty classes make to task time (maximum of four categories). Using this percentage breakdown and movement category degradation values, a weighted average can be calculated to arrive at the desired mechanical degraded ability.

Degraded Effectiveness Calculation

In DAMM, mechanical degradation is defined to include the manual dexterity, mobility encumbrance and near vision characteristics associated with maintenance tasks. Therefore, it is necessary to combine these three factors in the BRL model to produce a single estimate of the degradation for directed, physical movement. By using this single factor in the BRL algorithm, the problem of having to measure near visual performance is removed. Additionally, the algorithm, which discounts the effect of successive factors on Degraded Effectiveness ($ED_{JM}(t)$) according to

$$ED_{JM}(t) = \prod_{K=1}^{N} \left(1 - F^{K}_{JKM}(t)\right) \qquad (5)$$

is less likely to overestimate the impact of movement degradation. Once mechanical degraded ability factor has been corrected for task Demand (DM_{JI}) using

$$F_{JIM}(t) = \begin{cases} 0 & : \; DA_{IM}(t) > DM_{JI} \\ \dfrac{DM_{JI} - DA_{IM}(t)}{DM_{JI}} & : \; DA_{IM}(t) \leq DM_{JI} \end{cases} \qquad (3)$$

A mechanical degradation factor, $F_{JIM}(t)$, can be obtained and inserted into equation 5 to yield the overall degraded effectiveness for the task.

Redefinition of Near Vision

To account for near visual requirements which are not associated with directed physical movement, the physiological factor for near vision must be redefined. Specifically, it should be redefined as visual acuity required for such tasks as reading instructions, using measuring devices or acquiring a target when a lapse of other motion occurs. It is expected that optical coupling problems with various target acquisition systems will be a primary contributor to this source of degradation for combat tasks.

It should be noted that this definition does not include reference to the restriction of vision due to mask fogging. This effect occurs most frequently in conditions of high temperature/humidity or during periods of heavy exertion. Since these variables are associated with the BRL factor for heat stress, it would seem that this effect should be partially accounted for in the heat build-up factor.

CHAPTER V

DEMONSTRATION AND EVALUATION

General

This chapter addresses those issues which are related to applying the methodology described in this thesis. The following sections focus on three objectives as listed below.

1. Demonstrate the application of DAMM using a maintenance task which was not used to develop movement degradation factors.
2. Evaluate the performance and ease of application of DAMM in predicting task time degradation.
3. Discuss the sensitivity of DAMM parameters and analyze its impact upon unit effectiveness.

As with any modeling effort, the evaluation of DAMM should be based on how well it achieves its intended purpose. Unfortunately, the criterion used to assess its performance is difficult to establish given the limited amount of reliable information available on the subject. As such, qualitative evaluation schemes typically dominate the modeling of performance degradation.

In addition to its ability to provide reasonable estimates of performance degradation, the ease of application plays a central role in the evaluation of DAMM. Unless it can be applied with readily available references and expertise, it could become almost as costly to apply as the experimentation it is designed to replace.

Demonstration

Task Selection

As discussed in Chapter IV, a variety of criteria were used to select DO-49 maintenance tasks for analysis. However, for the purposes of methodology demonstration, the ability to observe each task element on video tape was not essential. Of the five remaining maintenance tasks, the M901 Improved Tow Vehicle (ITV) traverse mechanism appeared to offer the best mix of work content while meeting the desired criteria.

The ITV traverse mechanism task challenged DAMM's ability to predict degradation for a task requiring a much higher-than-average degree of manual precision. Performance of this task involved removal and installation of a variety of gears, washers, snap rings, screws and access plates. The fine linkages associated with many of the components caused the majority of task elements to be classified as "difficult." This was in distinct contrast to the machine gun and breech block repair tasks which had a much wider variety of handling classes and difficulty levels.

Task Analysis

The traverse mechanism video tapes were used for three purposes; (1) to gain sufficient experience with the task to distinguish between "difficult" and "easy" task elements, (2) to insure all task elements were being performed and in the manner prescribed by the appropriate TM [15] and (3) to obtain a percentage breakdown for task elements. It should be noted that experience with this task would eliminate the need to obtain this information from video tapes.

After viewing the tapes, the ITV TM was used to identify the task elements associated with this repair job. Appendix H contains a listing of these task elements. Using the DAMM decision model, task elements were classified and an estimate of their respective contributions to total unencumbered (BDU) task time obtained from the video tapes. An estimate of MOPP time for each element was also obtained for the purpose of evaluating the expected increase in the percentage of total task time spent on installation tasks. The results of this analysis are presented in Table 5-1.

As expected, there was a noticeable increase in the contribution of installation task elements to total task time in MOPP, justifying their higher degradation values. Overall, there was a five percent shift; the BDU task run showed 45 percent removal and 55 percent installation while the MOPP trial breakdown was 40 and 60 percent for removal and installation, respectively.

Given a predicted degraded ability of .735, a comparison to the experimentally determined ability of .667 shown in Table 5-2, indicates reasonable agreement between the two values. With the small number of observations used to estimate the RFD and IFD degradation values, which make up over 75 percent of the work content, a difference of approximately .07 is well within the ± 20 percent accuracy typically found with highly aggregated work measurement techniques such as MTM-3. However, caution should be exercised in interpreting the significance of these results. As will be discussed in the next chapter, a truely

Table 5-1. Traverse Mechanism Task Analysis

TASK ELEM.	MOVEM. CLASS	BDU TIME	MOPP TIME	% OF TOTAL (BDU/MOPP)	DEGR. FACTOR	CONTRIB TO TASK DEGR.
306	RHD	50.9	99.8	7.4/8.4	.88	.065
301	RHE	3.1	5.3	6.9/4.0	.93	.064
310	RHE	44.7	32.9			
302	RFD	30.6	39.3	29.5/27.1	.74	.218
303	RFD	15.4	26.4			
304	RFD	16.4	33.7			
305	RFD	48.1	80.2			
307	RFD	32.8	46.4			
308	RFD	23.6	39.8			
309	RFD	36.1	57.1			
312	IHD	17.0	39.3	2.5/3.3	.70	.018
311	IHE	43.7	30.1	7.1/3.3	.82	.058
317	IHE	5.3	9.0			
313	IFD	67.4	98.6	46.6/54.6	.67	.312
314	IFD	19.4	35.6			
315	IFD	28.2	79.4			
316	IFD	37.1	121.7			
318	IFD	36.0	61.8			
319	IFD	46.2	67.5			
320	IFD	86.3	184.4			

PREDICTED MECHANICAL DEGRADED ABILITY = .735

Table 5-2. Traverse Mechanism Degradation

BDU TRIAL*	TIME	MOPP TRIAL*	TIME
241	28.9	142	27.1
362	12.4	342	29.9
441	15.4	352	21.4
541	13.0		
MEAN = 17.43		MEAN = 26.13	

$$\text{Experimental Degraded Ability} = \frac{17.43}{26.13} = .667$$

*Based on trials where subjects had already performed the task at least three times. Lack of paired BDU and MOPP runs for these subjects required use of an overall average to estimate "experimental" degraded ability.

meaningful evaluation of DAMM can only be obtained through more precise estimates of movement category degradations and further application of this methodology to a much wider range of maintenance tasks.

Given a predicted mechanical degraded ability of .735, it is a simple matter to incorporate this factor into the calculation of degraded effectiveness for the traverse mechanism task as required in the BRL degradation model. Assuming a demand factor (DM_{JI}) of one (e.g. task must be accomplished as quickly as possible), a temperature of 10°C, and the appropriate MOPP IV Degraded Abilities (DA_{IM}) for Psychological and Heat Buildup Factors from Table 3-1, Degradation Factors (F_{JIM}) for each physiological area can be calculated as follows:

$$F_{J14} = \frac{DM_{J1} - DA_{14}}{DM_{J1}} = \frac{1 - .735}{1} = .265 \text{ (mechanical factor)}$$

$$F_{J24} = \frac{DM_{J2} - D_{24}}{DM_{J2}} = \frac{1 - .800}{1} = .200 \text{ (psychological factor)}$$

$$F_{J34} = \frac{DM_{J3} - DA_{34}}{DM_{J3}} = \frac{1 - .900}{1} = .100 \text{ (heat buildup factor)}$$

By ordering these factors, Degraded Effectiveness can then be calculated as follows:

$$ED_{J4}(10) = \prod_{K=1}^{3} \left(1 - F_{JK4}^{K}(10)\right)$$

$$= (1-.265^1)\ (1-.200^2)\ (1-.100^3) = .705$$

Based on this example, the task can be expected to take 1.42 (1/.075) times longer in MOPP than in BDU.

Evaluation

Comparison of Degradation Values

In addition to predicting the degraded effectiveness of specific tasks, as demonstrated in the previous section, a broader analysis of the degradation values asociaed with DAMMA is appropriate. Specifically, the degradations predicted by DAMM should be in the range of those reported through experimentation.

The review of maintenance-oriented field tests described in Chapter II (Table 2-1) revealed degraded effectiveness values in the the range .66 to 1.0. As a much larger data base, maintenance tasks asociated with MAGIC fall within the range .5 to 1.0. Although this data reflects moderate temperature ranges, it can be assumed that some heat buildup and psychological effects are included in these degradations. Given this assumption, it will be necessary to add in these effects, which are accounted for separately in the BRL model, in order to compare these values.

Using a hypothetical worst case of 40 percent RFD and 60 percent IFD, the mechanical degradation predicted by DAMM would be

$$(.40)(.736) + (.60)(.671) = .697$$

By adding in the degraded ability for heat buildup at 20°C (.6) and a psychological factor of .9, the resulting degraded effectiveness at a demand of one would be

$$ED_{J4}(20) = (1 - .400^1)(1 - .303^2)(1 - .100^3) = .539$$

As a best case, a task which consists solely of gross body motion (GBM) would involve a mechanical degradation of .891. Using a temperature of 0°C (no degradation), the resultant degraded effectiveness would be

$$ED_{J4}(0) = (1 - .109^1)(1 - .100^2)(1 - 0^3) = .883$$

It is apparent from these values that DAMM provides degradation estimates which are representative of those found in field situations. However, the range of effectiveness is not as wide as would be expected to occur in realistic situations. Although the aggregated classification methodology used in DAMM could be expected to underpredict degradation in difficult tasks and overpredict easy jobs (due the averaging of task element degradations within a given class), movement category degradations based wider range of tasks may improve the situation.

A potentially greater contribution to accuracy could be obtained through the addition of a third difficulty classification similar to that used in MAGIC. Assuming sufficient data was available to support this modification, a probable gain in accuracy would be realized at the expense of ease in application. The significant increase in movement categories would complicate the classification of task elements and the proportional breakdown.

Sensitivity of Unit Effectiveness

As discussed in Chapter III, the BRL degradation algorithm provides input to the Army Unit Resiliency Analysis (AURA) model. AURA is unique in that it represents an amalgamation of accepted state-of-the-art methodologies for evaluating the effectiveness of Army units. AURA outputs, displayed in Figure 5-1, provide time dependent information on unit resiliency. However, MOPP degradation is only one of the many input routines as shown in Figure 5-2.

Since the need for more accurate degradation information is a key motivating factor for this research, its impact upon unit effectiveness must be established. Two Army units were evaluated using AURA to investigate the relationship between degraded abilities, task performance and unit effectiveness.

A Forward Support Maintenance Company, which provides intermediate direct support maintenance to combat units, was initially evaluated

- QUANTITATIVE UNIT EFFECTIVENESS
- PERSONNEL AND MATERIEL LOSSES
- TASK PERFORMANCE AND DEGRADATION
- REASON FOR DEGRADATION ('ACHILLES' HEEL)
- MOST EFFECTIVE METHODS OF MISSION ACCOMPLISHMENT

Figure 5-1. AURA Outputs

AURA FAMILY OF METHODOLOGIES AND INPUTS

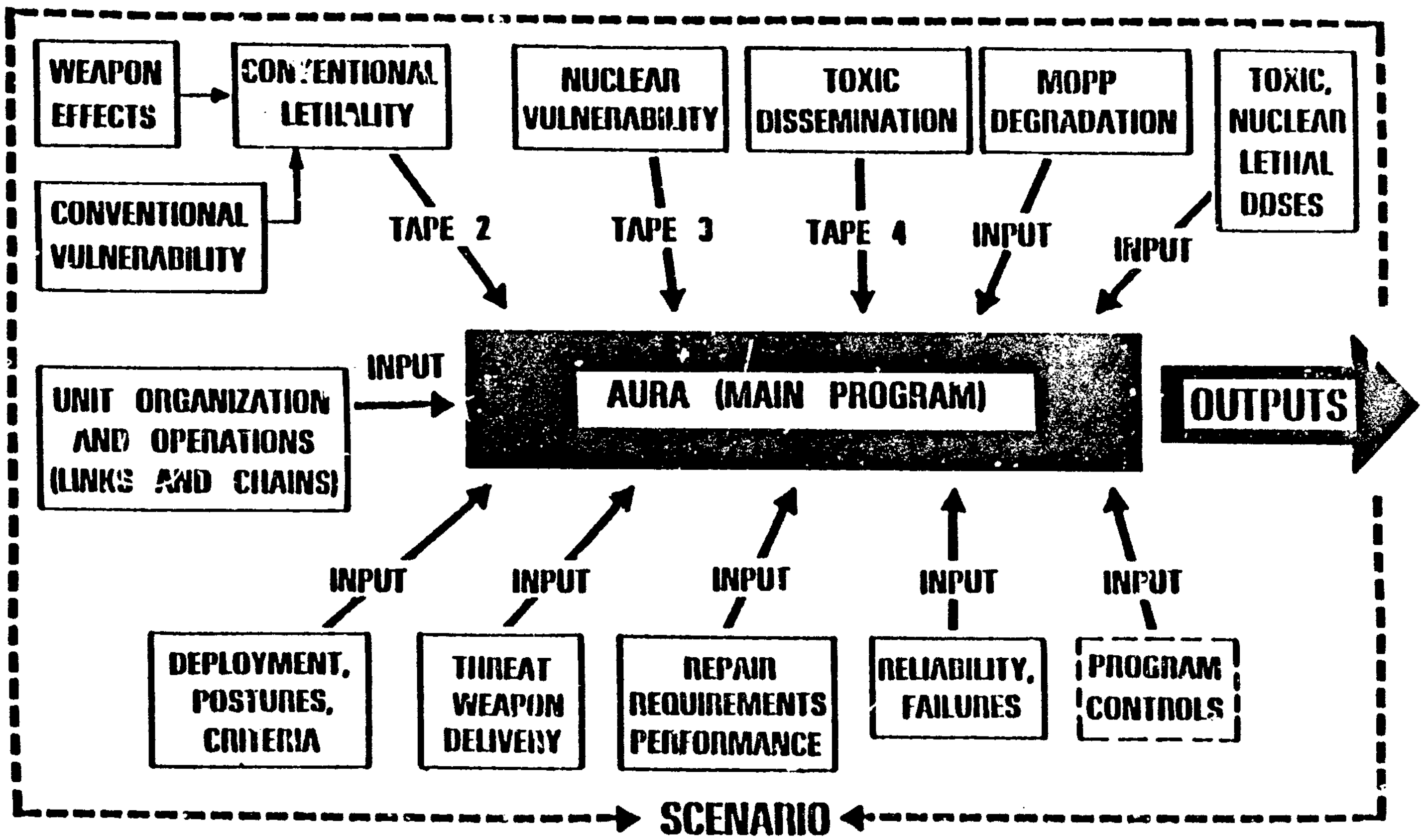


Figure 5-2. AURA Inputs [47]

without incorporating the impact of offensive action by threat forces. This scenario represented a unit which had assumed MOPP IV based on threat of chemical attack and continued to perform its mission in MOPP. Since heat stress and fatigue effects are not included, unit effectiveness remained constant over time.

