MANAGEMENT CONSULTING & RESEARCH, INC.

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VOLUME I

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SKILL TRAINING ANALYSIS: THE LINKAGE OF UNIT LEVEL SKILL TRAINING AND UNIT PRODUCTIVITY

By

Rodney D. McConnell
Ann O. Buchanan
Stuart C. Johnson
Don H. Murdock

14 June 1983

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Prepared For:

Office of the Assistant Secretary of Defense
Manpower, Reserve Affairs and Logistics

Contract Number: MDA903-82-C-0278

Prepared By:

MANAGEMENT CONSULTING & RESEARCH, INC.
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Falls Church, Virginia 22041
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Management Consulting & Research, Inc. (MCR) examined Service skill training conducted at the installation level and analyzed its impact on unit productivity. MCR also conducted a special purpose task that examined the Navy Pipeline Management System. Volume I of the report describes techniques developed for examining Air Force training and the linkage with maintenance productivity. It also describes the MCR examination of Army installation-level training and a brief discussion of

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UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) the Army's training effectiveness analysis process. Volume II of the report contains an examination of the Navy training pipeline with specific examination of two Navy ratings: Aviation Electronics Technician and Electronics Technician.

PREFACE

Management Consulting and Research, Inc. (MCR) provided support to the Office of the Assistant Secretary of Defense (OASD) for Manpower, Reserve Affairs and Logistics (MRA&L) under contract number MDA903-82-C-0278 for the examination of skill training. MCR analyses will assist in the evaluation and support of Service training programs.

This technical report is a contract deliverable that documents the skill training analyses conducted for each task of this project. The report is provided in two volumes:

- Volume I, "Skill Training Analysis: The Linkage of Unit Level Skill Training and Unit Productivity," and
- Volume II, "Skill Training Analysis: An Examination of the Navy Pipeline Management System."

We would like to acknowledge the continuing guidance and assistance of Mr. Michael J. Kendall, COTR, of the Training and Education Directorate, and the assistance provided by other members of the OSD staff and the Military Service staffs.

EXECUTIVE SUMMARY

This summary includes the study purpose, organization of this report, and observations made in the course of the study.

A. STUDY PURPOSE AND REPORT ORGANIZATION

The purpose of this study was to analyze Service skill training conducted at the installation level and to analyze its impact on unit productivity. MCR also conducted a special purpose task which was to examine the Navy Pipeline Management System with emphasis on a specific critical skill. The four tasks we performed are listed below:

- Task 1 -- an examination of the impact of a Field Training Detachment (FTD) on Air Force operational unit productivity;
- Task 2 -- an examination of the impact of installation level training using simulators on F-16 unit maintenance productivity;
- Task 3 -- an examination of the impact of installation level training on Army operational unit maintenance productivity; and
- Task 4 -- an examination of the Navy Pipeline Management system.

This report, which documents our work, is divided into two volumes: Volume I, "Skill Training Analysis: The Linkage of Unit Level Skill Training and Unit Productivity," and Volume II, "An Examination of the Navy Pipeline Management System."

Volume I of the report describes the two tasks on Air Force installation-level skill training and the task on Army installation-level skill training listed above. In the first Air Force task (described in Section II of Volume I), we developed two methods for linking skill training to maintenance productivity. In the second Air Force task (described in Section III of Volume I), we developed three techniques for examining the linkage between training and maintenance productivity. In the Army task (described in Section IV of Volume I), we examined Army installation level training. Section IV of Volume I also contains a description of the Army training effectiveness analysis process.

Volume II of the report contains an examination of the Navy training pipeline with specific examination of two Navy ratings: Aviation Electronics Technician and Electronics Technician.

B. OBSERVATIONS

The following observations were made in the course of our examination of skill training. The observations are grouped by each of the tasks we performed during the study.

- TASK 1: This task attempted to illustrate a verifiable, positive relationship between Field Training Detachment (FTD) training and job performance. Two methods were devised to illustrate this relationship: a Quality Assurance (QA) methodology, which compared individual performance evaluations in a statistical manner; and a Work Unit Code/Trend Analysis methodology, which compared average time to complete a like task between work centers. "Macro" measures of performance, such as the number of aircraft hours flown and the number of aborted flights due to mechanical problems, were not considered in this task. Although these measures might be more accurate maintenance performance measures, they are not directly relatable to training and could not be used. The results of our work in this task were not conclusive although they indicate that FTD training had some impact on productivity. The measures chosen did not capture significant differences, but this is explained by several biases that exist in the data that was used. This observation is not to say that FTD training is ineffective in terms of teaching new job skills. One must realize that personnel who go through FTD training have already received extensive training in their specialty fields, and this additional unit training is a refinement, or "add-on" to their broad training base.

The advantages of FTD training are in three areas:

- capability of rapid adjustment to local requirements,

- cost savings based on little or no need to travel to distant schools for training, and

- rapid return of students to the job.

Unit training goals can be met through FTD schooling and through an on-the-job training (OJT) program. OJT allows work to continue without loss of students and instructors to the local school, but FTD training helps to get a person on the job at a particular skill level in a shorter period of time. This fact, combined with modest increases in productivity (measured either in quantity or quality of work), should produce higher levels of aircraft availability without an increase in the size of the work force. Any increase in aircraft availability yields readiness improvements. This may be the most important benefit of FTD training.

In the course of our research on the QA methodology, we had the opportunity to examine the work of the QA section at several wings. The wing commander, in his attempt to achieve the highest number of mission available aircraft, has a valuable tool in his QA section. This group of highly skilled maintenance personnel of varied skills performs an important function in its evaluation of individual mechanics. Our analysis included a sample of 2,180 personnel tested by the QA sections at our sample wings; 702, or 32%, failed to pass the QA certification. These personnel had to be retrained and then recertified by their supervisors that they were capable of performing their work. Thus, we found that the QA section furnishes real-time feedback on the capability of the maintenance personnel to perform their tasks. Our data shows that the QA program is viable and doing its job of insuring that maintenance is properly performed.

- TASK 2: Our analysis in this task used three techniques to examine productivity. Each technique produced some positive analytical results. The approaches used were: examine productivity by action code, examine productivity by frequency, and use of analysis of variance, or ANOVA.

  - The productivity by action code approach allowed us to examine the effect training had on productivity in a graphical form. The results appeared to show that for both of the work unit codes (WUCs) examined (primary flight control electronics - 14A00 and turbofan power plant - 23Z00), the effect of training is significant in terms of productivity increases. It was obvious in our "wing-to-wing" comparisons. The attempt to group work centers by training status (high, medium, or low) and thus infer some meaning concerning the effect of frequency, did not provide useful results. Any relationship, holding training relatively constant, between frequency and productivity was not obvious.

  - The productivity by frequency (actions per worker) approach plotted frequency versus productivity. A regression line was fitted to each plot and the results for WUC 14A00 showed, in four out of six cases (six action codes), a positive correlation (negative slope) between frequency and productivity. The results for WUC 23Z00 were not clear. We examined three action codes and in two cases got a negative correlation between frequency and productivity. One case resulted in a positive correlation. Overall, the technique appears to show a positive relationship between frequency and productivity.

  - The use of ANOVA allowed us to examine the impact of both frequency and training on maintenance productivity. The statistical results were mixed, since in three out of four tests it was not indicated that these results were indicative of the overall Air Force maintenance population at the 90% confidence level. However, it must be noted that training, in both WUC examinations, has a much larger effect on productivity than frequency. In the case of WUC 23Z00, there was a positive indication of a relationship between training and productivity at the 90% confidence level.

  - In order to assure ourselves that the amount of time spent by work centers on the actions we examined was representative, we did a limited comparison of actions we examined to total actions worked on. There are 28 system level WUCs for the F-16. WUC 14000 was the highest manhour consumer in our sample (10.6%), WUC 23000 was fourth with 8.0%. There are seven subsystems within WUC 14000--WUC 14A00 was 32% or 3.4% of total wing manhours. There are twelve subsystems within WUC 23000--WUC 23Z00 was 24% of WUC 23000 or 2.0% of total wing manhours. Thus out of 113 subsystem WUCs the two WUCs we examined (14A00 and 23Z00) are quite representative of total wing maintenance since they consume over 5% of total maintenance manhours in the sample we looked at.

- Our intention was to show a relationship between maintenance productivity and installation-level training. We chose courses taught using simulators for our examination of training but did not compare simulator training with non-simulator training.

- TASK 3: In this task, data limitations reduced the scope of any conclusions that could be made with respect to the results of our analyses. No specific, quantitative observations or conclusions can be advanced concerning the relationship between installation-level maintenance training and productivity. Subjectively, installation-level training does seem to have a positive impact on maintenance productivity. Interviews were conducted with several individuals (ranging from mechanics to staff officers at the divisional level). All of these individuals had the same impression of installation-level training: although the positive benefit of the training may not be quantifiable, the benefit does exist. Mechanics were able to "diagnose problems better" and "perform troubleshooting actions with more accuracy" as the result of installation-level training (in this case, Detriot Diesel Allison courses).

  These subjective observations are all that can be said, at this time, concerning the relationship upon which this task has focused. Current databases from which information can be obtained for training/productivity analyses proved inadequate for a specific, quantitative analysis. Although the current databases are not appropriate for the kinds of analyses that we attempted, this will not necessarily be the case in the future. The Army is developing the systems to keep track of productivity information. When they are completed, the present type of analysis could be successful. In particular, the following data sources could provide appropriate information.

- The Maintenance Performance System (MPS). The Army Research Institute-developed MPS is currently in the test mode. As more data is collected by this system, and if the system is expanded so that data is collected at other Army installations, the system could prove to be a very effective training management tool, especially for the analyses of training and maintenance productivity.

- The Standard Army Maintenance System (SAMS). The SAMS is an automated maintenance management system that will replace The Army Maintenance Management System (TAMMS) and encompass all levels of Army material maintenance. SAMS will improve upon the present TAMMS system in that a maintenance job will be "tracked" on an in-shop computer as it progresses through work stages, and each different stage of work will be explicitly noted in the job record. Therefore, the records should be more accurate than those in TAMMS (which is automated at a much higher level) and include more detailed data on particular actions performed. Unfortunately, the SAMS system is not designed for training analysis purposes; no information that identifies individuals is included in this system. The system, however, is still in preliminary implementation stages. Data elements could theoretically be added to the system if a strong rationale were given for their inclusion. Even if individual identification were not included in the system, the improvements in accuracy and level of detail over the TAMMS database could be of benefit for training/productivity analyses. A "macro" level approach, which specifically identifies certain types of installation-level training with certain types of maintenance actions, would be much easier to accomplish if maintenance actions were identified more explicitly in an automated database. SAMS could provide this capability, whereas the current TAMMS does not.

- TASK 4: The Navy training pipeline is complex. Prior to fleet assignment, a new enlistee might attend as many as seven courses located at different schools. Mixing self-paced and group-paced fixed-length courses in the same pipeline can cause scheduling problems and student backlogs. A student may accelerate through one series of self-paced courses, only to have to wait for a start date for the next course if it is group-paced. The efforts of one school to solve its student backlog problem could contribute, however, to a student backlog for the follow-on course at another school.