Six AURA runs were made to investigate the impact of modifying baseline degraded effectiveness values for unit mechanics, as shown in Table 5-3. It should be noted that these values represent the average MOPP IV mechanical abilities for a specified range of Military Occupational Specialties (MOS). Based on the similarity of their normal work requirements, each MOS was placed into one of the groups listed and assigned a degraded ability value. Although not critical to the sensitivity analysis, these numerical values are a best estimate of the degradation normally associated with the common tasks in each specialty.

The behavior of unit effectiveness as a function of average mechanical degraded ability for unit mechanics is provided in Figure 5-3. At higher levels of degradation, the increase in unit effectiveness with increasing ability to perform is almost linear and becomes asymptotic beyond .70. Although the degradation level at which this asymptotic behavior occurs can be expected to vary based on input parameters and unit type, it is obvious that overestimating degradation has a substantial impact upon unit effectiveness below this critical point.

In a sensitivity analysis previously conducted by BRL [73], a M109 Field Artillery Battery was evaluated using a range of MOPP IV

Table 5-3. Mechanical Degraded Ability - Forward Support Maintenance Company

MOS Grouping	MECHANICAL DEGRADED ABILITY (Percent of Base) 50%	25%	10%	BASE	110%	125%
Supervisory*	.95	.95	.95	.95	.95	.95
Administrative*	.80	.80	.80	.80	.80	.80
Inspectors*	.90	.90	.90	.90	.90	.90
Track Mechanics	.38	.56	.68	.75	.83	.93
Wheel Mechanics	.35	.53	.63	.70	.77	.88
Electronics Repair	.33	.48	.59	.65	.72	.81
Armament Repair	.38	.56	.68	.76	.83	.93
Engineer Equip. Repair	.33	.48	.59	.65	.72	.81

*These personnel do not actually perform maintenance tasks. Degraded Abilities were not modified.

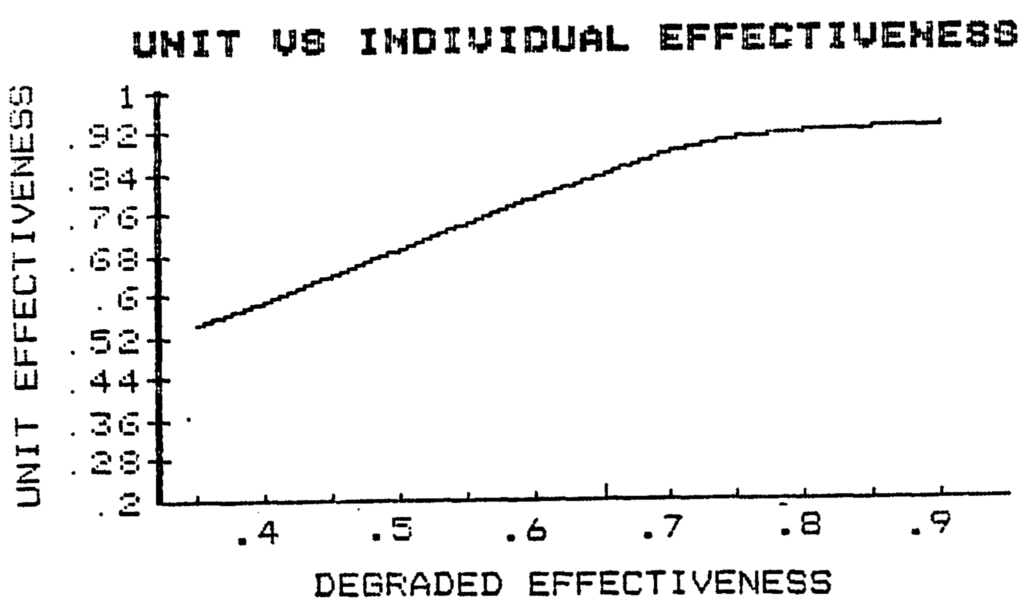


Figure 5-3. Unit Versus Individual Effectiveness

degraded abilities which were uniformly applied to the unit as a whole. However, unlike the maintenance unit, the artillery battery was subjected to several threat scenarios and unit effectiveness was evaluated over time. The results of these AURA runs are provided in Figures 5-4 and 5-5. Although each scenario resulted in slightly different curves, there was almost a one-to-one relationship between a reduction in MOPP IV effectiveness and unit effectiveness, particularly during the first few hours of simulated combat. This is consistent with the slope of the straight line portion of Figure 5-3.

In summary, the impact of individual performance degradation upon unit effectiveness is significant, especially at high levels of MOPP degradation. When the BRL degraded abilities for manual dexterity and mobility encumbrance are compared to the mechanical degraded ability developed for DAMM as in Figure 5-6, the projected difference in unit effectiveness could be 50 percent or more, depending upon the scenario and type of unit involved.

Sensitivity of Degraded Effectiveness

Given the sensitivity of unit effectiveness to changes in degraded effectiveness (ED), a brief analysis of those factors which influence this variable is also pertinent to the evaluation of DAMM. Based on the BRL model, ED is a function of individual Degraded Abilities (DA) involved with the task and the demand for these abilities. Assuming the relationships established by the mathematical algorithm correctly characterize personnel degradation, knowledge concerning how accurate one must be in determining mechanical degradation may prove useful.

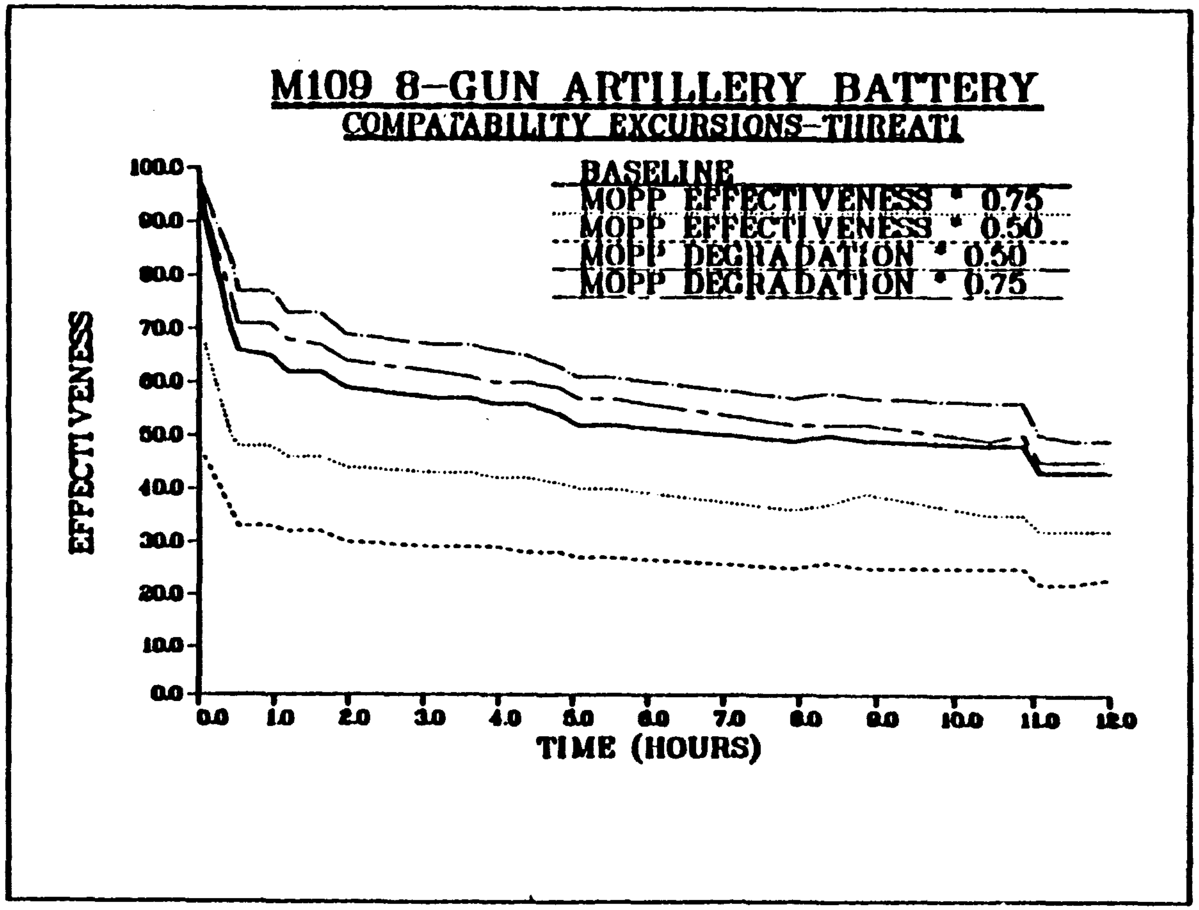


Figure 5-4. Effectiveness Results for Threat One [73]

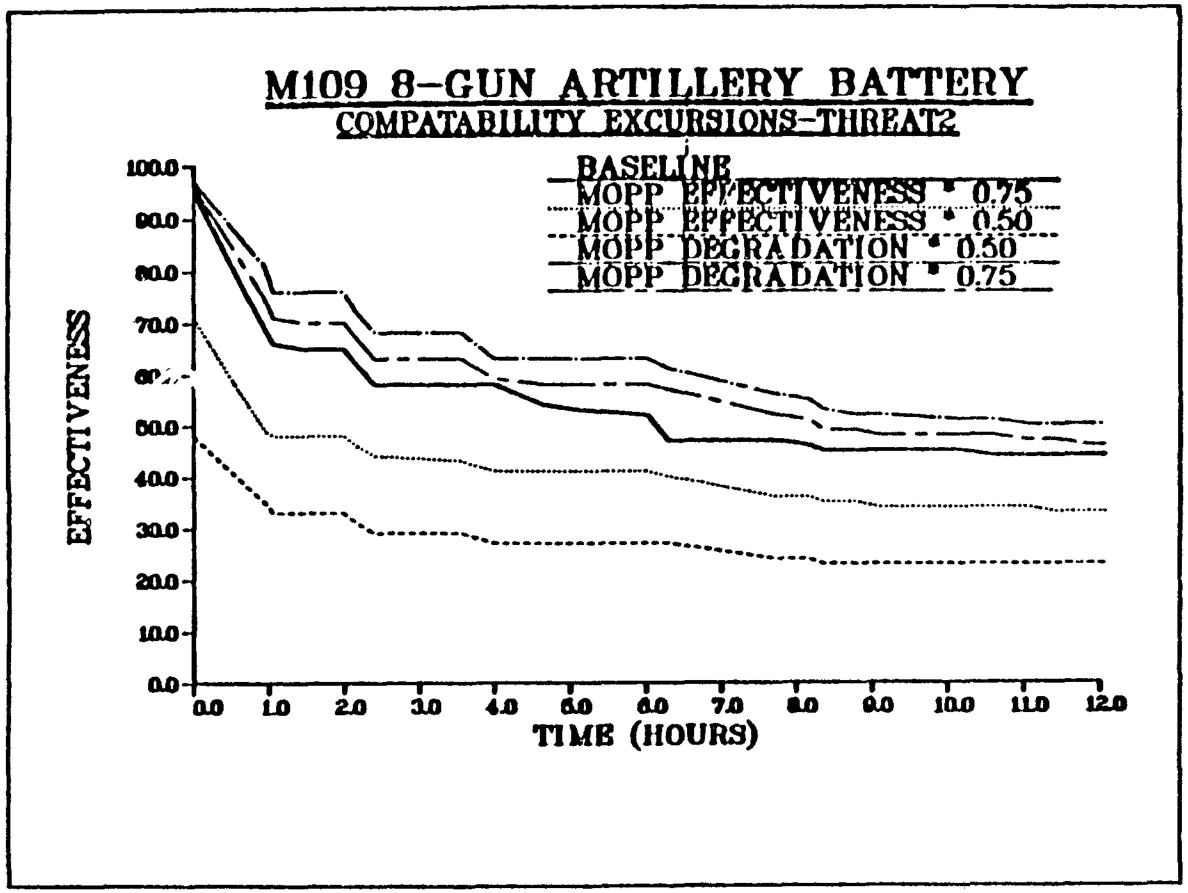


Figure 5-5. Effectiveness Results for Threat Two [73]

CURRENT BRL METHODOLOGY	DEGRADATION ANALYSIS METHODOLOGY FOR MAINTENANCE (DAMM)
DEGRADED ABILITIES	
Manual Dexterity = .30 Mobility Encumbrance = .50	Mechanical Ability = .80* (Range of .67-.93)
DEGRADED EFFECTIVENESS	
$ED = (1-.70^{1})\ (1-.50^{2})$ $= .225$	$ED = (1-.20^{1})$** $= .80$

* Average of the nine movement category degradation values

** For physical movement only (near vision component of physical movement not included)

Figure 5-6. Comparison of Methodologies

Because the BRL algorithm discounts the impact of successive degradation factors, the magnitude of the mechanical DA factor, in comparison to other potential sources of degradation, is critical. As supported in a wide variety of studies, heat stress associated with wearing protective clothing is the most significant contributor to performance degradation at high temperatures or humidity. This fact is properly reflected in heat buildup factors in the BRL Degraded Ability Matrix (Table 2-3). As a result, the impact of an incorrect estimate for mechanical DA is not as severe when heat buildup is the largest factor.

Based on a mechanical ability of .8 at MOPP IV, the effect of increasing DA error on degraded effectiveness at a temperature of 30°C (e.g. heat buildup is dominant) is shown in Figure 5-7. At this temperature, a 20 percent overestimate of mechanical DA only results in an ED error of 10 percent. However, the rapid decrease in ED at low temperatures (e.g. mechanical degraded ability is dominant), demands a much higher degree of accuracy and is a primary motivator for improved

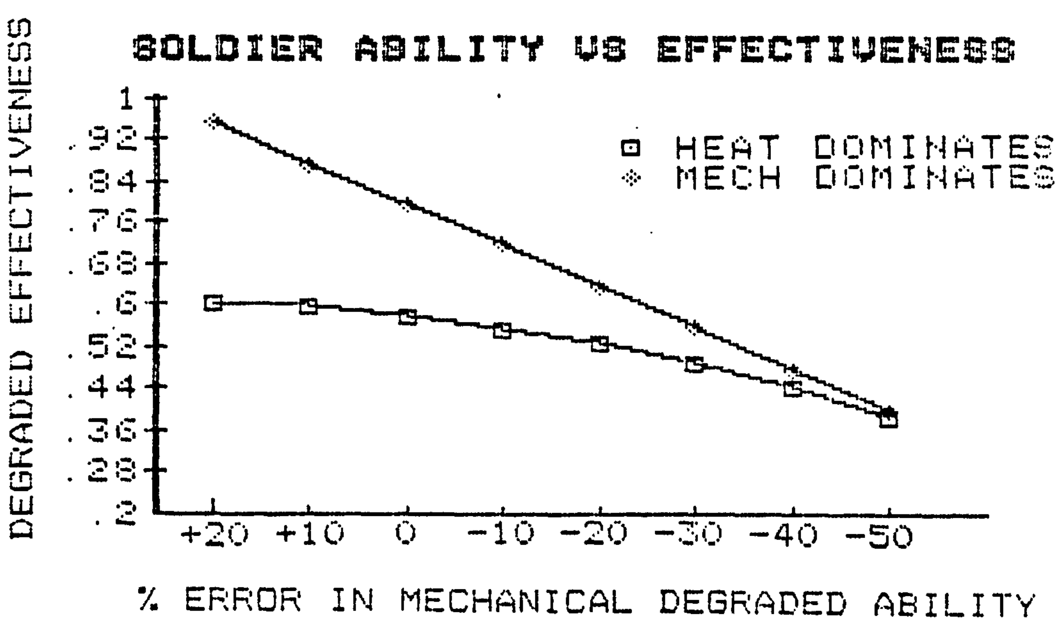


Figure 5-7. Soldier Ability Versus Effectiveness

degradation estimates. From this plot, the obvious concern should be for the overestimation of degraded abilities. DAMM has been specifically designed for just such a purpose.

CHAPTER VI

RECOMMENDATIONS AND CONCLUSIONS

Recommendations

Throughout this thesis, a concerted effort has been made to describe the knowledge voids which exist in the study of performance degradation. DAMM was developed to draw upon a variety of subject areas, ranging from work measurement to the modeling of degradation, to fill some of these voids. Its usefulness in accomplishing this purpose is the primary focus of this final chapter. With this goal in mind, the applications of DAMM and recommendations for its improvement will be discussed in the following sections.

Applications of Methodology

As the most direct application of DAMM, improved degradation estimates are important to variety of CW doctrinal and training areas. The most critical problem in these interest areas is usually the lack of realistic degradation data.

At least for maintenance tasks, DAMM provides a method to greatly expand the degradation data base for a wide variety of jobs without resorting to time consuming and costly experimentation. More specifically, "benchmark" maintenance tasks could initially be identified as a representative range of repair jobs and then evaluated using DAMM. Using a "pigeonholing" technique similar to UMS, other maintenance task degradations could be established based on their similarity to the benchmark jobs. For a higher level of aggregation, such as that required by AURA, an appropriate mix of these maintenance tasks could be identified for a given MOS. Using a weighted average based on typical task frequency, the degradation associated with an MOS could then be established.

The implications of this for combat doctrine and training are numerous. For example, with continuing emphasis on "fix forward" maintenance support, intermediate direct support maintenance teams must contend with possible chemical contamination. Using DAMM, it is possible to identify highly degraded maintenance tasks, without direct experimentation, and determine those equipment items that should be evacuated and decontaminated rather than fixing them on site in MOPP.

In addition, highly desirable task components identified by DAMM could assist in tactical decision making and individual training programs. Through quantitative estimates of degradation, more informed command decisions for the selective application of MOPP to specific individuals/tasks and better timing of MOPP level increases could improve unit effectiveness. Limited unit training time could be improved by focusing on the most degraded portions of a task and capitalizing on available "workarounds." Individual performance time could be cut by 50 percent or more based on the learning effects noted in many studies.

In view of the increased emphasis on CW operations, it may be useful to establish time standards for common repair tasks in MOPP. The Army Training and Evaluation Program (ARTEP), which provides training standards for virtually all Army units, could be modified to incorporate MOPP time standards using DAMM. In addition to providing a distinct training goal, this action would provide unit leaders with task-time degradation estimates needed for tactical decision making as described earlier.

In addition to the more direct applications discussed above, DAMM could indirectly assist in the evaluation of force development changes and help verify the operational effectiveness of new material. Inherent in this type of analysis is the general objective of verifying the capability of soldiers and units, under the various protective levels of MOPP, to perform essential tasks and employ/maintain their equipment. Figure 6-1 presents a few of the applications that DAMM may have in facilitating analysis in these areas.

EQUIPMENT DEVELOPMENT

- Concentrate research on those aspects of protective clothing which cause the highest degree of mechanical degradation (most "bang for the buck").

- Design equipment for maintainability in MOPP based on the characteristics associated with highly degraded task elements.

FORCE DEVELOPMENT

- Identify those maintenance-oriented MOSs that are highly degraded and use this information to assess their impact upon unit effectiveness.

- Analyze the ability of the current maintenance force structure to accomplish required missions in MOPP by providing more realistic estimates of MOPP degradation at low to moderate temperature ranges in computerized wargames and training simulations.

Figure 6-1. Applications for Equipment and Force Development

Recalibration of DAMM

In order to fully achieve the applications just discussed, additional research and experimentation is necessary. Of primary concern is the limited data base upon which DAMM movement category degradations are based. To fully validate the proposed maintenance task taxonomy, a much larger number of task elements are needed to estimate the degradation values within each category. Based on additional data, the method of the analysis demonstrated in Chapter IV can be used to recalibrate DAMM.

Based on a synthesis of data analysis, video tape observations and past MOPP performance test recommendations, a series of specific test design recommendations, provided in Figure 6-2, were developed to facilitate this recalibration effort. Since the DO-49 study is an on-going series of field tests, some of these recommendations have already been implemented based on this research effort.

Methodology Expansion

A variety of limitations were placed on the development of DAMM, largely due to data availability and limited research time. Of particular interest to current researchers would be its expansion to include jobs other than maintenance tasks. Limitations associated with skill/learning effects and group tasks represent other areas for substantial improvement.

Expansion to General Military Tasks. Based on the principles used to develop DAMM, it would be feasible to establish additional movement categories for general military tasks which do not involve the

TEST DESIGN

- Minimize task learning by allowing subjects to perform job at least twice prior to record runs.
- Recommend using a k-factor factorial design with 8 to 10 subjects per task.*
- Where possible, use same subjects for all tasks.
- Use posttest questionnaire to subjectively evaluate perceived degradation and workarounds.

TEST CONTROL

- Establish a standardized procedure for unencumbered work (restrict pauses, unusual methods, etc.)
- Minimize experimental condition changes.

DATA COLLECTION

- Identify key task elements in advance of test for filming close ups.
- Use consistent camera angles and ranges throughout test.

*Based on analysis of DO 49 maintenance task variability by an independent researcher [68]. Actual design was a four factor factorial to partition for subjects, MOPP, movement factors and day/night conditions. Desired power of the test was .90.

Figure 6-2. Testing Recommendations

removal and installation of components. Although the number of variables associated with these categories is likely to be larger than typically associated with well-defined task areas such as maintenance, it may be possible to develop separate taxonomies for specialized missions performed in the Army (e.g. Infantry, Armor, Artillery) as well as for general missions which all units must perform (e.g. clerical, supervisory, maintenance). By developing separate systems based on the principles of physical motion and performance degradation, it may be possible to reduce taxonomy size and variability to a manageable level and could facilitate the estimation of mechanical degradation associated with a given MOS. It is also expected that degradation values for similar movements in two separate taxonomies may be different based on typical work content (e.g. gross body movement degradation for infantry tasks may be higher than for maintenance tasks).

Skill Level. Some of the most troubling aspects of non-repetitive task analysis are related to learning effects and skill level. Although a commonly made assumption, it is unrealistic to assume a "fully-trained" status for all military personnel. An important addition to a methodology such as DAMM would be to introduce degradation factors for each category of movement which are dependent upon the skill level of the individual. The general intent would be to degrade less skilled soldiers more highly based on the task and MOPP learning that inevitably occurs. Unfortunately, very little data is available to support such an approach at the present time. However, with some additional effort to identify an appropriate mix of subjects of different skill levels, a reasonable factorial test could be designed to investigate this issue.

Group Tasks. DAMM was oriented toward individual performance in an effort to limit the scope of this research. However, expansion to group tasks would greatly improve its range of applicability. One possible approach would be to establish an activity network for the task to be analyzed and identify the critical path based on the precedence of task elements and expected completion times. However, it is possible that the critical path will change with the application of MOPP. As recommended by Cox and Jeffers [36], it may be necessary to establish a flexible task sequence, which recognizes that many group tasks do not have rigid task element schedules. The synergic relationship between group members, due to effects such as leadership and personnel skill levels, could also present problems in this area.

Conclusions

The development of the proposed Degradation Analysis Methodology for Maintenance was based on a series of intermediate objectives. In concluding this research, it is appropriate to review these objectives in the light of their contribution to DAMM.

In developing a taxonomy for maintenance task analysis, a review of maintenance management, work classification/measurement and human performance literature was conducted. The unique characteristics of maintenance tasks and the techniques for classifying and measuring low-quantity work proved to be major contributors to taxonomy development. A wide variety of MOPP performance testing results were used to establish the link between physiological factors and performance degradation. Recent maintenance-oriented field tests and operational testing of equipment were the most useful in identifying key elements of "mechanical" degradation due to protective clothing.

Based on a review of available performance degradation models, the BRL methodology was selected as the standard upon which DAMM would be based. The flexibility of this algorithm and the wide usage of the

Army Unit Resiliency Analysis (AURA) model which it supports were major factors in its selection.

Using the resulting taxonomy, individual movement category degradation values were estimated from selected DO-49 maintenance tasks. Regression analysis and two group comparison techniques were used to evaluate the consistency of the methodology. Given the limitations of the data, these tests proved sufficient method validity existed to warrant its incorporation into the BRL algorithm.

Criteria for evaluating DAMM was aimed at demonstrating its improved performance in predicting task-time degradation as compared to the current BRL methodology. The sensitivity of unit effectiveness to DAMM accuracy was evaluated through the use of AURA. Finally, the applications of DAMM were discussed and recommendations for methodology improvement provided. The result is a methodology which will improve the Army's ability to predict task-time degradation for maintenance tasks.

Based on the ability of our potential adversaries to employ chemical warfare, it is essential that our military forces be capable of operating in a chemically contaminated environment. The threat of reduced unit effectiveness is real from both the standpoint of chemical agent casualties and the restrictions placed on the individual soldier by our protective measures. As it was so aptly stated over 65 years ago

> Whether or not gas will be employed in future wars is a matter of conjecture, but the effect is so deadly to the unprepared that we can never afford to neglect the question.
>
> — General John J. Pershing
> Annual Report to Congress, 1919

APPENDIX A

Chemical Protective Ensemble

I. M17A1 Protective Mask

The M17A1 mask consists of the facepiece assembly, a pair of eyelens outserts, and a mask carrier. It is a combat mask which protects the face, eyes, and r.spiratory tract of the wearer from field concentrations of chemical and biological agents.

II. M6A2 Protective Hood

The M6A2 hood is made of butyl rubber coated nylon cloth. It covers the head and neck of the wearer. When properly fitted to the protective mask, it provides protection against vapors, aerosols, and agent droplets. The hood covers the head without interfering with the combat helmet.

III. Chemical Protective Suit

The Chemical Protective Suit (Overgarment) is a two-layer permeable fabric jacket and trouser suit designed to be worn over long sleeve fatigues and normal underclothing. The garment outer layer is a nylon/cotton twill, dyed olive drab, and treated with a water resistant polyurethane foam laminated to nylon tricot. It is intended for protection of personnel exposed to vapors, aerosols, and liquid agents.

IV. Chemical Protective Footwear Covers

The Chemical Protective Footwear Cover (Overboot) is a butyl rubber boot. The footwear covers are designed to exclude contamination from the boots and feet, and provide a rapid means for removal of contamination. This overboot is a one-size-fits-all cover which is worn over the combat boot.

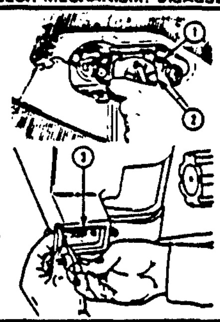
V. Chemical Protective Glove Set

The Chemical Protective Glove Set consists of a pair of 14.5 inch length, 0.025 inch thick butyl rubber outer gloves and a pair of thin cotton gloves. They are designed to exclude contamination from the hands, and provide a rapid means for removal of contamination. Since the outer cover does not allow the passage of air, the cotton liner glove serves to absorb perspiration.

APPENDIX B

M109 Breech Block Disassembly and Assembly*

CANNON BREECH MECHANISM: DISASSEMBLY AND ASSEMBLY



DISASSEMBLY

WARNING

Refer to failure to fire instructions in TM 9-2350-217-10N before opening breech.

NOTE

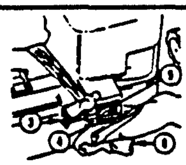
Before disassembling breech mechanism, remove elbow telescope (p 7-118).

A With firing mechanism block (1) in center position, push firing mechanism (2) into block and rotate clockwise to remove.

NOTE

For disassembly of firing mechanism, see page 7-118.

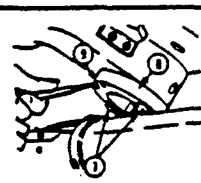
B Slide rack plate (3) rearward until it disengages from plunger.



WARNING

Remove breechblock operator rack springs only when breechblock is in closed position. Springs are under heavy pressure. UNDER NO CIRCUMSTANCES will removal of springs be attempted with breechblock open.

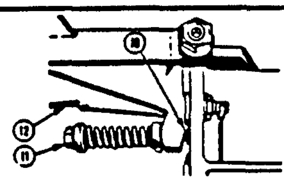
C With breechblock closed, drive rack plate (3) rearward. Stop plate (4) and rack springs (5) will pop out. Catch plate and springs with a clean rag (6).



NOTE

You may have a different type adjuster with lugs for a crescent wrench rather than holes for a spanner wrench.

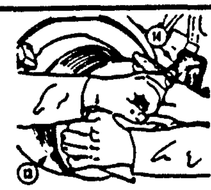
D Release pre-load on closing spring, using spanner wrench (7). Apply counterclockwise pressure on adjuster (8) and depress adjuster plunger (9). Rotate adjuster clockwise slowly until all torque has been relieved.



E Loosen lock nut (10) and remove cam damper (11). Cannon should be elevated slightly and cam (12) raised and secured with a strap to cab roof.