In addition to alleviating student backlogs, coordination can eliminate redundant or inadequate instruction and can help reduce attrition and time spent in training. The electronics technician (ET) pipelines reflect several instances of apparently redundant training. To reinforce the fundamental skills taught in the basic electricity and electronics course, the Class "A" schools teach basic electrical principles and refresher mathematics. Although this training appears redundant and increases the time spent in school, it has reduced attrition at the follow-on courses by reinforcing necessary fundamental skills. Overall pipeline attrition is another factor of considerable importance in the examination of training for critical skills. The estimated FY82 cohort attrition percentages for the six Navy training pipelines included in this analysis were computed and are summarized below:

- Aviation Electronics Technician -- 19.7%
- Electronics Technician/Advanced Electronics Field/Strategic Weapons Systems Submariner -- 40.4%
- Electronics Technician/Nuclear Field -- 57.6%
- Electronics Technician/Advanced Electronics Field/Conventional Surface -- 39.5%
- Electronics Technician/Advanced Electronics Field/Navigation Submariner -- 50.5%
- Electronics Technician/Advanced Electronics Field/Electronics Warfare Submariner -- 40.1%

Overall attrition figures could key Navy planners to problems in the pipeline as a whole, as opposed to specific courses within a particular pipeline. If overall attrition figures are deemed to be too high, then efforts should be made to determine the exact cause of the attrition. Perhaps entrance requirements for the rating under consideration need to be raised or courses need to be re-evaluated. This would ensure that training funds are expended in a fashion that yields the highest number of qualified sailors at the end of the training pipeline.

The Navy has initiated efforts to improve pipeline management and reduce the time spent at Navy schools. Special attention has been given to those skill areas requiring electronics training. One key to better pipeline management is a simpler pattern of training: keep the number of courses and the various school locations to a minimum.

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LIST OF EXHIBITS

LIST OF EXHIBITS (Cont'd)

I. INTRODUCTION

This report describes the results of a research project to perform skill training analyses in the various Services; in particular, to develop a linkage between individual training conducted at the installation level and unit productivity. This work was sponsored by the Office of the Assistant Secretary of Defense (Manpower, Reserve Affairs and Logistics). This section describes the:

- Purpose/Scope of Research,
- Background,
- General Approach, and
- Organization of this Report.

A. PURPOSE/SCOPE OF RESEARCH

The overall purpose of this project was to examine Service skill training conducted at the installation level and to analyze its impact on unit productivity. The MCR research required gathering information on both skill training and means of measuring maintenance productivity. MCR also conducted a special purpose analysis on the Navy Pipeline Management System with emphasis on a specific critical skill. This research is documented in Volume II of this report.

Our analysis involved four different tasks:

- an examination of the impact of a Field Training Detachment (FTD) on Air Force operational unit productivity,
- an examination of the impact of installation-level training using simulators on F-16 unit maintenance productivity,

- an examination of the impact of installation-level training on Army operational unit maintenance productivity, and

- an examination of the Navy Pipeline Management System.

B. BACKGROUND

OASD (MRA&L) has issued policy guidance that manpower impacts will be considered in system design and operation. This consideration requires both OSD and the Services to develop improved methods for evaluating manpower, personnel, and training. The analysis of critical skills, particularly the impact of maintenance manpower skills, is a key factor in these evaluations. Individuals who are required to operate and maintain weapon systems reach the journeyman level through individual training conducted at the installation level.

Due to a growing concern for the problems in maintaining and operating existing weapons systems, a comprehensive review of training was initiated by OASD (MRA&L). Some initial work has been completed concerning how weapon systems support can be improved with better training. In their first report[1/], MRA&L describes existing on-the-job training (OJT) programs and proposes ways to enhance training, especially OJT, in order to improve equipment maintenance. In a later report[2/], MRA&L

1/Report on the OJT Study Task: On-The-Job Training in the Department of Defense, OASD (MRA&L) under the auspices of the Defense Education and Training Executive Committee, January 1981.

2/Report on Individual Skill Training: Maintenance Training in the Department of Defense, OASD (MRA&L), May 1982.

provides an overview of the systems developed to train individuals in selected maintenance skills. The report covers the entire training plan, from initial skill training in formal schools to individual skill training received in the unit. Based on these completed and on-going study efforts, and in support of the MRA&L Training and Education Directorate, MCR has undertaken the present analysis to develop a linkage between individual training conducted at the installation level and unit productivity.

C. GENERAL APPROACH

In our analysis of the linkage of unit level skill training and productivity, our focus was on maintenance. The approach we followed was to choose specific highly visible skills and to examine the training provided and the related maintenance tasks performed. This required an initial research effort to find appropriate skills that required installation-level training or for which training was provided. Also, the initial research effort focused on available sources of maintenance measures of productivity. The intent of our analytical effort was to establish specific quantitative linkages between skill training provided by units and maintenance productivity.

D. ORGANIZATION OF THIS REPORT

The next three sections, II-IV, each describe one of three research tasks we performed (a fourth task is described in Volume II of this report):

- An Examination of the Impact of a Field Training Detachment (FTD) on Air Force Operational Unit Productivity;
- An Examination of Installation-Level Training Using Simulators on F-16 Unit Maintenance Productivity; and
- An Examination of the Impact of Installation-Level Training on Army Operational Unit Maintenance Productivity.

Each section has a subsection describing the approach or evaluation we used and a subsection describing our results.

There are also four appendices:

- Reference Sources,
- Summary Outputs from Methodological Data Bases,
- Back-up Data, and
- Training Effectiveness Analysis Background Materials.

II. AN EXAMINATION OF THE IMPACT OF A FIELD TRAINING DETACHMENT (FTD) ON AIR FORCE OPERATIONAL UNIT PRODUCTIVITY

This section discusses the impact of an FTD on maintenance performance at operational Air Force units. The analysis will develop a linkage between individual training conducted at the installation level and unit productivity. Training effectiveness must be measured in terms of on-the-job performance of personnel. The approach to this research task included:

- identifying appropriate measures of performance at the wing level; and
- developing methods for analyzing these measures in the context of the problem (i.e., the impact of FTD training).

The study focused on maintenance skills which are critical to the operational readiness of complex weapon systems. The study proceeded in three stages.

- A brief review of published research on initial skill training was accomplished.
- Field visits were made to operational units and their supporting FTDs to examine unit training at the installation level. This field work included interviews, observations of normal operations on the job, and the gathering of sample data for development of our methodology.
- The methodology was refined, additional data was collected, and the results were analyzed.

This section contains two subsections:

- Skill Training Evaluation, and
- Skill Training Evaluation Results.

Section II.A, Skill Training Evaluation, discusses individual training with emphasis on installation schools; special consideration in relating maintenance performance to training; sample selection; and two skill training evaluation methodologies.

Section II.B, Skill Training Evaluation Results, discusses application of the two skill training evaluation methodologies; analysis of the results obtained; and observations.

Supporting data is presented in Appendix B, Summary Outputs from Methodological Databases.

A. SKILL TRAINING EVALUATION

The focus of this study is the impact of training conducted at the installation level on maintenance job performance. The typical training flow for Air Force maintenance personnel is shown on Exhibit II-1. These enlistees attend initial entry training (basic military training and technical school) prior to assignment. During technical school, they will learn the basic skills required within their Air Force Specialty Code (AFSC). Next, they receive equipment-specific training in an installation Field Training Detachment (FTD). This is followed by on-the-job training (OJT) in the unit.

This section discusses the following topics:

- individual training with emphasis on installation schools and their relationship to the Air Force wing maintenance structure;
- special considerations involved in relating maintenance performance to FTD training;
- sample selection; and

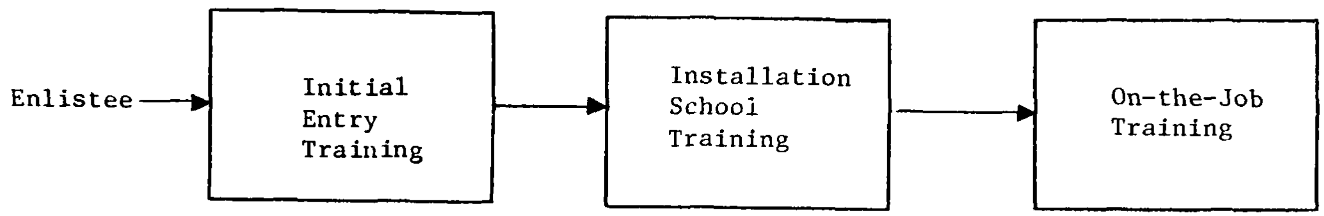


Exhibit II-1. TYPICAL TRAINING PATH OF AIR FORCE MAINTENANCE PERSONNEL

- MCR's two skill training evaluation methodologies, which are the:
    - Quality Assurance Methodology, and the
    - Work Unit Code/Trend Analysis Methodology.

1. Installation Schools

The primary functions of an installation school include the following:

- to supplement the generalized training received in formal schools with equipment-specific training related to types of equipment located at that installation;
- to provide transition training to personnel whose previous experience has been on other models of equipment; and
- to provide upgraded and refresher training.

There are two types of installation schools: officially recognized schools and unofficial schools. Officially recognized schools are specifically funded and are manned in accordance with authorization documents. Although these schools may be affiliated with Service training commands, their main purpose is to meet the specific needs of the associated unit at the installation. Included among the officially recognized schools are the Air Force Field Training Detachments, which focus on aviation maintenance training.

Unofficial installation schools are established by an operational unit, using its own manpower and funding resources. In the Air Force, unofficial schools are used extensively in the Tactical Air Command (TAC). The unofficial schools in TAC provide training in addition to that provided by the FTDs.

Most of the installation school training in the Air Force takes place at FTDs. Exhibit II-2 shows the organizational relationship between the Air Training Command and the FTDs. There are 49 FTDs assigned to the Strategic/Airlift Branch of the Field Training Group, and 40 are assigned to the Tactical Branch. Each FTD supports at least one unit.

The research documented by this section of the Technical Report focused on FTDs assigned to the Tactical Branch which supports TAC. Exhibit II-3 shows the relationship between the maintenance structure of a tactical wing and its supporting FTD. Typically, there are three or four flying squadrons in a wing. The Deputy Commander for Maintenance (DCM) manages equipment maintenance for these flying squadrons. The DCM is also responsible for assuring that maintenance training (FTD, OJT, and informal programs) is effective. Maintenance work is performed by work centers in the Aircraft Generation Squadron (AGS), Component Repair Squadron (CRS), and Equipment Maintenance Squadron (EMS). Some work centers are manned primarily by personnel trained in a single skill area (e.g., all jet engine mechanics), while others are manned by personnel trained in several skill areas (e.g., integrated avionics specialists, aircraft electrical systems specialists, and jet engine mechanics). Team maintenance (two or more individuals performing a single maintenance task) is standard procedure in most wings. Cross-skill maintenance (personnel who are trained in one skill area performing a maintenance task associated with a different skill area) is performed as required by workload and personnel shortages.