CAUTION

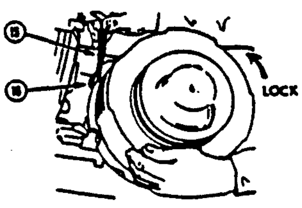
Never attempt to disassemble the breech mechanism with breech partially or fully closed. (Steps F and G must be done before steps H and K.)



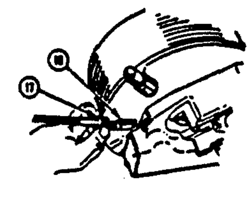
CAUTION

Since all spring tension has been released, be extra careful when opening breechblock (13). Using operating handle (14), support breechblock as it is being opened. Otherwise, carrier will slam open and may be damaged.

F Open breechblock (13).

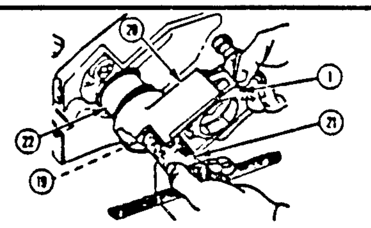


G Using drive punch (15), depress detent plunger (16). Rotate breechblock to locked position.



H Remove two screws or snap (17) and plunger group (18). Slide firing mechanism housing all the way to the right.

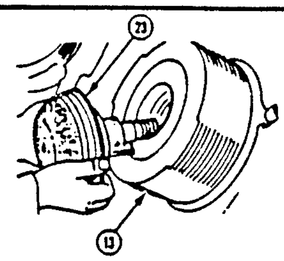
*Extracted from TM 9-2350-217-20N [7]



I Move extractor away from obturator nut (19). Support firing mechanism block (1) and housing (20). Unscrew obturator nut with spanner wrench (21). Remove firing mechanism housing, block, and obturator spring (22).

NOTE

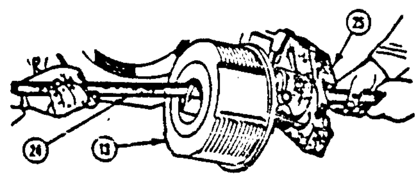
For disassembly of firing mechanism housing block, see page 7-110.



J Push on obturator, and then pull obturator group (23) away from breechblock (13).

NOTE

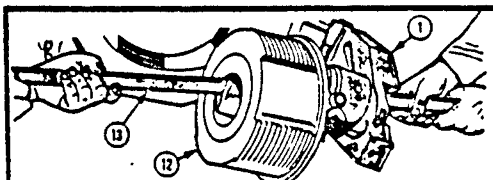
For disassembly of obturator group, see page 7-109.

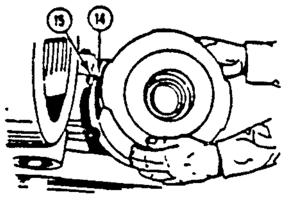


WARNING

It takes two men to remove a breechblock. Protect breechblock and carrier with rags.

K Insert cleaning staff (24) through breechblock (13) and carrier (25). Slide breechblock off carrier and onto staff.





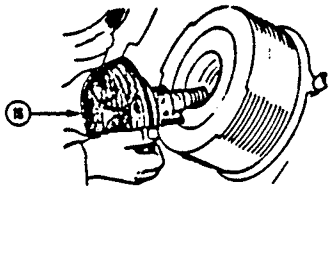
Cannon should be elevated slightly and cam raised and secured with a strap to cab roof.

WARNING

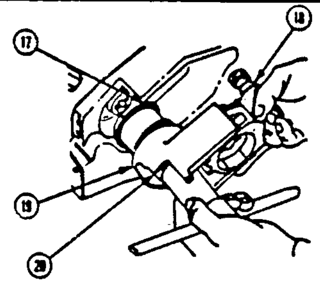
It takes two men to install a breechblock.

H With carrier (1) in fully open position, install breechblock (12). Use cleaning staff (13) wrapped with rags to protect carrier and breechblock.

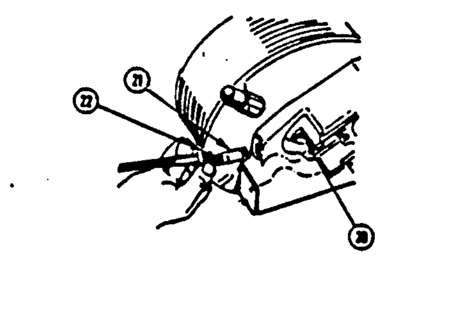
I With carrier in fully open position, align closing lug (14) with detent plunger (15). With operating rack and operating gear timing marks aligned in the center of the inspection hole, slide breechblock completely on. Recheck alignment marks.



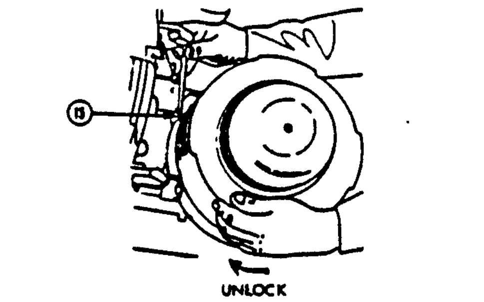
J Install obturator group (16) in breechblock.



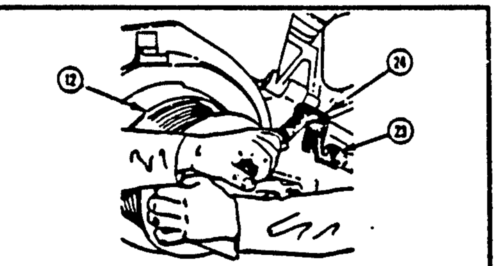
K Replace obturator spring (17). Install firing mechanism block (18) and housing (19). Secure obturator nut (20).



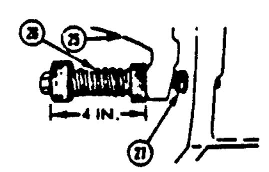
L Install plunger group (21) and two screws or snap (22). Be sure plunger tip seats in narrow slot of the obturator nut (20).



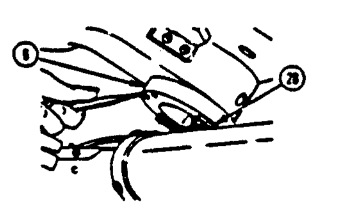
M Using drive punch, depress detent plunger (15) and rotate breechblock to unlock position.



N Engage clutch pin (23) to close breechblock (12). Return operating handle (24) to stop.



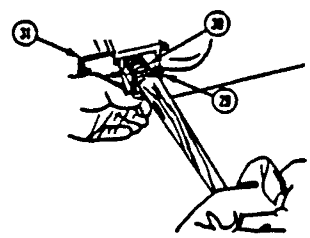
O Release strap holding cam (25) to roof and lower cam. Install cam damper (26). Adjust distance between spring cap ends to 4 inches (10 cm) for correct cam tension. Tighten lock nut (27).



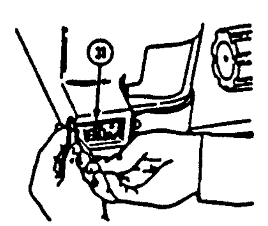
NOTE

You may have a different type adjustor with lugs for a crescent wrench rather than holes for a spanner wrench.

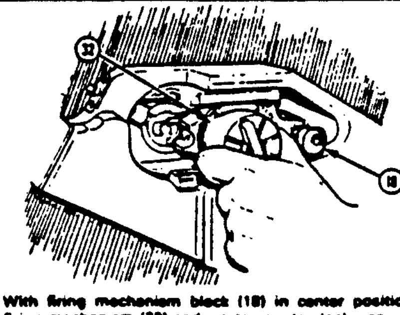
P Apply pre-load tension on breech mechanism leaf springs, using spanner wrench (28) installed in holes of adjustor (6). The notches in the adjustor provide graduations of adjustment. Do not apply more pre-load than is necessary to close breechblock securely. Use of the final notch reduces life of the leaf springs and should be used only as necessary.



Q Apply pressure to stop plate (29) and rack springs (30) with hammer handle and slide rack plate (31) over stop plate.



R Slide rack plate (31) forward until rear hole of rack plate engages plunger.

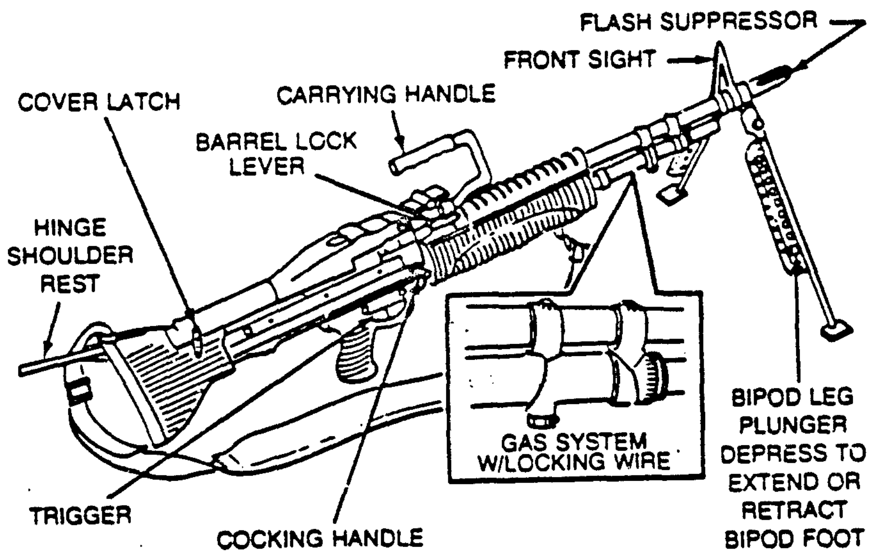


S With firing mechanism block (18) in center position, insert firing mechanism (32) and rotate counterclockwise.

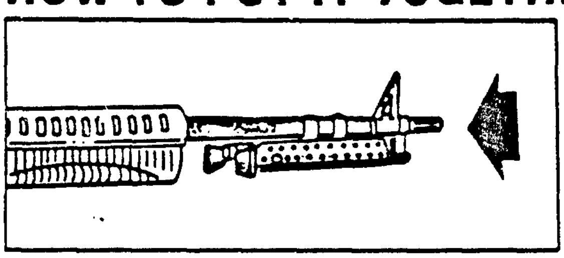
APPENDIX C

M60 Machine Gun Assembly and Disassembly*

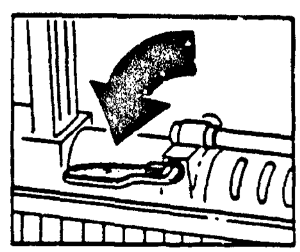
EXTERNAL PARTS AND WHERE TO FIND THEM



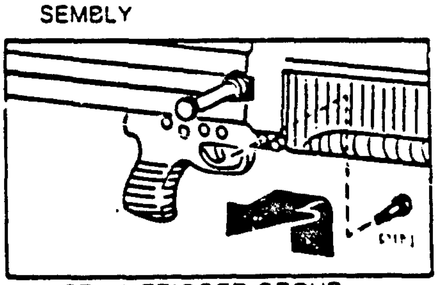
HOW TO PUT IT TOGETHER



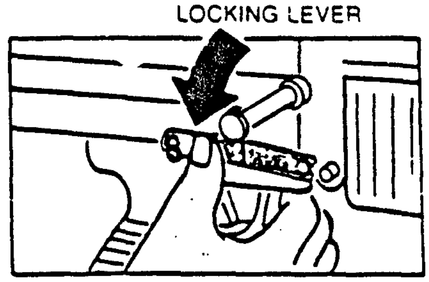
INSTALL BARREL WITH BIPOD ASSEMBLY



SECURE BARREL LOCKING LEVER



INSTALL TRIGGER GROUP



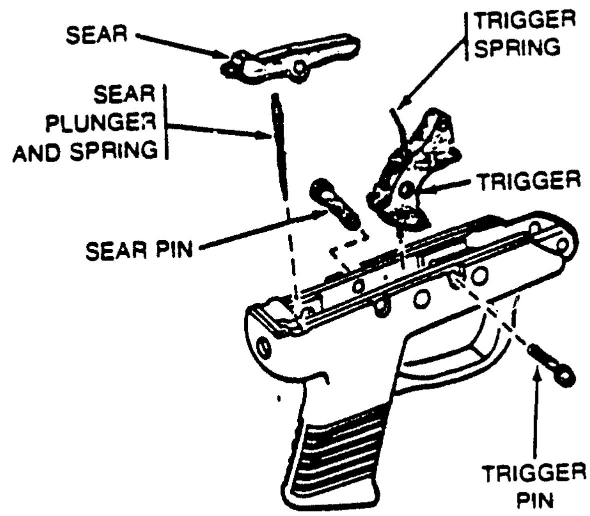
INSTALL LEAF SPRING

*Extracted from TM 9-1005-224-10 [6]

TRIGGER GROUP

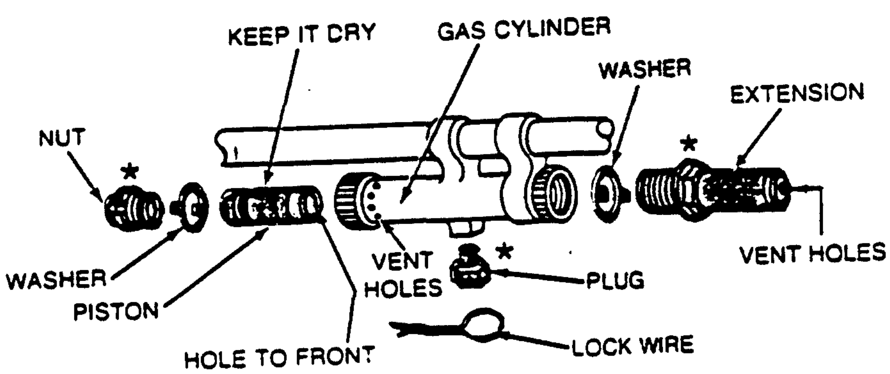
DISASSEMBLE

1 HOLD DOWN ON SEAR
2 REMOVE SEAR PIN
3 REMOVE SEAR, SEAR PLUNGER, AND SPRING
4 REMOVE TRIGGER PIN
5 REMOVE TRIGGER



GAS SYSTEM

USE COMBINATION WRENCH



*NO TORQUE REQUIREMENT

APPENDIX D

Data and Descriptive Statistics (BMDP1D)

I. M109 Breech Block Task - BDU Trials

A. Raw Data

M109 BREECH BLOCK BDU DATA

CASE NO.	LABEL	2	3	4	5	6	7	8	9	10	11
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

CASE NO.	LABEL	12	13	14	15	16	17	18	19	20	21
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2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

CASE NO.	LABEL	22	23	24	25	26
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2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

B. Descriptive Statistics

M109 BREECH BLOCK BDU DATA

VARIABLE NO. NAME	GROUPING VARIABLE LEVEL	TOTAL FREQUENCY	MEAN	STANDARD DEVIATION	ST.ERR OF MEAN	COEFF. OF VARIATION	SMALLEST VALUE	Z-SCORE	LARGEST VALUE	Z-SCORE	RANGE
2 [illegible]	TEAM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3 [illegible]	TEAM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4 [illegible]	TEAM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5 [illegible]	TEAM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6 [illegible]	TEAM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7 [illegible]	TEAM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8 [illegible]	TEAM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TM5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

WIDE GREEN BLOCK SBW DATA

VARIABLE NO NAME	GROUPING VARIABLE	LEVEL	TOTAL FREQUENCY	MEAN	STANDARD DEVIATION	ST ERR OF MEAN	COEFF OF VARIATION	SMALLEST VALUE	Z-SCORE	LARGEST VALUE	Z-SCORE	RANGE
9 LOCSOLV			8	7.338	2.585	1.0485	.40415	4.300	-.88	16.000	2.25	9.700
	TEAM	TM1	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM2	1	4.300	0.000	0.0000	0.00000	4.300	0.00	4.300	0.00	0.000
		TM3	-	8.000	.585	.4000	.08426	5.000	-.71	8.400	.71	.800
		TM4	1	8.100	0.000	0.0000	0.00000	8.100	0.00	8.100	0.00	0.000
		TM5	2	10.350	5.162	3.6500	.50473	6.700	-.71	14.000	.71	7.300
10 RPLGROP			8	27.383	3.880	1.0788	.10811	22.500	-1.83	33.300	1.75	8.800
	TEAM	TM1	2	24.050	2.616	1.8500	.10814	22.300	-.71	28.100	.71	3.700
		TM2	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM3	2	28.100	1.697	1.2000	.06033	27.100	-.71	30.200	.71	3.400
		TM4	1	33.300	0.000	0.0000	0.00000	33.500	0.00	33.300	0.00	0.000
		TM5	2	26.100	.848	.6000	.03251	25.500	-.71	26.700	.71	1.200
11 SPWNOUG			8	28.062	6.812	2.4064	.23438	21.300	-1.16	42.300	1.83	20.900
	TEAM	TM1	2	25.850	6.574	4.6500	.25361	21.300	-.71	30.500	.71	9.300
		TM2	1	23.600	0.000	0.0000	0.00000	23.600	0.00	23.600	0.00	0.000
		TM3	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM4	1	26.700	0.000	0.0000	0.00000	26.700	0.00	26.700	0.00	0.000
		TM5	2	36.150	8.556	6.0500	.23666	30.100	-.71	42.200	.71	12.100
12 REQTVM			8	5.712	1.068	.3777	.18701	3.700	-1.88	7.400	1.58	3.700
	TEAM	TM1	2	5.100	2.051	1.4500	.20410	3.700	-.71	6.600	.71	2.900
		TM2	1	7.400	0.000	0.0000	0.00000	7.400	0.00	7.400	0.00	0.000
		TM3	2	5.700	.424	.3000	.07442	5.400	-.71	6.000	.71	.600
		TM4	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM5	2	5.600	.141	.1000	.02571	5.400	-.71	5.800	.71	.200
13 RSOLK			8	25.553	5.287	1.8692	.211.6	17.700	-1.48	33.400	1.48	15.700
	TEAM	TM1	2	19.350	2.333	1.6500	.12065	17.700	-.71	21.000	.71	3.300
		TM2	1	20.200	0.000	0.0000	0.00000	20.200	0.00	20.200	0.00	0.000
		TM3	2	30.100	1.273	.9000	.04274	28.200	-.71	30.000	.71	1.800
		TM4	1	33.400	0.000	0.0000	0.00000	33.400	0.00	33.400	0.00	0.000
		TM5	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-.71	[illegible]	.71	[illegible]
14 IRSLK			8	27.875	4.418	1.0828	.15854	23.100	-1.06	34.800	1.82	11.500
	TEAM	TM1	2	25.350	3.182	2.2500	.12552	23.100	-.71	27.600	.71	4.500
		TM2	1	34.800	0.000	0.0000	0.00000	34.800	0.00	34.800	0.00	0.000
		TM3	2	28.900	5.851	4.2000	.20328	25.800	-.71	34.200	.71	8.800
		TM4	1	27.700	0.000	0.0000	0.00000	27.700	0.00	27.700	0.00	0.000
		TM5	2	25.100	2.828	2.0000	.11268	23.100	-.71	27.100	.71	4.000
15 ISSTVM			8	5.475	1.084	.3728	.18277	4.100	-1.30	8.000	1.48	3.300
	TEAM	TM1	2	5.350	.636	.4500	.10162	5.800	-.71	5.700	.71	.900
		TM2	1	5.500	0.000	0.0000	0.00000	5.500	0.00	5.500	0.00	0.000
		TM3	2	[illegible]	1.414	1.0000	.21427	[illegible]	-.71	[illegible]	.71	2.000
		TM4	1	6.000	0.000	0.0000	0.00000	8.000	0.00	8.000	0.00	0.000
		TM5	2	5.600	1.414	1.0000	.24283	4.600	-.71	6.600	.71	2.000
16 IPWNOUS			8	18.375	7.872	2.0772	.39062	8.300	-1.40	27.400	1.08	19.100
	TEAM	TM1	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-.71	[illegible]	.71	[illegible]
		TM2	1	22.700	0.000	0.0000	0.00000	22.700	0.00	22.700	0.00	0.000
		TM3	2	12.300	3.384	2.4000	.27594	9.900	-.71	14.700	.71	4.800
		TM4	1	8.300	0.000	0.0000	0.00000	8.300	0.00	8.300	0.00	0.000
		TM5	2	[illegible]	[illegible]	[illegible]	.22478	[illegible]	-.71	27.400	.71	[illegible]
17 TPWNOUS			8	26.888	8.230	2.2412	.30077	16.800	-1.19	38.000	1.78	21.200
	TEAM	TM1	2	24.700	.283	.2000	.01146	24.500	-.71	24.900	.71	.400
		TM2	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM3	2	18.850	7.142	5.0500	.35870	16.800	-.71	26.900	.71	10.100
		TM4	1	36.000	0.000	0.0000	0.00000	38.000	0.00	38.000	0.00	0.000
		TM5	2	31.300	1.697	1.2000	.05008	30.000	-.71	32.400	.71	1.400
18 IPLGROP			8	29.712	6.480	2.2882	.22333	21.600	-.88	42.000	2.21	20.400
	TEAM	TM1	2	26.050	4.031	2.8500	.16086	22.200	-.71	27.900	.71	5.700
		TM2	1	42.000	0.000	0.0000	0.00000	42.000	0.00	42.000	0.00	0.000
		TM3	2	[illegible]	1.768	1.2500	[illegible]	[illegible]	-.71	27.300	.71	[illegible]
		TM4	1	20.400	0.000	0.0000	0.00000	20.400	0.00	20.400	0.00	0.000
		TM5	2	23.550	2.758	1.9500	.11713	21.600	-.71	25.500	.71	3.900
19 SLSSRSLK			8	5.312	2.885	.9520	.58084	2.000	-1.04	11.000	2.30	9.000
	TEAM	TM1	2	8.000	4.243	3.0000	.53033	5.000	-.71	11.000	.71	6.000
		TM2	1	2.000	0.000	0.0000	0.00000	2.000	0.00	2.000	0.00	0.000
		TM3	2	4.500	.707	.5000	.15713	4.000	-.71	5.000	.71	1.000
		TM4	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM5	2	3.600	.848	.6000	.23570	3.000	-.71	4.200	.71	1.200
20 SLSSRSLK			8	8.312	1.768	.6200	.21374	5.700	-1.48	10.700	1.48	5.000
	TEAM	TM1	2	[illegible]	[illegible]	1.3500	.27051	[illegible]	-.71	[illegible]	.71	2.700
		TM2	1	6.700	0.000	0.0000	0.00000	6.700	0.00	6.700	0.00	0.000
		TM3	2	7 550	2.616	1.8500	.34653	5.700	-.71	9.400	.71	3.700
		TM4	1	7.100	0.000	0.0000	0.00000	7.100	0.00	7.100	0.00	0.000
		TM5	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-.71	10.700	.71	[illegible]
21 RSLCAM			8	9.538	3.144	1.1116	.33019	5.800	-1.38	14.700	1.61	9.100
	TEAM	TM1	2	10.950	5.303	3.7500	.48433	7.200	-.71	14.700	.71	7.500
		TM2	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM3	2	9.000	4.808	3.4000	.53426	5.600	-.71	12.400	.71	6.800
		TM4	1	7.400	0.000	0.0000	0.00000	7.400	0.00	7.400	0.00	0.000
		TM5	2	10.563	2.546	1.8000	.24244	8.700	-.71	12.300	.71	3.600
22 IEAMDAM			8	19.082	5.328	1.8484	.27428	5.500	-1.84	28.700	1.27	18.600
	TEAM	TM1	2	17.300	11.878	8.4000	.68607	8.900	-.71	28.700	.71	16.8?0
		TM2	1	22.100	0.000	0.0000	0.00000	22.500	0.00	22.503	0.00	0.000
		TM3	2	[illegible]	2.970	2.1000	.16142	16.800	-.71	23.100	.71	4.200
		TM4	1	20.2.0	0.000	0.0000	0.00000	20.200	0.00	20.200	0.00	0.000
		TM5	2	16. 00	1.550	1.1000	.08371	15.800	-.71	17.700	.71	2.200
23 TEAMTEM			8	[illegible]	9.480	3.2447	.20493	24.300	-1.28	64.300	1.87	30.?80
	TEAM	TM1	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-.71	[illegible]	.71	[illegible]
		TM2	1	48.400	0.000	0.0000	0.00000	48.400	0.00	48.400	0.00	0.000
		TM3	2	52.500	16.580	11.8000	.31786	40.700	-.71	64.300	.71	23.800
		TM4	1	51.600	0.000	0.0000	0.00000	51.600	0.00	51.600	0.00	0.000
		TM5	2	37.750	4.878	3.4500	.12926	34.300	-.71	41.300	.71	6.900
24 TADJUST			8	6.850	3.017	1.0668	.48363	2.000	-1.21	12.700	2.01	9.700
	TEAM	TM1	2	7.050	1.344	.9500	.19057	6.100	-.71	8.000	.71	1.900
		TM2	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM3	2	6.800	2.121	1.5000	.31196	5.300	-.71	8.300	.71	3.000
		TM4	1	6.200	0.000	0.0000	0.00000	6.200	0.00	6.200	0.00	0.000
		TM5	2	9.150	5.020	3.5500	.54866	5.600	-.71	12.700	.71	7.100
25 ISATCHPL			8	28.000	6.303	2.2282	.21732	22.200	-1.00	38.400	1.88	16.300
	TEAM	TM1	2	30.300	11.456	8.1000	.37808	22.200	-.71	38.400	.71	16.200
		TM2	1	28.100	0.000	0.0000	0.00000	28.100	0.00	28.100	0.00	0.000
		TM3	2	[illegible]	[illegible]	[illegible]	.11356	[illegible]	-.71	[illegible]	.71	[illegible]
		TM4	1	22.800	0.000	0.0000	0.00000	22.800	0.00	22.800	0.00	0.000
		TM5	2	31.600	8.810	8.2000	.28135	25.300	-.71	37.800	.71	12.600
26 IPTRSMRE			8	8.000	3.828	1.7654	.40315	5.100	-1.07	13.800	1.38	8.600
	TEAM	TM1	2	6.350	1.768	1.2500	.27839	5.100	-.71	7.600	.71	2.500
		TM2	1	7.200	0.000	0.0000	0.00000	7.200	0.00	7.200	0.00	0.000
		TM3	2	9.750	5.303	3.7500	.54393	6.000	-.71	13.500	.71	7.500
		TM4	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM5	2	9.350	4.313	3.0500	.46132	6.300	-.71	12.400	.71	6.100

II. M109 Breech Block Task - MOPP Trials

A. Raw Data

M109 BREECH BLOCK MOPP DATA

CASE NO.	LABEL	2 OPFIREMC	3 RCATCHPL	4 LADJUST	5 REANTEN	6 RCAMDAM	7 SECURCAM	8 OPENBBLK	9 LOCBBLK	10 RPLGREP	11 RPMMOUS
1	M152	5.100	22.700	18.100	20.400	12	21.100	5.500	5.400	21.600	22.800
2	M241	8.600	20	18.600	26.800	25.700	29.800	12.100	12	52.500	34.100
3	M252	6.100	41.800	20.300	32	32.300	30	8.800	8.100	23.100	32
4	M302	4.800	14.100	13.400	54.600	14.100	18.800	8.800	8.500	28.300	33.700
5	5375	5.300	16.800	14.400	47.800	16.800	20.300	8	5.800	28.600	32.800
6	8422	10.800	25.800	30.300	72.100	14.700	28.800	12.400	11.200	63.300	37.700
7	8588	10.200	35.800	7.100	46.100	17.800	28.300	10.200	7.600	41.400	44.700
8	9554	8.700	18.800	19.800	47.100	17.300	30.300	10.800	7.800	48.700	50.800

CASE NO.	LABEL	12 ROOTUB	13 RBBLK	14 IBBLK	15 IJOTUB	16 IPMMOUS	17 TPMMOUS	18 IPLGREP	19 ULOCBBLK	20 CLOSBBLK	21 RELCAM
1	M152	7.100	22.330	26.300	5.300	24.700	28.300	21.700	7.200	5.300	20.100
2	M241	7.400	37.800	21.600	8.600	58.800	37.400	40	8.200	8.400	17.800
3	M252	8.800	22.100	34.200	6.400	33	41	38	4.100	10.700	20.700
4	M302	5.800	20.100	27.100	5.800	9.800	28.500	23	4.500	8.100	10.700
5	5375	5.100	16.600	20.100	7.400	13.800	37.200	37.600	3.300	7.100	7.600
6	8422	7.300	43.800	35.800	7.800	26.200	44.100	44	6.400	10.300	8
7	8588	8.600	20.600	26.300	7.100	30.100	37.400	37.100	3.500	9.400	11.400
8	9554	7.100	23.800	27	5.700	31.300	38.300	34.400	3.800	14.600	17.100

CASE NO.	LABEL	22 ICAMDAM	23 TCANTEN	24 TADJUST	25 ICATCHPL	26 IPFIREMC
1	M152	27.200	57.100	11.100	22.500	6.700
2	M241	27.200	82.300	10.700	28.800	13.800
3	M252	24.100	45.800	10.900	33.700	11.100
4	M302	48.800	44.400	7.100	30.700	18.900
5	5375	25.600	34.100	5.200	38.200	6.200
6	8422	34.600	55.800	8.600	28.300	15.800
7	8588	26.800	61.400	6.300	33.100	11.800
8	9554	21.800	43.700	19.700	46.800	10.100