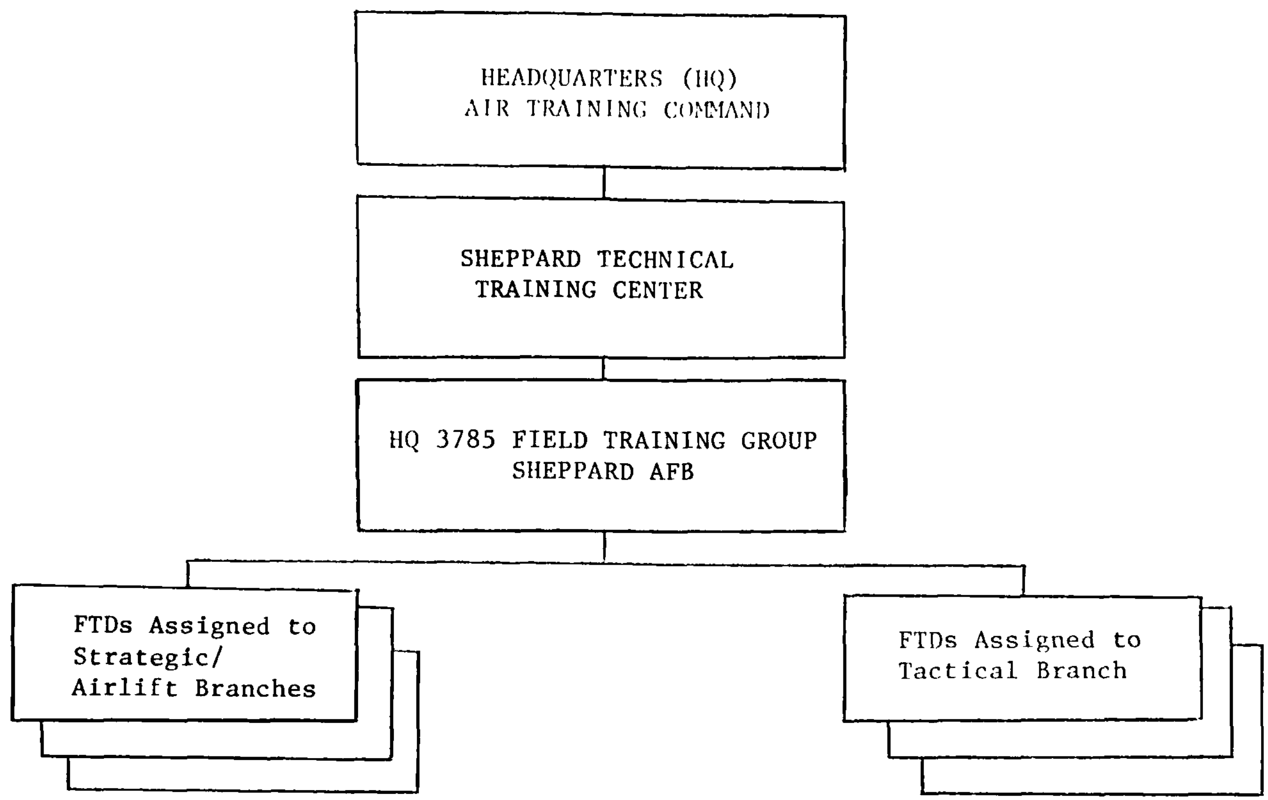


Exhibit II-2. AIR TRAINING COMMAND - FIELD TRAINING DETACHMENT RELATIONSHIP

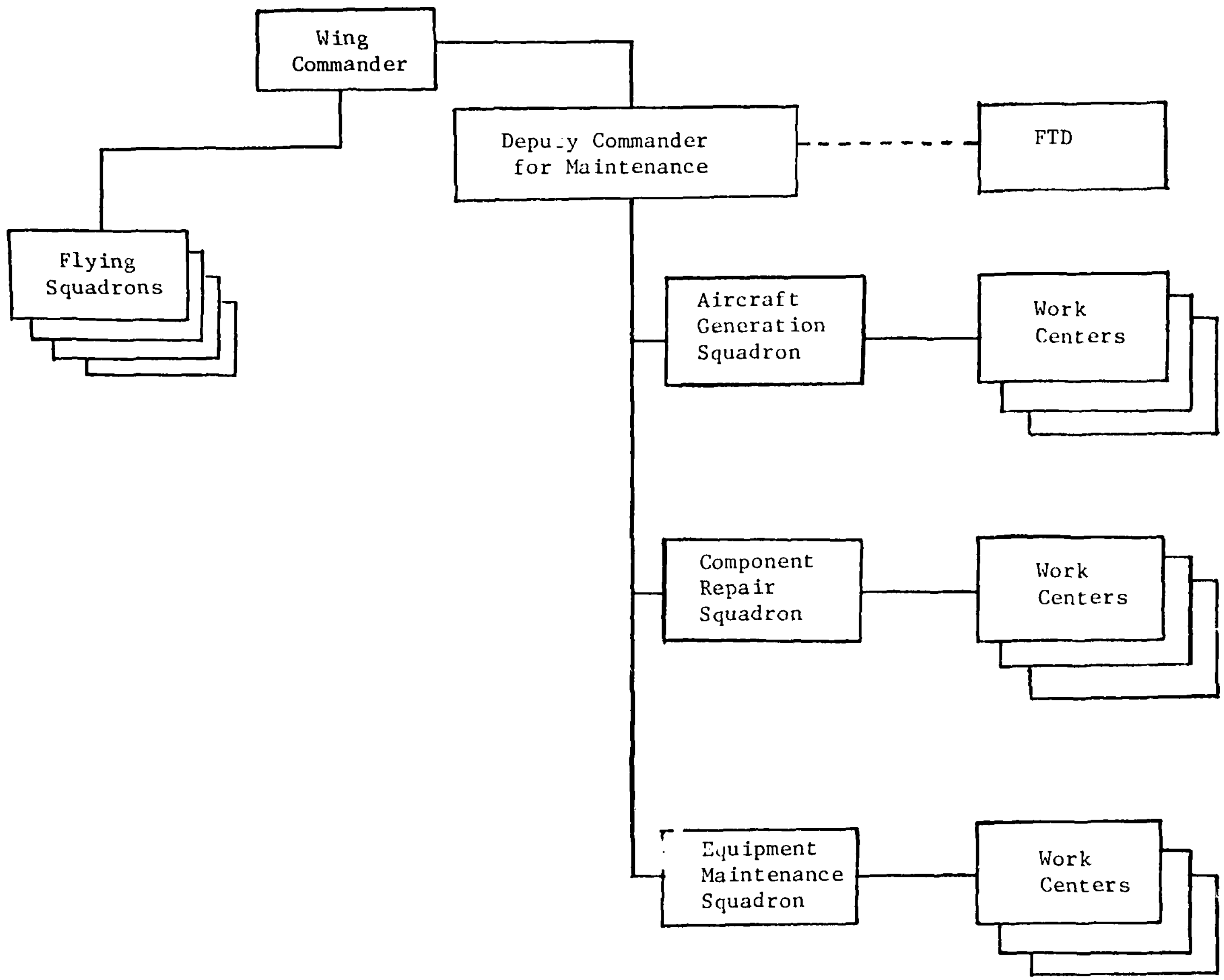


Exhibit II-3. TYPICAL RELATIONSHIP BETWEEN WING AND SUPPORTING FIELD TRAINING DETACHMENT

2. Special Considerations

Comparative analysis is the key to assessing the impact of training on job performance. This study attempts to measure the impact of FTD training by comparing the performance of more-trained maintenance personnel with less-trained maintenance personnel in the same skill area. In addition to training, several other factors (e.g., experience levels and quality of supervision) affect maintenance performance, but are not specifically addressed in this study.

There are several considerations involved in relating maintenance performance to amount of training:

- description of equipment,
- maintenance performed,
- training received, and
- identification of maintenance personnel.

Comparisons of performance can be made only when similar models of equipment are involved. The equipment and the maintenance task performed must be identified at a level which is specific enough to relate the maintenance performed to a single skill area and skill level. This, in turn, can be related to specific types and amounts of training.

In addition, the individuals must be designated in a manner that identifies their skill areas and the training they have received. When individuals performing similar maintenance tasks can be identified, comparisons can be made of the performance of personnel with different degrees of training in the same skill area.

Assessment of training effectiveness is more difficult, however, when only the organizations (e.g., work centers) performing the maintenance (and not the specific individuals) are identified. The maintenance organizations of all tactical wings report through the same management system[3/] and have similar work center structures. If corresponding work centers in different wings can be characterized in terms of the training and experience levels of their personnel, then comparisons can be made of the work centers' performances with respect to the same maintenance task on the same type of equipment. However, the precise relationship between work center differences in performance and in FTD training is not clear-cut. There are several problems with determining this relationship. First, the method of maintenance (i.e., team, cross-skill, or individual) is often difficult to identify. Second, the actual amount of work performed by each individual member of a work center is not easy to determine. Third, the impact of FTD training should be most evident on newly trained personnel (due to less OJT and less experience), yet these personnel have relatively little effect on overall work center team performance. Last, the maintenance experience and formal training received prior to FTD training differs among individuals.

3. Sample Selection

To insure homogeneity of the data, the following criterion was used to select our sample: select a representative

3/Defined in Air Force Regulation 66-1, Equipment Maintenance: Maintenance Management.

sample of data that minimizes the number of aircraft types and geographic locations involved in the data collection effort. Selection of the F-4 and F-15 aircraft allowed for a sufficient mixture of data to be collected from only three geographic locations, as follows:

- FTD 201, Langley AFB, VA
  - F-15 [1st Tactical Fighter Wing (TFW)]
- FTD 516, George AFB, CA
  - F-4 (35th TFW, 37th TFW)
- FTD 527, Luke AFB, AZ
  - F-4 [58th Tactical Training Wing (TTW)]
  - F-15 (405th TTW)

During the data collection phase of this study, it was learned that the 58th TTW was converting from F-4 aircraft to F-16 aircraft. Since necessary F-4 data was no longer available at that wing, the 58th TTW was deleted from the study. In addition, the 35th TFW was eliminated from the study because of extreme delays in receiving data.

The identity of the wings we analyzed is not relevant; hence, we have randomly titled them as Wing A, Wing B, and Wing C. They will be consistently referred to by these names in Section II.B, Skill Training Evaluation Results.

4. <u>Methodology</u>

As the first step in developing skill training evaluation methodologies, quantifiable measures of maintenance performance were formulated from existing historical data bases. One measure is maintenance man-hours per maintenance task, where "task" is a single procedure performed on a piece of equipment (e.g., removal of a component). The information is maintained by the Air Force Maintenance Data Collection (MDC) system based on information routinely submitted by work centers. A second measure identified is the rating received by an individual during a quality assurance (QA) personnel evaluation. In such an evaluation, an individual is rated as satisfactory or unsatisfactory by quality assurance personnel while performing a maintenance task. The rating applies to the specific task evaluated, and not to other tasks the individual is qualified to perform. Each wing has a Quality Assurance Section which develops a locally-computed standard baseline for specific actions. This standard is based on historical data and the ratings assigned to evaluations are derived by comparing the number of discrepancies (errors) in various categories to the baseline. Both the MDC system and QA evaluations are addressed in detail in Air Force Regulation 66-1 (Volume 2), Equipment Maintenance: Maintenance Management.

The remainder of this section discusses:

- Quality Assurance (QA) Skill Training Evaluation Methodology, and
- Work Unit Code/Trend Analysis (WUC/TA) Skill Training Evaluation Methodology.

a. Quality Assurance (QA) Skill Training Evaluation Methodology

The methodology described in this section is a five-step decision-making process which is shown in Exhibit II-4 and is explained in more detail below.

Step 1. Request QA personnel evaluation data from each wing examined.

Quality Assurance personnel evaluations provided the information needed for this method of skill training evaluation. Personnel are evaluated while performing a specific action by QA teams and are assigned a rating of pass or fail, depending on the number of errors detected. The three wings that were examined in this study routinely convert QA evaluation data into a standard format and store the data in computer files. This data availability and format provided two advantages.

- A large sample would easily be available for analysis.
- The data requested could be restricted to a specific time period.

An individual's training status is constantly changing, so a data request from a specific time period allowed for a precise link with the needed training information for that time period.

Step 2. Request Course Status Summaries from each wing.