B. Descriptive Statistics

M109 BREECH BLOCK MOPP DATA

VARIABLE NO. NAME	GROUPING VARIABLE	LEVEL	TOTAL FREQUENCY	MEAN	STANDARD DEVIATION	ST. ERR OF MEAN	COEFF. OF VARIATION	SMALLEST VALUE	Z-SCORE	LARGEST VALUE	Z-SCORE	RANGE
2 OPFIREMC			8	8.550	2.228	.7878	.32054	4.800	-1.06	10.800	1.34	6.000
	TEAM	TM1	1	5.100	0.000	0.0000	0.00000	5.100	0.00	5.100	0.00	0.000
		TM2	2	8.350	.354	.2500	.04235	8.100	-.71	8.600	.71	.500
		TM3	2	4.850	.495	.3500	.08888	4.800	-.71	5.300	.71	.700
		TM4	1	10.800	0.000	0.0000	0.00000	10.800	0.00	10.800	0.00	0.000
		TM5	2	9.450	1.061	.7500	.11225	8.700	-.71	10.200	.71	1.500
3 RCATCHPL			8	24.838	8.788	3.0088	.35370	14.100	-1.22	41.800	1.64	27.700
	TEAM	TM1	1	22.700	0.000	0.0000	0.00000	22.700	0.00	22.700	0.00	0.000
		TM2	2	30.900	15.414	10.9000	.49883	20.000	-.71	41.800	.71	21.800
		TM3	2	15.850	4.031	2.8500	.23770	14.100	-.71	18.800	.71	5.700
		TM4	1	25.800	0.000	0.0000	0.00000	25.800	0.00	25.800	0.00	0.000
		TM5	2	21.350	6.647	4.7000	.31253	16.800	-.71	25.800	.71	8.400
4 LADJUST			8	17.838	8.184	2.8843	.48387	7.100	-1.18	30.300	1.64	23.200
	TEAM	TM1	1	18.100	0.000	0.0000	0.00000	18.100	0.00	18.100	0.00	0.000
		TM2	2	22.800	8.981	6.4000	.38424	18.600	-.71	30.300	.71	12.800
		TM3	2	13.900	.707	.5000	.05087	13.400	-.71	14.400	.71	1.000
		TM4	1	30.300	0.000	0.0000	0.00000	30.300	0.00	30.300	0.00	0.000
		TM5	2	9.350	3.061	1.4000	.31032	7.100	-.71	10.800	.71	2.800
5 REANTEN			8	44.812	14.887	5.2828	.33381	20.400	-1.18	72.100	1.38	48.300
	TEAM	TM1	1	20.400	0.000	0.0000	0.00000	20.400	0.00	20.400	0.00	0.000
		TM2	2	29.400	3.606	2.5500	.12265	26.800	-.71	32.000	.71	5.100
		TM3	2	51.100	4.887	3.2000	.08133	47.800	-.71	54.600	.71	6.800
		TM4	1	72.100	0.000	0.0000	0.00000	72.100	0.00	72.100	0.00	0.000
		TM5	2	46.600	.028	.4800	.01384	46.100	-.71	47.100	.71	.800
6 RCAMDAM			8	18.862	6.817	2.2388	.33883	12.000	-1.10	32.300	1.81	20.300
	TEAM	TM1	1	12.000	0.000	0.0000	0.00000	12.000	0.00	12.000	0.00	0.000
		TM2	2	28.800	3.180	2.8000	.13432	25.700	-.71	32.300	.71	8.800
		TM3	2	16.480	.495	.3500	.03041	16.100	-.71	16.800	.71	.700
		TM4	1	14.700	0.000	0.0000	0.00000	14.700	0.00	14.700	0.00	0.000
		TM5	2	17.350	.212	.1500	.01223	17.300	-.71	17.800	.71	.300
7 SECURCAM			8	27.050	5.220	2.1003	.23386	18.800	-1.21	30.800	1.00	10.700
	TEAM	TM1	1	28.800	0.000	0.0000	0.00000	28.800	0.00	28.800	0.00	0.000
		TM2	2	29.900	.424	.3000	.01444	29.800	-.71	30.800	.71	.600
		TM3	2	20.050	.354	.2500	.01763	19.800	-.71	20.300	.71	.500
		TM4	1	28.800	0.000	0.0000	0.00000	28.800	0.00	28.800	0.00	0.000
		TM5	2	29.350	2.758	1.0500	.05783	28.300	-.71	30.300	.71	2.800
8 OPENBBLK			8	9.662	2.871	.0443	.27832	5.500	-1.58	12.400	1.44	7.000
	TEAM	TM1	1	5.500	0.000	0.0000	0.00000	5.500	0.00	5.500	0.00	0.000
		TM2	2	10.450	1.768	1.2500	.16223	8.800	-.71	12.100	.71	2.500
		TM3	2	7.400	.848	.6000	.11467	8.400	-.71	8.800	.71	1.200
		TM4	1	12.400	0.000	0.0000	0.00000	12.400	0.00	12.400	0.00	0.000
		TM5	2	10.550	.488	.3500	.04603	10.200	-.71	10.800	.71	.700

[illegible] SCREEN BLOCK [illegible] DATA

VARIABLE NO NAME	GROUPING VARIABLE LEVEL		TOTAL FREQUENCY	MEAN	STANDARD DEVIATION	ST ERR OF MEAN	COEFF OF VARIATION	SMALLEST VALUE	SMALLEST Z-SCORE	LARGEST VALUE	LARGEST Z-SCORE	RANGE
9 [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TEAM	TM1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10 [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TEAM	TM1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11 [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TEAM	TM1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12 [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TEAM	TM1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13 [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TEAM	TM1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14 [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TEAM	TM1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15 [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TEAM	TM1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16 [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TEAM	TM1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17 [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TEAM	TM1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18 [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TEAM	TM1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19 [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TEAM	TM1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20 [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TEAM	TM1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21 [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TEAM	TM1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22 [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TEAM	TM1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23 [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TEAM	TM1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24 [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TEAM	TM1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
25 [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TEAM	TM1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
26 [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TEAM	TM1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TM5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

III. M60 Machine Gun Task - BDU Trials

A. Raw Data

M60 MACHINE GUN BDU DATA

CASE NO.	LABEL	2 COCKUPN	3 RBARREL	4 LBENUT	5 RBENUT	6 LEXTEN	7 REXTEN	8 LEEPLUG	9 REEPLUG	10 IEXTEN	11 TEXTEN
1	8122	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	8372	6.200	5	4.500	13.500	3.200	14.300	10.100	4.700	14.500	3.800
3	8264	6.500	5.600	5	11.300	5	15.700	4.200	3.600	10.600	3.100
4	8361	6.400	6.400	17.100	8.400	4.300	16.800	11.800	4.100	19.600	16
5	8303	3.300	16.600	12.250	8.600	6.300	18.300	4.600	3.700	25.600	16.600
6	8301	3.300	9.200	10.300	12.300	5.100	10.800	13.500	3.600	15.800	3.400
7	8302	4.300	7	13.300	7.800	9.400	17.800	7.700	3.500	18	3
8	8433	4.800	8.100	7.600	11.800	8.800	19.100	8.300	6.100	16.600	3.600
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	8400	8.100	6.100	3.600	11.600	3.200	16.800	3.300	5	18.600	3.700
11	8401	6.800	4.700	6	10.300	8	17.800	3.800	5	20.700	3.800

CASE NO.	LABEL	12 IBENUT	13 TBENUT	14 IEEPLUG	15 TEEPLUG	16 IBARREL	17 ALPSPRG	18 ATRIGGP	19 ABEARTRG	20 IBEARTRG	21 ITRIGPP	22 ILPSPRG
1	8122	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	8372	10.100	5.700	4.800	8.900	15.700	5.800	13.200	20.100	61.800	11.300	9.500
3	8264	18.800	4.800	5.800	3.500	12.700	6.700	9.100	15.800	66.800	65.600	10.300
4	8361	20.800	4.600	5.400	8.800	11.100	6.200	10.800	23.600	66.100	28.700	16
5	8303	12.400	4	7	5	8.100	5.300	8.266	26.400	45.166	16.700	16
6	8301	16.500	4.800	7.800	4.800	4.300	6.400	8.800	17.300	61.500	47.600	16.800
7	8302	14.000	4.100	6.700	4.800	10.300	3	5.600	20.600	57.300	28.400	9.400
8	8433	17.100	8.300	7.700	7.400	8.700	4.700	5.300	22	65.600	16.700	7.700
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	8400	13.700	3.100	5.800	4.800	5.700	4.800	7.200	16.100	52.800	30.100	7.700
11	8401	17.800	3.200	6.800	8.100	6.400	3.800	8.800	14.100	38.800	8.300	8.700

B. Descriptive Statistics

M60 MACHINE GUN BDU DATA

VARIABLE NO. NAME	GROUPING VARIABLE	LEVEL	TOTAL FREQUENCY	MEAN	STANDARD DEVIATION	ST. ERR OF MEAN	COEFF. OF VARIATION	SMALLEST VALUE	Z-SCORE	LARGEST VALUE	Z-SCORE	RANGE
2 COCKUPN			11	5.300	.680	.1358	.10633	3.800	-1.75	6.100	1.18	1.600
	SUBJECT	SUBJ1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ2	2	6.250	.212	.1500	.03477	6.100	-.71	6.400	.71	.300
		SUBJ3	4	4.675	.276	.1377	.05756	4.300	-.71	4.400	1.18	.300
		SUBJ4	4	4.700	.216	.1081	.04728	4.400	-.38	5.100	1.39	.700
3 RBARREL			11	7.136	2.184	.6586	.30 [illegible]	4.700	-1.12	10.800	1.76	6.200
	SUBJECT	SUBJ1	1	5.800	0.000	0.0000	0.00000	5.800	0.00	5.800	0.00	0.000
		SUBJ2	2	8.600	2.687	1.8000	.30842	5.800	-.71	8.800	.71	3.600
		SUBJ3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	7.300	2.521	1.2606	.34303	4.700	-1.08	10.600	1.36	5.800
4 LBENUT			11	8.400	4.207	1.2688	.51196	3.800	-1.12	17.100	2.08	13.800
	SUBJECT	SUBJ1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ2	2	4.750	.354	.2500	.07442	4.500	-.71	5.000	.71	.500
		SUBJ3	4	13.225	2.866	1.4334	.21677	10.300	-1.03	17.100	1.36	6.800
		SUBJ4	4	6.300	1.690	.8452	.20480	3.800	-1.30	7.600	.74	4.000
5 RBENUT			11	11.227	2.237	.6745	.19928	7.800	-1.48	15.700	2.00	7.800
	SUBJECT	SUBJ1	1	15.700	0.000	0.0000	0.00000	15.700	0.00	15.700	0.00	0.000
		SUBJ2	2	12.350	1.626	1.1500	.13168	11.200	-.71	13.500	.71	2.300
		SUBJ3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	11.100	.840	.4227	.06780	10.300	-1.47	11.800	.78	1.400
6 LEXTEN			11	5.600	1.664	.5021	.29013	3.200	-1.33	8.400	1.93	5.200
	SUBJECT	SUBJ1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ2	2	6.450	.778	.5500	.17670	5.900	-.71	8.000	.71	1.100
		SUBJ3	4	7.000	2.336	1.1668	.33340	4.800	-.88	9.400	1.03	4.600
		SUBJ4	4	4.575	1.428	.7145	.31236	3.300	-.38	6.800	1.00	3.500
7 REXTEN			11	16.301	2.300	.6962	.14088	10.800	-2.42	19.1 [illegible]	1.17	8.300
	SUBJECT	SUBJ1	1	18.300	0.000	0.0000	0.00000	18.300	0.00	[illegible]	0.00	0.000
		SUBJ2	2	15.500	.990	.7000	.06400	14.800	-.71	16.200	.71	1.400
		SUBJ3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	17.425	1.237	.6183	.07097	16.300	-.89	19.100	1.35	3.100
8 LEEPLUG			11	7.464	2.602	1.1043	.51740	3.300	-1.06	13.500	1.88	10.200
	SUBJECT	SUBJ1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ2	2	7.200	4.101	2.9000	.56961	4.300	-.71	10.100	.71	5.800
		SUBJ3	4	8.450	3.542	1.3708	.41711	6.800	-1.18	13.500	1.03	6.700
		SUBJ4	4	4.350	1.370	.6850	.31403	3.300	-.77	6.300	1.43	3.000
9 REEPLUG			11	4.345	.910	.2761	.21075	3.600	-1.05	6.100	1.83	2.300
	SUBJECT	SUBJ1	1	4.700	0.000	0.0000	0.00000	4.700	0.00	4.700	0.00	0.000
		SUBJ2	2	4.150	.778	.5500	.18743	3.600	-.71	4.700	.71	1.100
		SUBJ3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	5.175	.666	.3330	.12881	4.500	-.88	6.100	1.43	1.600

M60 MACHINE GUN RAW DATA

VARIABLE NO NAME	GROUPING VARIABLE	LEVEL	TOTAL FREQUENCY	MEAN	STANDARD DEVIATION	ST ERR OF MEAN	COEFF OF VARIATION	SMALLEST VALUE	SMALLEST Z-SCORE	LARGEST VALUE	LARGEST Z-SCORE	RANGE
10 IESTEM			11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SUBJECT	SUBJ1	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ2	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-.71	[illegible]	.71	[illegible]
		SUBJ3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11 TESTEM			11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SUBJECT	SUBJ1	1	[illegible]	0.000	0.0000	0.00000	[illegible]	0.00	[illegible]	0.00	0.000
		SUBJ2	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-.71	[illegible]	.71	[illegible]
		SUBJ3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12 IECRUT			11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SUBJECT	SUBJ1	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ2	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-.71	[illegible]	.71	[illegible]
		SUBJ3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13 TECRUT			11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SUBJECT	SUBJ1	1	[illegible]	0.000	0.0000	0.00000	[illegible]	0.00	[illegible]	0.00	0.000
		SUBJ2	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-.71	[illegible]	.71	[illegible]
		SUBJ3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14 IECPLUG			11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SUBJECT	SUBJ1	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ2	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-.71	[illegible]	.71	[illegible]
		SUBJ3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15 TECPLUG			11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SUBJECT	SUBJ1	1	[illegible]	0.000	0.0000	0.00000	[illegible]	0.00	[illegible]	0.00	[illegible]
		SUBJ2	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-.71	[illegible]	.71	[illegible]
		SUBJ3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16 IBARREL			11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SUBJECT	SUBJ1	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ2	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-.71	[illegible]	.71	[illegible]
		SUBJ3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17 BLFSPRG			11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SUBJECT	SUBJ1	1	[illegible]	0.000	0.0000	0.00000	[illegible]	0.00	[illegible]	0.00	0.000
		SUBJ2	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-.71	[illegible]	.71	[illegible]
		SUBJ3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18 ATRIGGR			11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SUBJECT	SUBJ1	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ2	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-.71	[illegible]	.71	[illegible]
		SUBJ3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19 BSEARTRG			11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SUBJECT	SUBJ1	1	[illegible]	0.000	0.0000	0.00000	[illegible]	0.00	[illegible]	0.00	0.000
		SUBJ2	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-.71	[illegible]	.71	[illegible]
		SUBJ3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20 ISEARTRG			11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SUBJECT	SUBJ1	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ2	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-.71	[illegible]	.71	[illegible]
		SUBJ3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21 ITRIGGR			11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SUBJECT	SUBJ1	1	[illegible]	0.000	0.0000	0.00000	[illegible]	0.00	[illegible]	0.00	0.000
		SUBJ2	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-.71	[illegible]	.71	[illegible]
		SUBJ3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22 ILFSPRG			11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SUBJECT	SUBJ1	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ2	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-.71	[illegible]	.71	[illegible]
		SUBJ3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

IV. M60 Machine Gun Task - MOPP Trials

A. Raw Data

1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

B. Descriptive Statistics

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

M60 MACHINE GUN MOPP DATA

VARIABLE NO. NAME	GROUPING VARIABLE	LEVEL	TOTAL FREQUENCY	MEAN	STANDARD DEVIATION	ST. ERR OF MEAN	COEFF OF VARIATION	SMALLEST VALUE	Z-SCORE	LARGEST VALUE	Z-SCORE	RANGE
12 [illegible]			11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SUBJECT	SUBJ1	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ2	0									
		SUBJ3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13 [illegible]			11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SUBJECT	SUBJ1	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ2	0									
		SUBJ3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14 [illegible]			11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SUBJECT	SUBJ1	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ2	0									
		SUBJ3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15 [illegible]			11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SUBJECT	SUBJ1	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ2	0									
		SUBJ3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16 [illegible]			11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SUBJECT	SUBJ1	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ2	0									
		SUBJ3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17 [illegible]			11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SUBJECT	SUBJ1	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ2	0									
		SUBJ3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18 [illegible]			11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SUBJECT	SUBJ1	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ2	0									
		SUBJ3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19 [illegible]			11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SUBJECT	SUBJ1	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ2	0									
		SUBJ3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20 [illegible]			11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SUBJECT	SUBJ1	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ2	0									
		SUBJ3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21 [illegible]			11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SUBJECT	SUBJ1	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ2	0									
		SUBJ3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22 [illegible]			11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SUBJECT	SUBJ1	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ2	0									
		SUBJ3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SUBJ4	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

APPENDIX E

Sample Regression Output - IFE (BMDP1R)

```
PAGE    1
BMDP1R - MULTIPLE LINEAR REGRESSION
DEPARTMENT OF BIOMATHEMATICS
UNIVERSITY OF CALIFORNIA, LOS ANGELES, CA 90024
(213) 825-5940            TWX  UCLA LSA
PROGRAM REVISED JUNE 1981
MANUAL REVISED -- 1981
COPYRIGHT (C) 1981 REGENTS OF UNIVERSITY OF CALIFORNIA
EXECUTED ON 85/03/24 AT [illegible]

TO SEE REMARKS AND A SUMMARY OF NEW FEATURES FOR
THIS PROGRAM, STATE NEWS  IN THE PRINT PARAGRAPH
THIS VERSION OF BMDP HAS BEEN CONVERTED FOR USE ON
CDC 6000 AND CYBER SERIES COMPUTERS BY
    [illegible], VOGELBACK COMPUTING CENTER
    NORTHWESTERN UNIVERSITY
    2129 SHERIDAN ROAD
    EVANSTON, ILLINOIS 60201

PROGRAM CONTROL INFORMATION

/PROBLEM       TITLE IS 'IFE RATIO'
/INPUT         FORMAT IS FREE
               VARIABLES ARE 6.
               UNIT IS 2
/VARIABLE      NAMES ARE EVENT,ROUTING,HOPPTIME,X1,X2,X3,Y
               ADD=1
               LABEL=EVENT
/TRANSFORM     Y=ROUTING/HOPPTIME.
/REGRESS       DEPENDENT IS Y
               INDEPENDENT ARE X1,X2,X3
/PRINT         DATA
               CORRELATION.
/PLOT          RESID
               NORM
/END

BMDP UNIT NO.  2 SPECIFIED IN THE INPUT  PARAGRAPH
WILL REFER TO LOCAL FILE NAME IFEDAT? FOR THIS PROBLEM.
```

```
PAGE    2     IFE RATIO

PROBLEM TITLE IS
IFE RATIO

NUMBER OF VARIABLES TO READ IN. . . . . . . . . .      6
NUMBER OF VARIABLES ADDED BY TRANSFORMATIONS. .        1
TOTAL NUMBER OF VARIABLES . . . . . . . . . . .        7
NUMBER OF CASES TO READ IN. . . . . . . . . . .   TO END
CASE LABELING VARIABLES . . . . . . . . . . . .    EVENT
MISSING VALUES CHECKED BEFORE OR AFTER TRANS. .  NEITHER
BLANKS ARE. . . . . . . . . . . . . . . . . . .  MISSING
INPUT UNIT NUMBER . . . . . . . . . . . . . . .        2
REWIND INPUT UNIT PRIOR TO READING. . DATA. . .      YES
NUMBER OF WORDS OF DYNAMIC STORAGE. . . . . . .     [illegible]

***** TRAN     PARAGRAPH IS USED *****

VARIABLES TO BE USED
     2 ROUTING      3 HOPPTIME     4 X1           5 X2           6 X3
     7 Y

INPUT FORMAT IS
FREE

MAXIMUM LENGTH DATA RECORD IS   60 CHARACTERS.
   REGRESSION INTERCEPT . . . . . . . . . . . . . .  .NON-ZERO
   GROUPING VARIABLE  . . . . . . . . . . . . . . .
   WEIGHT VARIABLE  . . . . . . . . . . . . . . . .
   PRINT COVARIANCE MATRIX. . . . . . . . . . . . .       NO
   PRINT CORRELATION MATRIX. . . . . . . . . . . .       YES
   PRINT CORRELATION OF REGRESSION COEFFICIENTS. .        NO
   PRINT RESIDUALS . . . . . . . . . . . . . . . .       YES
   PRINT NORMAL PROBABILITY PLOT . . . . . . . . .       YES
   PRINT DETRENDED NORMAL PROBABILITY PLOT . . . .       YES

NUMBER OF CASES READ. . . . . . . . . . . . . . .       14

VARIABLE             MEAN STANDARD DEVIATION COEFFICIENT     MINIMUM       MAXIMUM
                                             OF VARIATION
   2 ROUTING     12.54857          5.38292      .42746      5.35000      18.60000
   3 HOPPTIME    17.04357          7.54534      .44377      5.53000      28.25000
   4 X1            .35714           .49725     1.39239      0.00000       1.00000
   5 X2            [illegible]      [illegible] [illegible] [illegible]  [illegible]
   6 X3            .21429           .42582     1.98716      0.00000       1.00000
   7 Y             .70766           .18147      .26042       .41000       1.10448
```

PAGE 3 IPE RATIO

CORRELATION MATRIX

		ROUTING	HOPPTIME	X1	X2	X3	Y
		1	2	4	5	6	7
ROUTING	2	1.0000					
HOPPTIME	3	.[illegible]	1.0000				
X1	4	-.[illegible]	-.4700	1.0000			
X2	5	.[illegible]	.[illegible]	-.2602	1.0000		
X3	6	.[illegible]	.[illegible]	-.3002	-.2727	1.0000	
Y	7	.[illegible]	-.2000	-.0751	-.0662	.0137	1.0000

PAGE 4 IPE RATIO

REGRESSION TITLE IS
IPE RATIO

DEPENDENT VARIABLE. . . . . 7 Y
TOLERANCE 0100
ALL DATA CONSIDERED AS A SINGLE GROUP

MULTIPLE R .1707 STD. ERROR OF EST. .2151
MULTIPLE R-SQUARE .0291

ANALYSIS OF VARIANCE

	SUM OF SQUARES	DF	MEAN SQUARE	F RATIO	P(TAIL)
REGRESSION	.0120	3	.0040	.100	.9602
RESIDUAL	.4027	10	.0403		

VARIABLE		COEFFICIENT	STD. ERROR	STD. REG COEFF	T	P(2 TAIL)	TOLERANCE
INTERCEPT		.02324					
X1	4	-.07677	.18708	-.183	-.4[illegible]	.[illegible]	.[illegible]
X2	5	-.08006	.17663	-.161	-.450	.6247	.62050
X3	6	-.04067	.17663	-.110	-.262	.7931	.62050

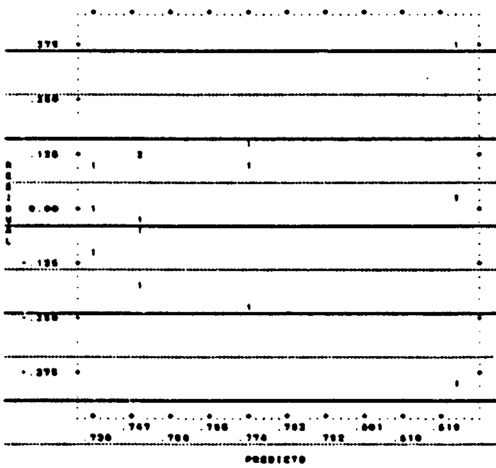
PAGE 5 IFE RATIO

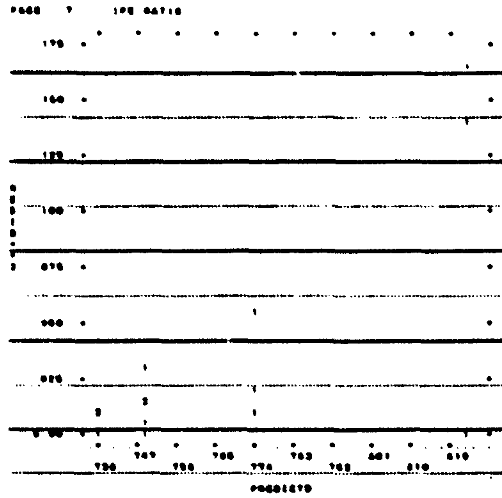
LIST OF PREDICTED VALUES, RESIDUALS AND VARIABLES
NOTE - NEGATIVE CASE NUMBER DENOTES A CASE WITH MISSING VALUES.
THE NUMBER OF STANDARD DEVIATIONS FROM THE MEAN IS DENOTED BY UP TO 3 ASTERISKS TO THE RIGHT
OF EACH RESIDUAL OR VARIABLE
MISSING VALUES AND VALUES OUT OF RANGE ARE DENOTED BY VALUES
GREATER THAN OR EQUAL TO [illegible] IN ABSOLUTE VALUE

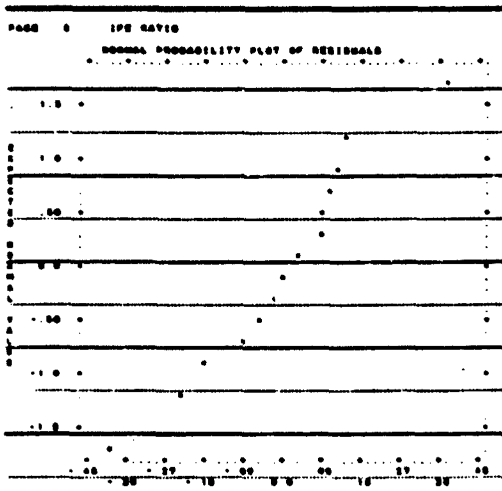
CASE LABEL	NO.	RESIDUAL	PREDICTED VALUE	VARIABLES 2 ROUTING	3 [illegible]	4 X1	5 X2	6 X3	7 Y
[illegible]	1	[illegible]	[illegible]	[illegible] *	[illegible] *	1.000 *	0	0	[illegible]
1253	2	-.1731	.7483	7.200	12.50	1.000 *	0	0	.5700 *
[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	1.000 *	0	0	[illegible]
1254	4	.1207	.7461	13.50	15.50	1.000 *	0	0.	.8707
[illegible]	5	[illegible]	[illegible]	[illegible]	[illegible]	1.000 *	0	0	[illegible]
2001	6	-.82955E-01	.7272	17.60	27.63 *	0	1.000 *	0.	.6442
[illegible]	7	[illegible]	[illegible]	[illegible] *	[illegible]	0	1.000 *	0	[illegible]
2004	8	.13738E-02	.7272	16.35 *	25.30 *	0	1.000 *	0	.7366
[illegible]	9	[illegible]	[illegible]	[illegible] *	[illegible]	0	0	1.000 *	[illegible]
2112	10	.1407	.7735	16.00	17.50	0	0	1.000 *	.9143
[illegible]	11	[illegible] *	[illegible]	[illegible]	[illegible] *	0	0	1.000 *	[illegible] *
2121	12	.3712 *	.8232	7.600	6.530 *	0.	0	0	1.194 **
[illegible]	13	[illegible]	[illegible]	[illegible] *	[illegible] *	0.	0	0.	[illegible]
2134	14	-.4032 *	.8232	6.900 *	10.43	0.	0.	0.	.4200 *

SERIAL CORRELATION OF RESIDUALS = -.2755

PAGE 6 IFE RATIO







APPENDIX F

Kruskal-Wallis and T Test Output (BMDP3S and BMDP3D)

I. Finger Movement Categories

A. T Test Output

```
                    FINGER MOVEMENT DEGRADATION

DIFFERENCES ON SINGLE VARIABLES

**************
* DEGRAD     *   VARIABLE NUMBER   2          GROUP     2 IFE          4 RFE
**************                                MEAN              .7706          .8428
           STATISTICS    P-VALUE    DF        STD DEV           .0361          .0703
                                              S.E.M.            .0180          .0314
T (SEPARATE)      -1.86   .0958     6.3       SAMPLE SIZE           4              5
T (POOLED)        -1.82   .1106     7         MAXIMUM           .8230          .9550
                                              MINIMUM           .7370          .7830
F(FOR VARIANCES)
    LEVENE          .64   .4503     1,   7

NUMBER OF INTEGER WORDS OF STORAGE USED IN PRECEDING     PROBLEM      288
CPU TIME USED            .064 SECONDS
```

```
**************
* DEGRAD     *   VARIABLE NUMBER   2          GROUP     1 IFD          3 RFD
**************                                MEAN              .6710          .7358
           STATISTICS    P-VALUE    DF        STD DEV           .0732          .0890
                                              S.E.M.            .0328          .0445
T (SEPARATE)      -1.12   .3120     5.2       SAMPLE SIZE           5              4
T (POOLED)        -1.20   .2656     8         MAXIMUM           .7580          .8590
                                              MINIMUM           .5680          .6170
F(FOR VARIANCES)
    LEVENE          .03   .8683     1,   6

NUMBER OF INTEGER WORDS OF STORAGE USED IN PRECEDING     PROBLEM      288
CPU TIME USED            .064 SECONDS
```

```
**************
* DEGRAD     *   VARIABLE NUMBER   2          GROUP     1 IFD          2 IFE
**************                                MEAN              .6710          .7706
           STATISTICS    P-VALUE    DF        STD DEV           .0732          .0361
                                              S.E.M.            .0328          .0180
T (SEPARATE)      -2.61   .0234     7.6       SAMPLE SIZE           5              4
T (POOLED)        -2.48   .0384     8         MAXIMUM           .7580          .8230
                                              MINIMUM           .5680          .7370
F(FOR VARIANCES)
    LEVENE         2.34   .1644     1,   8

NUMBER OF INTEGER WORDS OF STORAGE USED IN PRECEDING     PROBLEM      288
CPU TIME USED            .326 SECONDS
```

```
**************
* DEGRAD     *   VARIABLE NUMBER   2          GROUP     3 RFD          4 RFE
**************                                MEAN              .7358          .8428
           STATISTICS    P-VALUE    DF        STD DEV           .0890          .0703
                                              S.E.M.            .0445          .0314
T (SEPARATE)      -1.82   .1250     6.3       SAMPLE SIZE           4              5
T (POOLED)        -1.90   .0981     7         MAXIMUM           .8590          .9550
                                              MINIMUM           .6170          .7830
F(FOR VARIANCES)
    LEVENE          .10   .6767     1,   7

NUMBER OF INTEGER WORDS OF STORAGE USED IN PRECEDING     PROBLEM      288
CPU TIME USED            .066 SECONDS
```