In order to link QA personnel evaluations with training information, we required outputs from the training subsystem of the Maintenance Management Information and Control

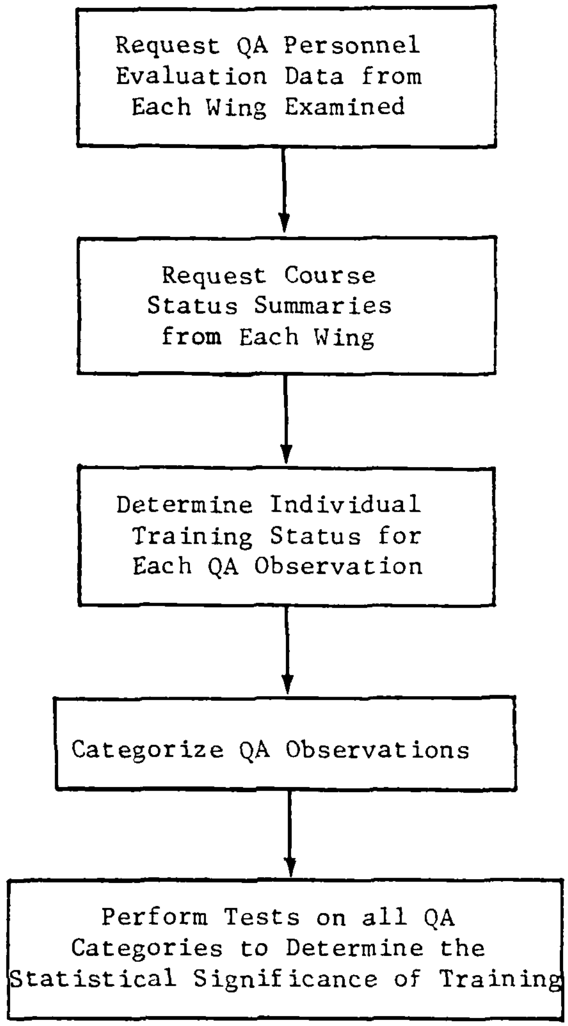


Exhibit II-4. QA DECISION MAKING PROCESS

System (MMICS). Course Status Summaries for particular Field Training Detachment (FTD) courses were requested from each wing, and the information in these summaries was used to determine the individual trainings satus for personnel listed on the QA report. Not all Course Status Summaries from each wing were obtained, however, and some individual QA evaluations were eliminated as a result. Sample QA data from the 1st TFW provided the basis for the criteria by which a Course Status Summary was requested. If a specific AFSC was not represented or was sparsely represented in the QA data, then all FTD courses pertaining to that AFSC were eliminated from the course report list. This data use limitation, however, had a negligible effect on overall QA data sample size. Our final sample used 90.4% of all QA observations that were originally obtained.

Step 3. Determine individual training status for each QA observation.

Once QA data and Course Status Summaries were obtained for the three wings in our sample, training status determinations had to be made for each QA observation. For the purpose of this analysis, individuals were classified as trained, untrained, or OJT trained. These determinations are defined as follows.

- Trained (T)--in order for an individual to be considered "trained" in this analysis, that individual must have completed all courses that were required of him.
- Untrained (U)--an individual is labeled "untrained" in this analysis if he is listed as "awaiting training" for any course that is required for him.

- OJT Trained (OJT)--if an individual is not listed for any courses on the Course Status Summaries, either as awaiting completion of training (AWACT) or completed training (COMPL), then he is considered OJT.

"Required" courses have different meanings in the different wings examined. In the 1st and 37th TFWs, courses are considered to be required for an individual if he is listed for the course in any way, either AWACT or COMPL. However, in the 405th TTW, course requirements are listed for each work center. Personnel assigned to a specific work center are required to take all courses that are pertinent to the operation of that work center. Exhibits II-5 (1st TFW/37th TFW) and II-6 (405th TTW) illustrate the process for determining individual training status for QA observations in the wings examined. The process relates requirements criteria to the T/U/OJT definitions to determine to which category a specific QA observation is assigned. This process was followed for all QA observations in the three wings examined. It provided a database in which individual training status is directly linked with individual job performance (as measured by a QA rating).

Step 4. Categorize QA observations.

This step transformed the data into a form that lends itself to statistical applications. Each QA observation is represented as being in one of six training/performance categories:

- trained/passed QA evaluation,
- untrained/passed QA evaluation,
- OJT trained/passed QA evaluation,

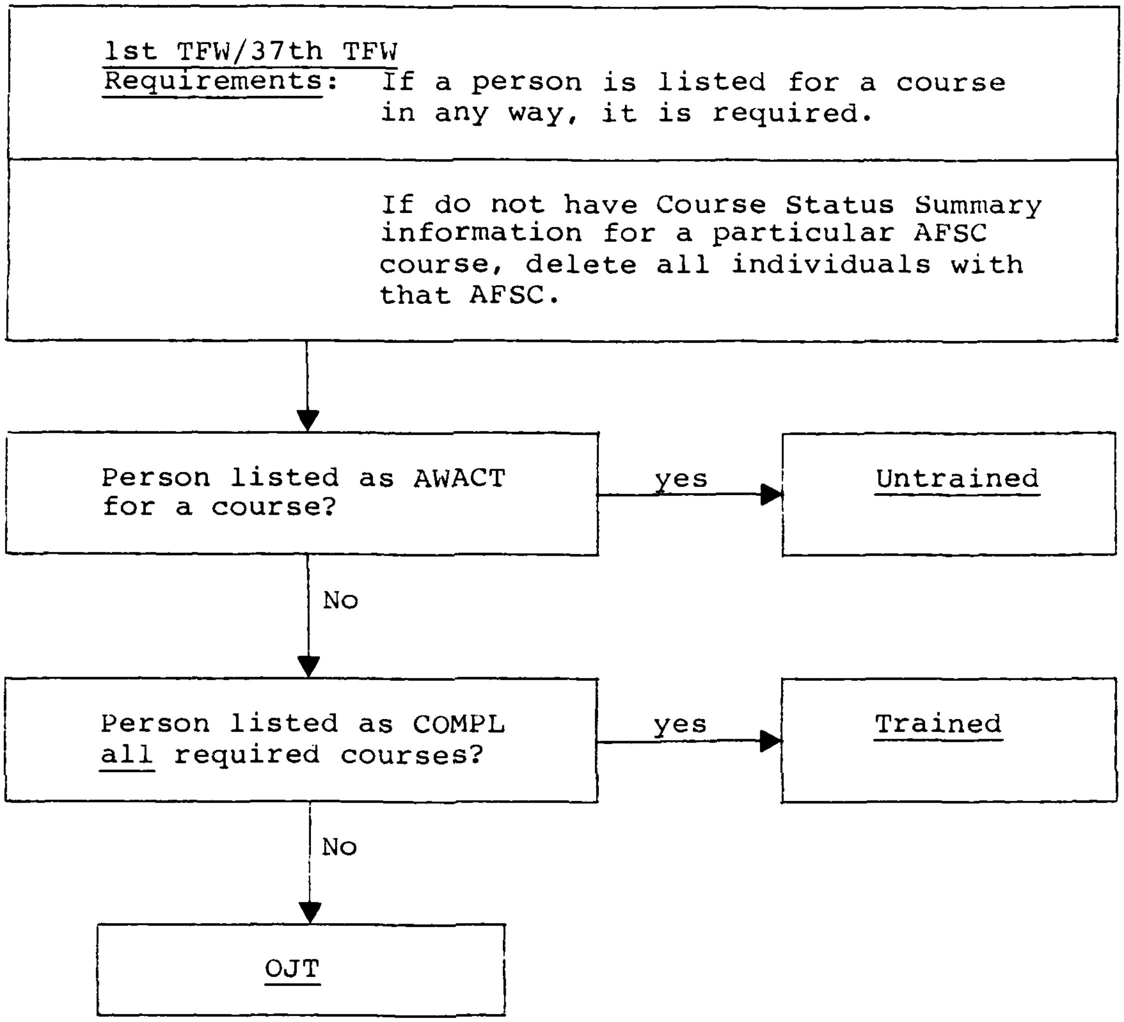


Exhibit II-5. INDIVIDUAL TRAINING STATUS DETERMINATION PROCESS (1st TFW/37th TFW)

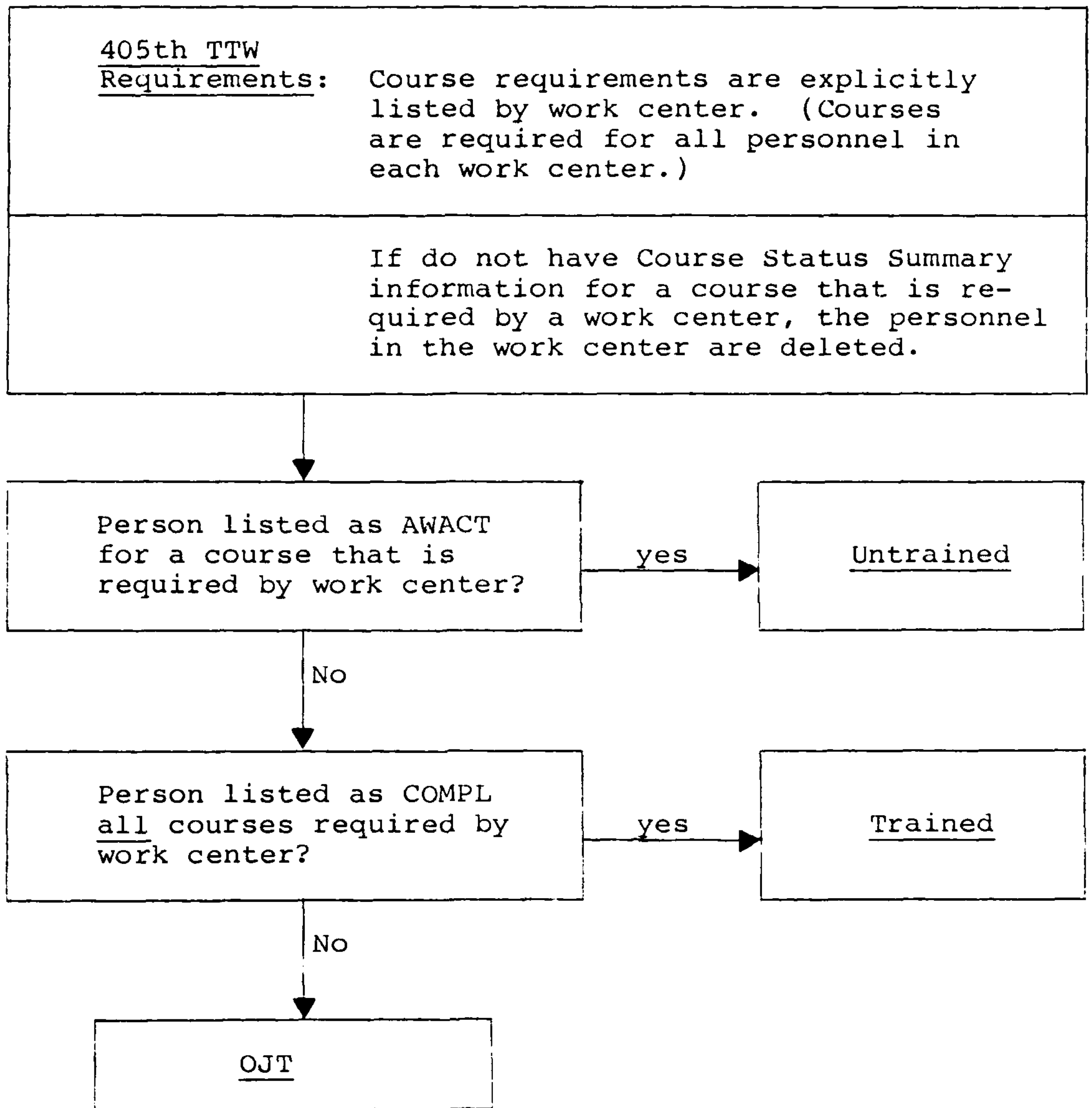


Exhibit II-6. INDIVIDUAL TRAINING STATUS DETERMINATION PROCESS (405th TTW)

- trained/failed QA evaluation,
- untrained/failed QA evaluatin, and
- OJT trained/failed QA evaluation.

Step 5. Perform tests on all QA categories to determine the statistical significance of training.

The observations in the training/performance categories were used to perform statistical tests on the effectiveness of training within a specific wing at particular training levels. Once this step was completed, the results were analyzed and observations made concerning these results.

b. Work Unit Code/Trend Analysis (WUC/TA) Skill Training Evaluation Methodology

This methodology evaluates the effect training differences have on the time a work center takes to perform a task. This methodology was developed by MCR using two Air Force data sources:

- maintenance information, taken from the Maintenance Data Collection (MDC) System; and
- training information, taken from the training subsystem of the Maintenance Management Information and Control System (MMICS).

There are seven decision-making steps in this process as shown on Exhibit II-7. Each step is described in detail below.

Step 1. Choose high manhour consuming WUCs for each wing, determine overlap WUCs, and request WUC/TA reports.

The maintenance information used in this method was based on data recorded by each work center on Air Force form

Choose high manhour consuming WUCs for each wing, determine overlap WUCs, and request WUC/TA reports.

Request training information from the wings being examined based on a determination of which AFSCs work on each WUC action.

Link training information to each work center group performing a WUC action. Delete WUC actions for which training data is not available.

Compare work centers involved in like WUC actions. Delete actions where the time difference between work centers is greater than 100%.

Compare work centers involved in like WUC actions. Calculate time ratio for each comparison. Calculate training percentage for each work center group.

Aggregate all comparison information.

Perform analytical tests and determine significance of training.

Exhibit II-7. WUC/TA DECISION MAKING PROCESS

AFTO 349, "Maintenance Data Collection Record," which is entered into the MDC system. The standard output report used is called the Work Unit Code (WUC) Trend Analysis (TA) report. The WUC identifies the equipment (e.g., F-100 engine) on which maintenance is performed for a major weapon system (e.g., F-15 aircraft). The Action Taken (AT) Code identifies what work was done on the equipment (e.g., AT code R for "Remove and Replace"). The WUC/TA report lists the length of time that a work center took to do a particular maintenance action on a particular type of aircraft. High-manhour consuming WUCs were chosen so as to ensure a large sample of typical tasks. "Overlap" WUCs were used so that inter-wing comparisons could be made. The term overlap means that two wings each list the same WUC as high-manhour consuming.

Step 2. Request training information from the wings being examined based on a determination of which AFSCs work on each WUC action.

The linkage of maintenance action performed to individual training requires a knowledge of which skills are required to work on which pieces of equipment. In our analysis, we attempted to precisely identify the skill (AFSC) that is associated with a particular maintenance action. For example, in the Aircraft Generation Squadron (AGS), a weapons flight consists of AFSC 462X0 personnel (weapons mechanic). Therefore, all work performed by a weapons flight can be assumed to be done by any of their trained personnel. On the other hand, the specialist flights of the AGS include personnel with a variety of different AFSCs. Therefore, only specific personnel can be expected to do particular jobs. For example, personnel holding AFSC 326X6 (integrated avionics attack control specialist) are expected to perform the action to replace (R) the radar transmitter for the fire control system of the F-15 (WUC 74FAO). There are usually about 12 to 15 personnel with this AFSC in the F-15 AGS specialist flight, which includes an approximate total of 90 personnel.

In order to request the proper training information for each AFSC, it is necessary to determine which local course(s) taught by the FTD apply to the AFSC and WUC under examination. Continuing with the example above, the course 326X6-002 (F-15 Fire Control) is required for all personnel holding that AFSC to be considered fully trained in the 1st TFW.

Step 3. Link training information to each work center group performing a WUC action. Delete WUC actions for which training is not available.

Next, it was necessary to calculate a specific number of trained, untrained, and on-the-job trained (OJT) personnel within each work center for each specific AFSC performing a WUC action under consideration. In this methodology, the terms trained, untrained, and OJT have the same meaning as in the QA procedure. Also, the linkage between training information and individuals in work centers who are performing specific actions is accomplished in the same way as in the QA methodology. In those cases where training information was not available, the WUC action was deleted.

Step 4. <u>Compare work centers involved in like WUC actions. Delete actions where the time difference between work centers is greater than 100 percent.</u>

Once training information was linked with WUC/TA data, comparisons between work center groups performing like actions were made. Where two or more work centers were involved in like WUC actions, we compared the times associated with the action performed. When the time difference in a comparison was greater than 100 percent, we deleted the action. The observations deleted were included and tested in one set of comparisons (1st TFW) and did not change the results. However, it was still determined that including observations which had large differences (over 100%) would not be analytically sound. These large differences appear to be caused by something in the quantity or quality of the work being performed that is not readily apparent and not the result of training differences. In examining work center groups, training data (the percentage of personnel classified T, U, or OJT within the work center group) and the time spent in doing a specific action were used in each set of comparisons.

Step 5. <u>Compare work centers involved in like WUC actions. Calculate time ratio for each comparison. Calculate training percentage for each work center group.</u>

In each comparison, we noted which work center was more trained and which work center was less trained. We then compared the WUC action times of these work centers in the following ratio form:

$$\frac{\text{More-trained work center action time}}{\text{Less-trained work center action time}}$$

This ratio expresses the more-trained work center's action time as a fraction of the less-trained work center's action time. If this fraction is less than 1, the more-trained work center performed faster; if the number is greater than 1, the more-trained work center was slower.

The reason for this comparison is straightforward. A difference in training should equate to a difference in time spent to perform a task. As the training difference increases, the time difference should also increase. In this case, however, a simple "difference in time" would not be an appropriate comparative variable. A ratio allows for a more straightforward comparison with training differences which are in percentages.

Comparisons in this fashion were accomplished for all work center groups performing the same WUC action within a wing (intra-wing), and between wings that have the same type of aircraft (inter-wing). Average values for the variables were then calculated.

We computed an average value for the following variables: more-trained work center training percentage, less-trained work center training pecentage, and work center action time ratio. These values were computed for both intra-wing and inter-wing work center comparisons.

Step 6. Aggregate all comparison information.

All of the comparative variables were added together and averaged to derive an average value for each intra-wing and inter-wing set of comparisons.

Step 7. Perform analytical tests and determine significance of training.

Our results should allow a significance test to be performed at this final step. The analysis is intended to show the significance of training on maintenance productivity measured in performance time. The observations and resulting comparisons were analyzed and observations made concerning them.

B. SKILL TRAINING EVALUATION RESULTS

This section discusses the following:

- application of the QA and WUC/TA skill training evaluation methodologies,
- analysis of QA and WUC/TA results, and
- observations with respect to results that were obtained.

1. Application of Methodologies

The QA and WUC/TA skill training evaluation methodologies were applied to data from three wings: 1st TFW, 37th TFW, and the 405th TTW. Our original plans had included two additional wings: the 58th TTW and the 35th TFW. The 58th was excluded because the wing was converting from F-4 to F-16 aircraft. The 35th TFW was excluded because data was not available until late in the study, and our sample contained enough data to perform the hypothesis testing necessary to determine the linkage between installation training and maintenance performance.

a. QA Application

The QA skill training evaluation methodology was applied to approximately 2,400 evaluations from the three wings that were examined. With the elimination of those evaluations for which there was no FTD course data, the QA database contained a total of 2,180 evaluations. The decision-making process previously illustrated was utilized to associate a training status with each of their evaluations. Each QA personnel evaluation was classified into a training/performance category (e.g., trained/passed).

After completing the classifications, the data for this analysis was in a form that lends itself to statistical analysis. An appropriate statistical method for testing data of this type is a hypothesis test for proportions. An example will illustrate the test procedure.

In this type of a problem, two populations are under consideration (e.g., one of trained individuals and one of untrained individuals). Exhibit II-8 displays sample data for trained and untrained individuals from the QA database.

All Comparisons (All Wings, All Skill Levels)				
		Number of Evaluations		
		# Trained	# Untrained	# Total
QA Evaluation Status	Pass	500	286	786
	Fail	260	135	395
	Total	760	421	1181

Exhibit II-8. SAMPLE DATA FROM THE QA DATABASE

To distinguish the true populations from the samples taken from the two populations, the following variables are defined:

P_1 = proportion of the sample of trained individuals who passed their QA evaluation

$$= \frac{500 \text{ of sample who passed}}{760 \text{ total number in sample}} = .658$$

P_2 = proportion of the sample of untrained individuals who passed their QA evaluation

$$= \frac{286 \text{ of sample who passed}}{421 \text{ total number in sample}} = .679$$

ρ_1 = proportion of the true population of trained individuals who passed their QA evaluation

ρ_2 = proportion of the true population of untrained individuals who passed their QA evaluation

The question is whether or not the hypothesis $H_o: \rho_1 = \rho_2$ is accepted or rejected statistically. If the difference between the two sample proportions P_1 and P_2 is statistically significant, then the hypothesis H_o is rejected, and trained individuals can therefore be considered more likely to pass QA evaluations than untrained individuals.

In order to perform the desired hypothesis test, values for ρ_1 and ρ_2 are needed. Because the hypothesis tested is $H_o: \rho_1 = \rho_2$, only one value has to be derived. From our data, the best sample estimate for ρ_1 and ρ_2 is ρ, or the proportion of individuals who passed their QA evaluation from the combined sample group. In this example, $\rho = \frac{786}{1181}$, or .666.

All of the proportions needed to test the hypothesis $H_o: \rho_1 = \rho_2$ are now available. The next step is to compute the standard error of the difference $P_1 - P_2$, which is:

$$\sigma_{P_1-P_2} = \sqrt{\bar{p}(1-\bar{p}) \quad (1/N_1+1/N_2)}$$

Where N_1 = total number of evaluations of trained personnel (from Exhibit II-8).

N_2 = total number of evaluations of untrained personnel (from Exhibit II-8).

Computing this value gives us:

$$P_1-P_2 = \sqrt{(.666) \ (1-.666) \ (\frac{1}{760} + \frac{1}{421})} = .029$$

This standard error value is now used in computing the Z-statistic for the hypothesis. This statistic is compared against a normal distribution at a specific level of confidence to determine whether or not the hypothesis $\rho_1=\rho_2$ should be rejected.

The formula for the Z-statistic is:

$$Z = \frac{P_1-P_2- \frac{N}{2N_1N_2}}{\sigma_{P_1-P_2}}$$

where N = total number of evaluations of all personnel; N_1+N_2 (from Exhibit II-8).

Computing this value gives us:

$$Z = \frac{.658 - .679 - \frac{(1181)}{(2) \ (760) \ (421)}}{.029} = -.793$$

At a 90 percent level of significance, the hypothesis H_o: $\rho_1=\rho_2$ is rejected only if the Z-statistic is greater than 1.28. In this case, -.793 is clearly not greater than 1.28, so the hypothesis $\rho_1=\rho_2$ cannot be rejected. In other words, this statistical result does not show that trained individuals are more likely to pass a QA evaluation than untrained individuals.

Exhibits II-9 and II-10 show the QA evaluation comparison data and the statistical results for each set of comparisons made using the QA database. Two tests were performed on each category:

- one comparing trained individuals with untrained individuals, and
- one comparing both trained and OJT individuals with untrained individuals.

These two types of comparisons were made for the following reason. The first attempts to determine the statistical significance of FTD course training, and the second measures the significance of no training at all ("untrained" in the sense that the individual has not been formally trained at the FTD level or trained on-the-job). In most cases, the test results indicated that the hypothesis $H_o: \rho_1 = \rho_2$ cannot be rejected.

b. WUC/TA Application

The WUC/TA skill training evaluation methodology was applied to data received from the three wings in our final sample. Exhibit II-11 lists the WUCs that were chosen for analysis. All of these WUCs are in the top-25 manhour consuming components list for two different wings that use the same aircraft. A training status was then associated with this WUC/TA information using the decision-making process previously illustrated. Training percentages were then computed for each work center involved in overlap actions.