B. Kruskal-Wallis Test Output

```
KRUSKAL-WALLIS ONE WAY ANALYSIS OF VARIANCE TEST RESULTS

VARIABLE      2 [illegible]
 GROUP            FREQUENCY        RANK
NO  NAME                           SUM
 1  [illegible]       6?           12.0?
 2  [illegible]       6?           33.0?

KRUSKAL-WALLIS TEST STATISTIC =    [illegible]
LEVEL OF SIGNIFICANCE =   .0491? USING CHI-SQUARE DISTRIBUTION WITH     1 DEGREES OF FREEDOM

MANN-WHITNEY TEST STATISTIC =        [illegible]
LEVEL OF SIGNIFICANCE =   .0491? USING NORMAL TWO-TAIL APPROXIMATION

NUMBER OF INTEGER WORDS OF STORAGE USED IN PROCESSING    PROBLEM    4?70
CPU TIME USED        .?00 SECONDS
```

```
KRUSKAL-WALLIS ONE WAY ANALYSIS OF VARIANCE TEST RESULTS

VARIABLE      2 [illegible]
 GROUP            FREQUENCY        RANK
NO. NAME                           SUM
 1  [illegible]       5?           37.0?
 2  [illegible]       4            18.0?

KRUSKAL-WALLIS TEST STATISTIC =    1.?2?2?
LEVEL OF SIGNIFICANCE =   .2?0? USING CHI-SQUARE DISTRIBUTION WITH     1 DEGREES OF FREEDOM

MANN-WHITNEY TEST STATISTIC =        [illegible]
LEVEL OF SIGNIFICANCE =   .2?0? USING NORMAL TWO-TAIL APPROXIMATION

NUMBER OF INTEGER WORDS OF STORAGE USED IN PROCESSING    PROBLEM    4?70
CPU TIME USED        .287? SECONDS
```

```
KRUSKAL-WALLIS ONE WAY ANALYSIS OF VARIANCE TEST RESULTS

VARIABLE      2 [illegible]
 GROUP            FREQUENCY        RANK
NO. NAME                           SUM
 1  [illegible]       5?           33.0?
 2  [illegible]       4            12.0?

KRUSKAL-WALLIS TEST STATISTIC =    4.?4?4?
LEVEL OF SIGNIFICANCE =   .0330? USING CHI-SQUARE DISTRIBUTION WITH     1 DEGREES OF FREEDOM

MANN-WHITNEY TEST STATISTIC =        2.00?
LEVEL OF SIGNIFICANCE =   .0330? USING NORMAL TWO-TAIL APPROXIMATION

NUMBER OF INTEGER WORDS OF STORAGE USED IN PROCESSING    PROBLEM    4?70
CPU TIME USED        .270? SECONDS
```

```
KRUSKAL-WALLIS ONE WAY ANALYSIS OF VARIANCE TEST RESULTS

VARIABLE      3? [illegible]
 GROUP            FREQUENCY        RANK
NO. NAME                           SUM
 1  [illegible]       4            14.0
 2  [illegible]       5?           31.0?

KRUSKAL-WALLIS TEST STATISTIC =    2.17?1?
LEVEL OF SIGNIFICANCE =   .1400? USING CHI-SQUARE DISTRIBUTION WITH     1 DEGREES OF FREEDOM

MANN-WHITNEY TEST STATISTIC =        4.00?
LEVEL OF SIGNIFICANCE =   .1400? USING NORMAL TWO-TAIL APPROXIMATION

NUMBER OF INTEGER WORDS OF STORAGE USED IN PROCESSING    PROBLEM    4?70
CPU TIME USED        [illegible] SECONDS
```

II. Hand Movement Categories

A. T Test Output

```
                 HAND MOVEMENT DEGRADATION

DIFFERENCES ON SINGLE VARIABLES

*************
* DEGRAD    *    VARIABLE NUMBER    2          GROUP     2 INE           4 RNE
*************                                  MEAN              .8010           .9240
              STATISTICS     P-VALUE    DF     STD DEV           .0826           .0884
                                               S.E.M.            .0337           .0312
T (SEPARATE)        -2.70    .0204     11.3    SAMPLE SIZE           6               8
T (POOLED)          -2.67    .0206     12      MAXIMUM           .8750          1.0730
                                               MINIMUM           .7050           .8400
F(FOR VARIANCES)
     LEVENE           .01    .9423      1,  12

NUMBER OF INTEGER WORDS OF STORAGE USED IN PRECEDING     PROBLEM        289
CPU TIME USED          .066 SECONDS


*************
* DEGRAD    *    VARIABLE NUMBER    2          GROUP     1 IND           3 RND
*************                                  MEAN              .6950           .8840
              STATISTICS     P-VALUE    DF     STD DEV           .1213           .0500
                                               S.E.M.            .0606           .0288
T (SEPARATE)        -2.81    .0456      4.2    SAMPLE SIZE           4               3
T (POOLED)          -2.50    .0547      5      MAXIMUM           .8600           .9400
                                               MINIMUM           .5910           .8440
F(FOR VARIANCES)
     LEVENE          1.44    .2838      1,  5

NUMBER OF INTEGER WORDS OF STORAGE USED IN PRECEDING     PROBLEM        280
CPU TIME USED          .062 SECONDS


*************
* DEGRAD    *    VARIABLE NUMBER    2          GROUP     1 IND           2 INE
*************                                  MEAN              .6950           .8010
              STATISTICS     P-VALUE    DF     STD DEV           .1213           .0826
                                               S.E.M.            .0606           .0337
T (SEPARATE)        -1.53    .1897      4.9    SAMPLE SIZE           4               6
T (POOLED)          -1.66    .1353      8      MAXIMUM           .8600           .8750
                                               MINIMUM           .5910           .7050
F(FOR VARIANCES)
     LEVENE           .28    .6216      1,  8

NUMBER OF INTEGER WORDS OF STORAGE USED IN PRECEDING     PROBLEM        289
CPU TIME USED          .530 SECONDS


*************
* DEGRAD    *    VARIABLE NUMBER    2          GROUP     3 RND           4 RNE
*************                                  MEAN              .8840           .9240
              STATISTICS     P-VALUE    DF     STD DEV           .0500           .0884
                                               S.E.M.            .0288           .0312
T (SEPARATE)         -.96    .3694      6.8    SAMPLE SIZE           3               8
T (POOLED)           -.74    .4772      9      MAXIMUM           .9400          1.0720
                                               MINIMUM           .8440           .8400
F(FOR VARIANCES)
     LEVENE          1.30    .2830      1,  9

NUMBER OF INTEGER WORDS OF STORAGE USED IN PRECEDING     PROBLEM        280
CPU TIME USED          .066 SECONDS
```

B. Kruskal-Wallis Test Output

```
KRUSKAL-WALLIS ONE WAY ANALYSIS OF VARIANCE TEST RESULTS

VARIABLE      2 [illegible]
 GROUP            FREQUENCY      RANK
NO. NAME                         SUM
 1   1NG              5          30.0
 2   2NG              5          [illegible]

KRUSKAL-WALLIS TEST STATISTIC =    3.75000
LEVEL OF SIGNIFICANCE =  .0528 USING CHI-SQUARE DISTRIBUTION WITH     1 DEGREES OF FREEDOM

MANN-WHITNEY TEST STATISTIC =        [illegible]
LEVEL OF SIGNIFICANCE =  .0528 USING NORMAL TWO-TAIL APPROXIMATION

NUMBER OF INTEGER WORDS OF STORAGE USED IN PRECEDING    PROBLEM    [illegible]
CPU TIME USED        .206 SECONDS
```

```
KRUSKAL-WALLIS ONE WAY ANALYSIS OF VARIANCE TEST RESULTS

VARIABLE      2 [illegible]
 GROUP            FREQUENCY      RANK
NO. NAME                         SUM
 1   1NG              4          12.0
 2   2NG              2          [illegible]

KRUSKAL-WALLIS TEST STATISTIC =    2.00000
LEVEL OF SIGNIFICANCE =  .1573 USING CHI-SQUARE DISTRIBUTION WITH     1 DEGREES OF FREEDOM

MANN-WHITNEY TEST STATISTIC =        [illegible]
LEVEL OF SIGNIFICANCE =  .1573 USING NORMAL TWO-TAIL APPROXIMATION

NUMBER OF INTEGER WORDS OF STORAGE USED IN PRECEDING    PROBLEM    [illegible]
CPU TIME USED        .202 SECONDS
```

```
KRUSKAL-WALLIS ONE WAY ANALYSIS OF VARIANCE TEST RESULTS

VARIABLE      2 [illegible]
 GROUP            FREQUENCY      RANK
NO. NAME                         SUM
 1   1NG              4          12.0
 2   1NG              [illegible]          43.0

KRUSKAL-WALLIS TEST STATISTIC =    3.[illegible]
LEVEL OF SIGNIFICANCE =  .0[illegible] USING CHI-SQUARE DISTRIBUTION WITH     1 DEGREES OF FREEDOM

MANN-WHITNEY TEST STATISTIC =        [illegible]
LEVEL OF SIGNIFICANCE =  .0[illegible] USING NORMAL TWO-TAIL APPROXIMATION

NUMBER OF INTEGER WORDS OF STORAGE USED IN PRECEDING    PROBLEM    [illegible]
CPU TIME USED        .260 SECONDS
```

```
KRUSKAL-WALLIS ONE WAY ANALYSIS OF VARIANCE TEST RESULTS

VARIABLE      2 [illegible]
 GROUP            FREQUENCY      RANK
NO. NAME                         SUM
 1   2NG              3          15.0
 2   2NG              [illegible]          [illegible]

KRUSKAL-WALLIS TEST STATISTIC =     .37500
LEVEL OF SIGNIFICANCE =  .5403 USING CHI-SQUARE DISTRIBUTION WITH     1 DEGREES OF FREEDOM

MANN-WHITNEY TEST STATISTIC =        [illegible]
LEVEL OF SIGNIFICANCE =  .5403 USING NORMAL TWO-TAIL APPROXIMATION

NUMBER OF INTEGER WORDS OF STORAGE USED IN PRECEDING    PROBLEM    [illegible]
CPU TIME USED        .300 SECONDS
```

APPENDIX G

Progressive Resistance Experiment [68]

I. Experimental Design

A. Choice of Factors and Levels

Four movement categories, IFE, RFE, IHE, RHE, were selected to construct a small task which would require the performance of subtasks which could be classified into one of the above categories. Five individuals (all Army officers familiar with chemical protective equipment) were selected to perform this task. Each individual would perform the task six times, three in normal field clothing (BDU) and three in protective clothing (MOPP). Differences between BDU and MOPP performance were of primary interest. Differences in individual performance across the four categories was also investigated.

B. Design

A work station was built which required the subject to pick up a 7/16" nut and thread it onto a bolt against some spring resistance to a point at which it could no longer be finger tightened (IFE, install finger easy). At this point, the subject was to pick up a wrench and continue to tighten the nut until a washer mounted on the mechanism stopped the movement and then put the wrench down (IHE, install hand easy). The subject was then instructed to pick the wrench up and loosen the nut until it could be removed from the bolt and place the nut down beside the work station (RFE, remove finger easy). The range of movements were the same for all individuals and each subject was allowed to practice the task in BDU and MOPP prior to any data collection. The scheduling of subjects and treatments was completely randomized.

A factorial design was chosen in order to examine the interactions between individuals, the classification categories and protective posture. Degradation was defined as the ratio of the average BDU trial time and average MOPP trial time for each individual/classification category combination.

II. Results

Subject Degradations (BDU Time/MOPP Time)

Movement Category	A	B	C	D	E	AVE
IFE	.606	.576	.511	.525	.462	.536*
IHE	1.074	1.360	1.189	1.077	1.297	1.199*
RHE	.978	1.121	1.003	.793	1.102	.999
RFE	.910	.651	.917	1.025	.440	.789

*Subjects finger tightened nut down farther in MOPP and required less time to tighten nut with wrench.

APPENDIX H

ITV Traverse Mechanism Task Elements

EVENT	CODE	EVENT DESCRIPTION	TM REFERENCE*
301	RHE	Loosen Gear Shaft Nut	4-20 b (1d)
302	RFD	Remove Nuts, Gear & Washers	4-20 b (1d)
303	RFD	Remove #6 Spacer Plate	4-20 b (1b)
304	RFD	Remove #22 Plate & Shim	4-20 b (1f)
305	RFD	Remove T.M. Plate Screws	4-20 b (1e)
306	RHD	Remove T.M. Plate	4-20 b (1e)
307	RFD	Remove Ring Plate	4-20 b (1s)
308	RFD	Remove Cover Plate	4-20 b (1h)
309	RFD	Remove Snap Rings & Gears	4-20 b (1j)
310	RHE	Remove Gear Shaft Assembly	4-20 b (1k)
311	IHE	Install Gear Shaft Assembly	4-20 f (2j)
312	IHD	Install T.M. Plate	4-20 f (2o)
313	IFD	Secure T.M. Plate	4-20 f (2o)
314	IFD	Install #6 Spacer Plate	4-20 f (2r)
315	IFD	Install #22 Plate & Shim	4-20 f (2p)
316	IFD	Install Nuts, Washers & Gear	4-20 f (2q)
317	IFD	Install Cover Plate	4-20 f (2c)
318	IFD	Install Ring Plate	4-20 f (2b)
319	IFD	Install Gears & Snap Rings	4-20 f (2m)

*Obtained from TM 9-2350-259-34 [8]

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