COMPARISON GROUPING	EVALUATION RATING	COMPARISON SET TRAINED TO UNTRAINED			COMPARISON SET TRAINED + OJT TO UNTRAINED		
		#T PERSONNEL	#U PERSONNEL	# TOTAL	#T + O PERSONNEL	#U PERSONNEL	# TOTAL
OVERALL COMPARISONS (ALL WINGS, ALL SKILL LEVELS)	PASS	500	286	786	1192	286	1478
	FAIL	260	135	395	567	135	702
	TOTAL	760	421	1181	1759	421	2180
WING B ALL SKILL LEVELS	PASS	115	182	297	355	182	537
	FAIL	50	74	124	110	74	184
	TOTAL	165	256	421	465	256	721
WING C ALL SKILL LEVELS	PASS	330	43	373	740	43	783
	FAIL	168	43	211	397	43	440
	TOTAL	498	86	584	1137	86	1223
WING A ALL SKILL LEVELS	PASS	55	61	116	97	61	158
	FAIL	42	18	60	60	18	78
	TOTAL	97	79	176	157	79	236
WING B SKILL LEVEL 3	PASS	28	61	89	83	61	144
	FAIL	14	16	30	21	16	37
	TOTAL	42	77	119	104	77	181
WING B SKILL LEVEL 5	PASS	62	112	174	215	112	327
	FAIL	21	52	73	50	52	102
	TOTAL	83	164	247	265	164	429
WING B SKILL LEVELS 7 & 9	PASS	25	9	34	57	9	66
	FAIL	15	6	21	39	6	45
	TOTAL	40	15	55	96	15	111
WING C SKILL LEVEL 3	PASS	90	3	93	139	3	142
	FAIL	13	0	13	16	0	16
	TOTAL	103	3	106	155	3	158
WING C SKILL LEVEL 5	PASS	186	29	215	467	29	496
	FAIL	129	35	164	346	35	381
	TOTAL	315	64	379	813	64	877
WING C SKILL LEVELS 7 & 9	PASS	54	11	65	134	11	145
	FAIL	26	8	34	35	8	43
	TOTAL	80	19	99	169	19	188
WING A SKILL LEVEL 3	PASS	9	27	36	19	27	46
	FAIL	6	9	15	7	9	16
	TOTAL	15	36	51	26	36	62
WING A SKILL LEVEL 5	PASS	42	31	73	66	31	97
	FAIL	33	9	42	50	9	59
	TOTAL	75	40	115	116	40	156
WING A SKILL LEVEL 7	PASS	4	3	7	12	3	15
	FAIL	3	0	3	3	0	3
	TOTAL	7	3	10	15	3	18
OVERALL-SKILL LEVEL 3	PASS	127	91	218	241	91	332
	FAIL	33	25	58	44	25	69
	TOTAL	160	116	276	285	116	401
OVERALL-SKILL LEVEL 5	PASS	290	172	462	748	172	920
	FAIL	183	96	279	446	96	542
	TOTAL	473	268	741	1194	268	1462
OVERALL-SKILL LEVELS 7 & 9	PASS	83	23	106	203	23	226
	FAIL	44	14	58	77	14	91
	TOTAL	127	37	164	280	37	317

Exhibit II-9. QA EVALUATION COMPARISON DATA

COMPARISON GROUPING	COMPARISON SET	STD. ERROR $\sigma_{P_1-P_2}$	z STATISTIC	90% LEVEL OF SIGNIFICANCE ($z > 1.28$) H_0 REJECTED
OVERALL COMPARISONS (ALL WINGS, ALL SKILL LEVELS)	TRAINED TO UNTRAINED	.0287	-.7931	NO
	TRAINED + OJT TO UNTRAINED	.0254	-.1242	NO
WING B-ALL SKILL LEVELS	TRAINED TO UNTRAINED	.0455	-.4164	NO
	TRAINED + OJT TO UNTRAINED	.0339	1.4582	YES
WING C-ALL SKILL LEVELS	TRAINED TO UNTRAINED	.0561	2.7780	YES
	TRAINED + OJT TO UNTRAINED	.0537	2.6937	YES
WING A-ALL SKILL LEVELS	TRAINED TO UNTRAINED	.0718	-3.0155	NO
	TRAINED + OJT TO UNTRAINED	.0649	-2.5249	NO
WING B SKILL LEVEL 3	TRAINED TO UNTRAINED	.0833	-1.7281	NO
	TRAINED + OJT TO UNTRAINED	.0606	-.0896	NO
WING B SKILL LEVEL 5	TRAINED TO UNTRAINED	.0615	.8946	NO
	TRAINED + OJT TO UNTRAINED	.0423	2.9189	YES
*WING B SKILL LEVELS 7 & 9	TRAINED TO UNTRAINED	.1471	-.1416	NO*
	TRAINED + OJT TO UNTRAINED	.1363	-.3286	NO*
*WING C SKILL LEVEL 3	TRAINED TO UNTRAINED	.1921	-1.5497	NO*
	TRAINED + OJT TO UNTRAINED	.1759	-1.5531	NO*
WING C SKILL LEVEL 5	TRAINED TO UNTRAINED	.0679	1.8835	YES
	TRAINED + OJT TO UNTRAINED	.0643	1.7538	YES
*WING C SKILL LEVELS 7 & 9	TRAINED TO UNTRAINED	.1212	.5239	NO*
	TRAINED + OJT TO UNTRAINED	.1016	1.8172	YES*
*WING A SKILL LEVEL 3	TRAINED TO UNTRAINED	.1400	-1.4084	NO*
	TRAINED + OJT TO UNTRAINED	.1126	-.4649	NO*
WING A SKILL LEVEL 5	TRAINED TO UNTRAINED	.0943	-2.4840	NO
	TRAINED + OJT TO UNTRAINED	.0889	-2.5062	NO
*WING A SKILL LEVEL 7	TRAINED TO UNTRAINED	.3162	-2.1082	NO*
	TRAINED + OJT TO UNTRAINED	.2357	-1.6971	NO*
OVERALL- SKILL LEVEL 3	TRAINED TO UNTRAINED	.0497	.0369	NO
	TRAINED + OJT TO UNTRAINED	.0416	1.3247	YES
OVERALL- SKILL LEVEL 5	TRAINED TO UNTRAINED	.0370	-.8532	NO
	TRAINED + OJT TO UNTRAINED	.0326	-.5394	NO
OVERALL- SKILL LEVELS 7 & 9	TRAINED TO UNTRAINED	.0893	.1620	NO
	TRAINED + OJT TO UNTRAINED	.0791	1.1130	NO

* Test sample is not large enough (<30). Result is deleted.

Exhibit II-10. QA
STATISTICAL RESULTS

Wings	WUC	Aircraft	Description of WUC
Wing B; Wing C	23Z00	F-15	F-100 Jet Engine
Wing B; Wing C	71AEO	F-15	Inertial Measurement Unit
Wing B; Wing C	74FAO	F-15	Radar Transmitter
Wing B; Wing C	74FCO	F-15	Radar Receiver
Wing B; Wing C	74FSO	F-15	Radar Target Data Processor
Wing B; Wing C	74FUO	F-15	Radar Set Antenna
Wing B; Wing C	74KAO	F-15	Heads-up Display Unit
Wing B; Wing C	74KCO	F-15	Signal Data Processor
Wing B; Wing C	75BDO	F-15	Guided Missile Launcher
Wing A	1225A	F-4	Seat Bucket Assembly
Wing A	23Z00	F-4	J-79 Jet Engine
Wing A	513H0	F-4	Air Data Computer
Wing A	71H00	F-4	Inertial Navigation System
Wing A	71H20	F-4	Navigational Computer
Wing A	71H60	F-4	Platform, Gyro Stabilized
Wing A	74B00	F-4	APQ-120 Radar Set
Wing A	74BBO	F-4	LRU-18 Control Oscillator
Wing A	74BJO	F-4	Antenna Control
Wing A	74BPO	F-4	Wave Guide Assembly, LRU-19
Wing A	74BVO	F-4	LRU-16 Antenna
Wing A	75130	F-4	Aero 7-A Launcher

Exhibit II-11. WUCS CHOSEN FOR INTER- AND INTRA-WING COMPARISONS (WUC/TA METHODOLOGY)

At this point, the WUC/TA data was ready for comparison. Comparisons were made (inter- and intra-wing) between work centers that were performing the same action. The following figures were computed:

- average trained percentage of the more-trained work centers,
- average trained percentage of the less-trained work centers,
- average percentage differences in training, and
- the average time ratio.

Exhibit II-12 lists these figures along with the number of comparison groups in each WUC/TA sample. These overall results indicate that increased levels of training tend to be related to decreased time to perform maintenance.

2. Analysis

Results of analyses following application of the QA and WUC/TA skill training evaluation methodologies are presented in this section. We have included a discussion of the biases that may affect the true relationship between training and productivity. Each method is addressed separately.

a. QA Analysis

QA personnel evaluation methodology ., ovided inconclusive results. Several valid statistical tests were made between trained/passed and trained-plus-OJT/passed with untrained/passed personnel. In the tests that compared trained to untrained

Results \ Comparison Unit	WING B 1/	WING C 1/	WING A 1/	WING B/C 2/	(Combined Total)
Number of Comparisons	17	119	79	62	277
Average Trained Percentage of More-trained Work Centers	66.2%	75.6%	55.5%	71.8%	68.4%
Average Trained Percentage of Less-trained Work Centers	25.2%	54.4%	34.2%	40.7%	43.8%
Average Percentage Difference in Training	41.0%	21.2%	21.3%	31.1%	24.6%
Average Time Ratio	.956	1.005	.997	.963	.982

1/Intra-wing
2/Inter-wing

Exhibit II-12. SUMMARY RESULTS: WUC/TA SKILL TRAINING EVALUATION individuals, 18 percent (2 out of 11) showed statistically significant results (i.e., trained individuals were more likely to pass a QA evaluation than untrained individuals). Testing both trained and OJT with untrained individuals yielded a 45 percent (5 out of 11) figure of statistically significant results. These results, however, cannot be termed as representative of the effects of training on QA performance because of several biases:

- First, the tasks being evaluated were not easily definable in terms of what was actually being done. Tasks are often described in the QA reports by Work Unit Code (WUC) at the system level, which is the broadest possible description of a specific work action. For example, 23Z00 is a WUC that describes work done on the F-100 engine system. An operation that can be classified as a 23Z00 action can also be classified into a myriad of subsystems under the 23Z00 heading (e.g., 23A00-Inlet Fan Module). Similarly, actions can be further classified within subsystems to the component level (e.g., 23AAC-Retaining Plate and #1 Bearing in the Inlet Fan Module). Therefore, it is difficult to determine the exact nature of the task being evaluated.

- The relationship between FTD training received and the task evaluated is hard to define and, in some cases, could be erroneous. The broad nature of the WUC codes used to describe work actions makes it difficult to determine what kind of training could be required for specific actions. Because of this difficulty, an implicit assumption of this analysis is that the FTD training received by an individual is directly related to the action being tested. This assumption could be inaccurate, and therefore bias the results.

- Although categories for analysis were established for each wing and by skill levels, categories were not set up for specific AFSCs. Incorporating more than one AFSC into a testing category could lead to a bias because of the different nature of training for the different AFSCs. One AFSC could have several associated FTD courses, while another could have only one. In this case, a person classified as "trained" in the first AFSC will have more FTD training than a person "trained" in the second AFSC. Level of training (defined as the number of FTD courses taken) is not considered in this methodology.

- This analysis does not consider how fast the evaluated action was performed because of the lack of this kind of data in the QA reports. This variable, however, could be important. It could show that trained individuals performed faster in accomplishing a task. If this were so, our analysis could be focusing on the wrong indicator to measure the effects of training.

- Because of data limitations, this analysis does not consider how well individuals performed within the pass/fail categories. Ideally, mistakes are counted in the QA evaluation procedure, and up to five "minor" mistakes can be made before an individual receives a fail rating. Therefore, performance could be measured more adequately by the number of mistakes made, as opposed to the rating received. In reality, however, the number of mistakes is rarely recorded on the computerized QA reports; the only measure of performance is the actual rating. Once again, this analysis could be focusing on the wrong indicator to measure the effects of training.

Most of the biases that contributed to the analyses results are directly related to the database from which the QA methodology was built. The form and scope of available QA data is not particularly suited for our purposes. Perhaps the most serious data biases involve the lack of precision in defining the task being evaluated and the resulting difficulty in linking FTD training to specific tasks. A more in-depth analysis of the method by which specific tasks are linked to specific FTD training courses could lead to more conclusive results.

Two tests were performed on all categories within the QA database:

- one comparing trained individuals with untrained individuals, and

- one comparing both trained and OJT individuals with untrained individuals.

The rationale for performing these two tests for each category is discussed above (Section II.B.1.a). Theoretically, one would expect that the results from these two tests would be approximately the same, since FTD course training and OJT training serve the same purpose. Our results are inconclusive in establishing any reliable relationship between the tests, mainly because of data biases. Statistically significant figures were obtained for both methods of testing, and these figures seemed to indicate that the trained plus OJT versus untrained comparisons were more statistically significant than the trained versus untrained comparisons. A simple analysis of these statistical significance figures, however, does not address one important consideration: the cost versus the benefit of training an individual by the FTD as opposed to OJT. The actual time in training is much shorter in an FTD course. Although such training removes the individual from the work center while the course is in session, the individual returns to work at a higher skill level. Assuming that an average time for OJT training in an Air Force unit is approximately twelve months, FTD training could be more cost effective in terms of preparing an individual to perform at a particular skill level.

b. WUC/TA Analysis

The results of our WUC/TA examination, presented in Exhibit II-12, generally show that increased levels of training tend to be related to decreased time to perform maintenance. These results could be erroneous, however, because data-oriented biases such as those that limited our QA analysis may obscure more meaningful findings:

- The task description for each WUC is very general for defining similar tasks. Difficulties encountered in tasks are not well defined by such descriptions as "remove and replace."

- The interpretation of personnel awaiting FTD training as untrained. Actually these personnel have received basic technical training in their AFSC and, in some cases, have job experience on other aircraft doing similar work. Because of this, our comparison of work centers shows large differences in numbers of untrained personnel and only small differences in time to perform work. Since we did not know which personnel in the work center did a specific job, we assumed all personnel could have done the job. This may be compensated for by the fact that we used average times for several jobs in the same work center.

- Record keeping for time spent on a task may vary from one work center to another. Although timekeeping is important, the requirement to document all time while at work may disguise how much time was actually spent on a particular job.

- Inter-wing comparisons are biased by different FTD training, different approaches to using personnel, and different time-keeping procedures.

- The use of cross-training in mixed (more than one AFSC) work centers may also lead to biases in establishing the WUC-training relationship in this methodology.

We have attempted to establish a relationship between work centers, WUC, and AFSC installation-level (FTD) training using standard output data from base-level information systems (MDC and MMICS). We have tried to assess training effectiveness measured by the time documented to do a task. This disregards quality of work and assumes that all work was done correctly.

Our sample can be considered as representative in terms of examination of those jobs that occur with greatest frequency and use the most time within the maintenance squadrons.

The results of our analysis, illustrated in Exhibit II-12, cannot be considered statistically significant. The overall weighted variation in trained personnel was 24.6 percent, which compares with an overall time ratio of only .982. This can be partially explained by the biases previously listed. The result does show, however, that trained personnel appear to have some effect on time of work performance.

3. Observations

This study has attempted to illustrate a verifiable, positive relationship between FTD training and job performance. Two methods were devised to illustrate this relationship: a QA methodology, which compared individual performance evaluations in a statistical manner; and a WUC/TA methodology, which compared average time to complete a like task between work centers. "Macro" measures of performance, such as the number of aircraft hours flown and the number of aborted flights due to mechanical problems, were not considered in this study. Although these measures might be more accurate maintenance performance measures, they are not directly relatable to training and could not be used. The results of our work to date are not conclusive although they indicate that FTD training has some impact on productivity. The measures chosen did not capture significant differences, but this is explained by several biases that exist in the data that was used.

This conclusion is not to say that FTD training is ineffective in terms of teaching new job skills. One must realize that personnel who go through FTD training have already received extensive training in their specialty fields, and this additional unit training is a refinement, or "add-on" to their broad training base.

The advantages of FTD training are in three areas:

- capability of rapid adjustment to local requirements,
- cost savings based on little or no need to travel to distant schools for training, and
- rapid return of students to the job.

Unit training goals can be met through FTD schooling, and through an OJT program. OJT allows work to continue without loss of students and instructors to the local school, but FTD training helps to get a person on the job at a particular skill level in a shorter period of time. This fact, combined with modest increases in productivity (measured either in quantity or quality of work), should produce higher levels of aircraft availability without an increase in the size of the work force. From a cost/benefit point of view, any increase in aircraft availability yields readiness improvements. This may be the most important benefit of FTD training.

The wing commander, in his attempt to achieve the highest number of mission available aircraft, has a valuable tool in his QA section. This group of highly skilled maintenance personnel of varied AFSCs performs an important function in their evaluation of individual mechanics. Of the 2180 personnel tested by the QA sections at our sample wings and included in our sample data, 702 (or 32%) failed to pass the QA certification. These personnel had to be retrained and then recertified by their supervisors that they were capable of performing their work. Thus, we found that the QA section furnishes a real-time feedback on the capability of the maintenance personnel to perform their tasks. Our data shows that the QA program is viable and doing its job of insuring that maintenance is properly performed.

III. AN EXAMINATION OF THE IMPACT OF INSTALLATION-LEVEL TRAINING USING SIMULATORS ON F-16 UNIT MAINTENANCE PRODUCTIVITY

This section discusses the potential relationships between the use of Simulated Aircraft Maintenance Trainers (SAMTs) in Air Force Field Training Detachment (FTD) courses and unit maintenance productivity.

In our previous research on FTD training, documented in Section II, we set out to establish a linkage between individual training conducted at the installation level and unit productivity. The results of that research, although not conclusive, did indicate that FTD training does have some impact on productivity. Productivity measures were found to capture small differences; biases in the data that were used prevented more significant results. The research task documented in this section is a refinement of our previous research, and was undertaken because of continued interest in the impact of FTD training on unit productivity. It specifically focuses on F-16 FTD courses that use maintenance simulators in the curriculum, and the effects that such training with simulators has on maintenance productivity. We did not quantify the specific impact of training simulators.

The linkage between training and productivity is tenuous under any circumstances, since so many other influences impinge on work productivity. Such things as reporting procedures, facilities, and parts availability can change the results achieved. However, intuitively, training must have an effect on maintenance productivity and, if a large enough sample is chosen and carefully analyzed, effects should become apparent. The introduction of a maintenance simulator as an additional variable is not easily measured, since training will occur whether the simulator is available or not. The simulator does allow the student to diagnose rare symptoms and thus, on the occasion that something out of the ordinary occurs, be able to fix it properly. The simulator appears to provide a means of achieving a higher quality of maintenance, although our method of measuring productivity by time-to-repair will not make this readily obvious.

The approach used in this task was to relate training received by maintenance personnel at the installation level to on-the-job performance. This approach included:

- identifying skills taught using maintenance simulators at the wing level, and
- developing methods for analyzing the impact of these learned skills on maintenance productivity.

The research focused on maintenance skills critical to the operation of the F-16 aircraft. The study was conducted in the following order:

- research the use of SAMTs by FTDs for training maintenance personnel at the wing level;
- select appropriate sample organizations;
- request and receive training and maintenance productivity information from the selected units; and
- develop a methodology for analyzing the data, analyze the data, and document the results.

This section contains two subsections:

- Skill Training Evaluation, and
- Application of Methodology and Results.

Section III.A, Skill Training Evaluation, discusses the use of maintenance simulators, analytical considerations, assumptions, sample selection, and the methodology developed for analyzing the relationship between training and maintenance productivity.

Section III.B, Application of Methodology and Results, discusses data and computations, the application of our techniques, analysis of the results obtained, and observations.

Supporting information is presented in Appendix C, Backup Data.

A. SKILL TRAINING EVALUATION

This subsection discusses the following topics:

- Aircraft Maintenance Simulators,
- Analytical Considerations,
- Assumptions,
- Sample Selection, and
- Methodology.

1. Aircraft Maintenance Simulators

The use of aircraft maintenance simulators can be very helpful in conducting skill training. This section addresses these topics: the effects of having maintenance simulators, a description of what kind of simulators are available for F-16 training at the wing level, and what the trainers do.

a. Effects of Having Maintenance Simulators

As a training device, a maintenance simulator can be designed to provide facilities important for instructing students, in contrast to actual equipment that is designed to operate effectively in an operational environment. Maintenance simulators can be designed to include a large variety of faults with which maintenance personnel should be familiar, including faults that cannot be demonstrated conveniently on actual equipment trainers or faults that occur rarely in real life.

All modern maintenance simulators incorporate some type of computer support. This support provides numerous training enhancements.

- The computer can automatically record student responses to training situations, thereby reducing the need for constant observation by the instructor (and providing accurate records of performance).
- The computer can assist students without an instructor's intervention.
- The instructors can use information collected by the computer to better guide each student through training by focusing on weak areas.

Simulators can be made rugged enough to sustain damage or abuse by students and thus provide greater reliability and availability in the classroom than is often possible with actual equipment. Training which would be avoided because of safety reasons (e.g., exposure of students to dangerous electrical charges or hydraulic pressures) can be undertaken with little risk on a simulator. F-16 maintenance training conducted at the Field Training Detachment (FTD) level is enhanced by the use of aircraft simulators. These simulators are organized into sets. A full set may have 11 different simulators or trainers. Each individual trainer simulates different functions aboard the aircraft. These simulators are divided into two major types:

- Simulated Aircraft Maintenance Trainers (SAMTs). These computerized, fault-oriented trainers provide an advanced method of training maintenance technicians to diagnose and correct system malfunctions. SAMTs provide a method of teaching operational procedures in a very cost-effective manner. Power requirements are lower than with actual equipment, and simulator system response to student inputs is identical to that of the aircraft.

- Hardware Trainers. These trainers provide a physical simulation of actual maintenance areas. These simulators focus on "hands-on" training experiences for the repair of common malfunctions in some of the more mechanical areas of the aircraft; diagnostic skills are not stressed within these simulators.

b. F-16 Aircraft Maintenance Simulators

The full group of simulators is called a mobile training set (MTS) and consists of seven SAMTs and four hardware simulators (or trainers). Each simulator is numbered, although not all numbers are used. Six SAMTs are manufactured by Honeywell and one by Educational Computer Corporation (ECC). The hardware trainers are made by General Dynamics. The list below shows simulator number, title and manufacturer:

Simulator Number	Simulator Title and Manufacturer
2	SAMT--Flight Control/Instrumentation (Honeywell)
3	SAMT--Navigation (Honeywell)
4	SAMT--Electronics (Honeywell)
6	Hardware--Seat and Canopy (General Dynamics)
7*	SAMT--Hydraulics (Honeywell)
10	SAMT--Engine Start (Honeywell)
11	SAMT--Engine Diagnostics (Honeywell)
12	SAMT--Engine Operating Procedure (Honeywell)
13	Hardware--F-100 Engine (General Dynamics)
14	Hardware--Gun (General Dynamics)
15	Hardware--Fuel (General Dynamics)
22	SAMT--Environmental Control (ECC)

*No longer in use.

The following is a listing of where MTSs have been provided for training support in the Continental U.S. (CONUS).

Location	Supported Unit	MTS Status (Issue Dates)
Hill AFB	388th TFW	Issued MTS 1 (Jan. - Dec. 79)
MacDill AFB	56th TTW	Issued MTS 2 (Feb. 79 - May 80) MTS 2 moved to Shaw AFB in Jan. 82. Issued MTS 5 (Apr. 83).
Shaw AFB	363rd TTW	Issued MTS 2 (Jan. 82)
Luke AFB	58th TTW	Issued MTS 6 (Aug. - Sep. 82)
Nellis AFB	474th TFW	Issued MTS 4 (Nov. 82 - Apr. 83)

This information is shown graphically on Exhibit III-1.

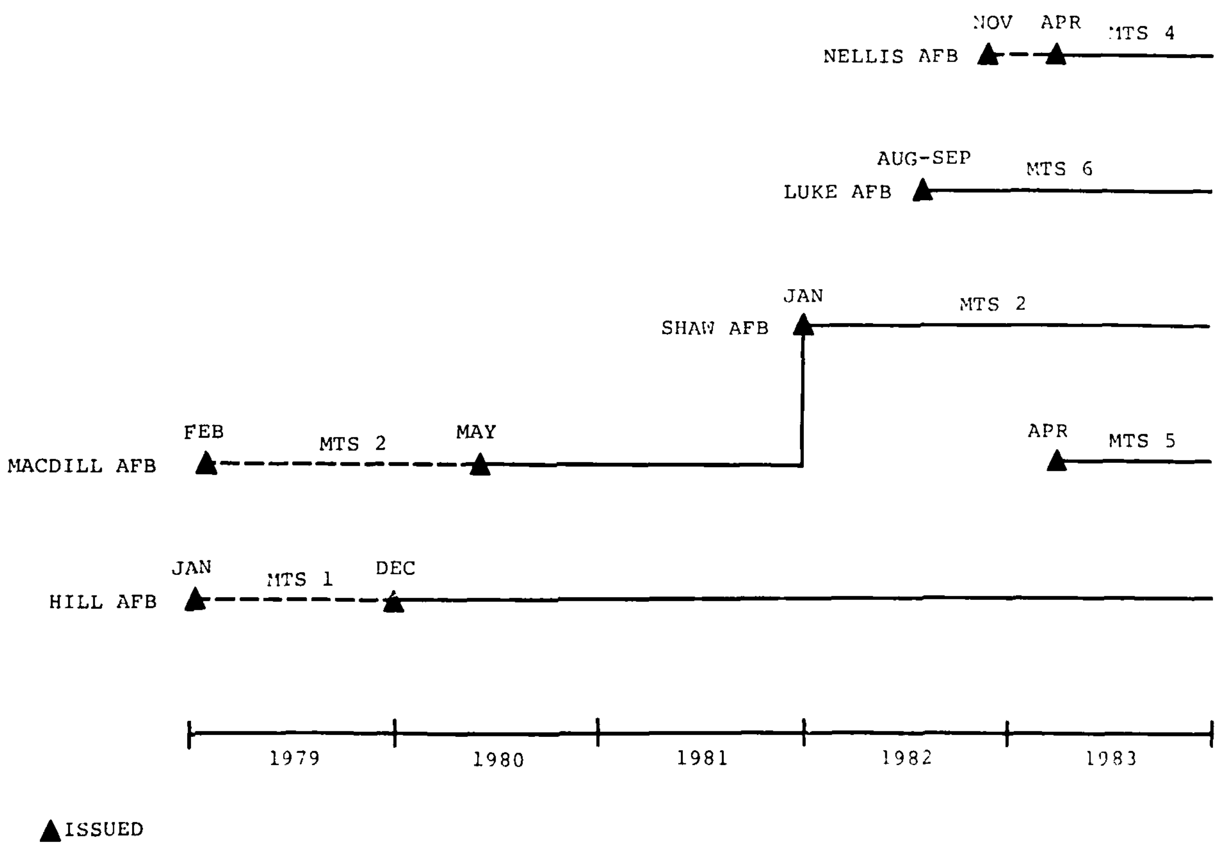


Exhibit III-1. MTS LOCATIONS (CONUS)

c. Use of Simulators

The following listing shows the simulator number and title, aircraft component repaired by primary work unit codes (WUCs) that are part of the malfunctions taught using the simulators, and the course title/AFSC for which the simulator is used.

Simulator	Aircraft Equipment Repaired-WUCs	Courses/AFSC
2, Flight Control/ Instrumentation	14A00, Primary Flight Control Electronics 14B00, Primary Flight Control Actuators 51A00, Primary Flight Instruments 51F00, Control Air Data Computer	Integrated Avionics Instrument and Flight Control System Specialist (F-16); for AFSC 326X7
3, Navigation	71A00, TACAN Navigation Set 71B00, Instrument Landing Set	Integrated Avionics, Navigation, and Penetration Aids Systems Specialist (F-16); for AFSC 326X8.
4, Electronics	42000, Electrical Power Supply	Aircraft Electrical Systems Technician (F-16); for AFSC 423X0.
6, Seat and Canopy	12000, Crew Station System	Aircrew Egress Systems Technician (F-16); for AFSC 423X2.
10, Engine Start 11, Engine Diagnostics 12, Engine Operating Procedure 13, F-100 Engine	23000, Turbofan Power Plant;iary 24000, Auxiliary Power Plant	Jet Engine Technician (F-16); for AFSC 426X2.

Simulator	Aircraft Equipment Repaired-WUCs	Courses/AFSC (Cont'd)
14, Gun	75A00, Gun System	Weapons System Maintenance Technician (F-16); for AFSC 462X0.
15, Fuel	46000, Fuel System	Aircraft Fuel Systems Technician (F-16); for AFSC 423X3.
22, Environmental Control	41000, Environmental Control System	Aircraft Environmental System Technician (F-16); for AFSC 423X1

2. Analytical Considerations

This study examines the impact of FTD training, particularly the training that incorporates the use of maintenance simulators, on maintenance productivity. In our previous research, we found that the Air Force Quality Assurance (QA) program worked well and had an impact on the care taken in aircraft maintenance as well as the assurance that maintenance personnel were maintaining aircraft properly and safely. However, no quantitative measures were developed from that particular research that could be used to demonstrate the linkage between training and maintenance. Our previous work did show that the use of work unit code trend analyses (which focus on time to complete a maintenance action) might prove to be a useful tool in linking training and maintenance productivity. Therefore, in this phase of our work we have focused on that aspect -- time to complete a maintenance action -- as the measure of performance and related it to training conducted at the unit (wing) level.

Many factors beyond training at the unit/base level and the use of actual or simulated equipment can profoundly influence our capability to maintain military equipment. These factors include:

- the quality of personnel recruited by the military services,
- the policies used by the Services to assign recruits to occupational specialties,
- the amount and type of training to be accomplished at technical schools,
- the complexity of the information that must be assimilated in order to accomplish maintenance,
- quality of maintenance supervision,
- equipment design, and
- maintenance policy.

These factors are recognized as being important considerations in equipment maintenance analyses, but, due to our specific concern in this study on training and maintenance simulators, these factors are not explicitly addressed.

3. Assumptions

The analytical task of linking training, frequency, and productivity measures is based on several major assumptions relating to the data and the procedures followed to process the data. These assumptions include the following.

- An implicit assumption in this analysis is that the data being analyzed is accurate and complete. Problems with data recording and data entry could lead to biased or inaccurate data analyses. In spite of these possible inaccuracies in the data collection system, this study is based on information inputted to the MDC system. Data which is verifiable as inaccurate is excluded from our analysis. All other data is included.

- Data entered in the maintenance data collection (MDC) system is assumed to represent "successfully completed" work actions.

- Time of performance shown on MDC printouts for work actions is the elapsed time (difference between start and stop time).

- We are assuming that the current work center training percentages are indicative of the training percentage of each work center over time. Training data is only available for the current time period, whereas the productivity data that is associated with this training data is obtained for a period of six months. The number of trained personnel or "training percentage" that we use for a work center can change drastically over that period of time; however, because of the lack of more complete data, the current training percentage is used in our analysis for all work centers.

- Each member of a work center has an equal opportunity to perform a particular action. Thus, for all work performed, the calculations will use the total workers (with appropriate AFSC) in each work center.

- We can identify particular WUCs that are associated with actions taught using maintenance simulators. However, these WUCs are often very specific. In order to match this information with the level of detail obtained in our WUC-related data requests, we are assuming that associated higher level WUCs are also taught, in sufficient detail, on the SAMTs.

- If a maintenance simulator is supposed to be used in training, and an MTS is present at a base, then we are assuming that the SAMT is used in all appropriate training (we are not accounting for any simulator downtime).

4. Sample Selection

For this task, we chose a sample large enough to assure reasonable results for our analysis. We chose the two F-16 wings which had used simulators in their FTD training for a period of over one year. We also chose another F-16 wing which had never had simulators for their FTD training and had the F-16 for a long period of time (over three years) so comparative analyses might be made. Our final selection of sample wings was as follows:

- Hill AFB, UT -- 388th TFW,
- MacDill AFB, FL -- 56th TTW, and
- Nellis AFB, NV -- 474th TFW.

An examination of Exhibit III-1 shows that at Hill AFB, all training used simulators, all Nellis AFB training did not use simulators, and most MacDill AFB training used simulators.

The identity of the wings we examined is not relevant; hence, we have randomly titled them as Wing J, Wing K, and Wing L. The work centers for the wings were assigned numbers for identification. This alpha-numeric code is used throughout the analysis portion of this section to identify specific work centers.

5. Methodology

The methodology used for examining the linkage between FTD-provided training, specifically that training using simulated aircraft maintenance trainers and hardware trainers, and maintenance productivity relies heavily on the work MCR accomplished in our previous research. The inference, or intuitive sensing, is that as the number of FTD-trained personnel in a work center increases, the productivity of that work center will increase. Productivity is measured in terms of the worker hours used to complete a specific work action. Obviously, the complexity of work actions can vary even when a specific subassembly is being worked on and the action code used is fairly specific. This complexity or difference in work performed should be statistically smoothed by taking a large enough sample of particular types of work.

The following subsections will address three subjects:

- Determination of Training Status,
- Determination of Maintenance Productivity, and
- Analytical Techniques.

a. Determination of Training Status

The process of determining the training status of specific work centers involves obtaining the training requirements for the skills involved in performing the work, finding which individuals have received the required FTD course training, and calculating the overall work center training status. The procedure we followed in the wings examined in this task for calculating trained/untrained status is listed below.

- Determine which skills might be examined based on the maintenance simulators provided by the Air Force for FTD training.

- Obtain copies of programs of instruction (POIs) published by Air Training Command for these skills. Examine the POIs to see which maintenance simulators are used in FTD courses for the appropriate skills. This examination results in a determination of whether the training uses the maintenance trainer in a manner that appears to assure a measurable impact on task performance for a specific skill.

- Request course status summaries from each wing for the skills chosen for examination.

- Calculate trained/untrained personnel status for any work center that will be examined. The examination of specific work centers is determined by analysis of maintenance productivity information. Only those work centers that had a measurable sample of work actions were chosen. This is explained in Section III.B.1.

- The determination of whether a person is trained or untrained proceeds as follows:
  - If a person has taken the required FTD course for his AFSC, he is considered to be trained.
  - If a person has not taken the required FTD course for his AFSC, he is considered to be untrained.
- Calculate work center trained percentages for specific skills (AFSCs). When a work center contains only one AFSC, then the calculation consists of dividing the number of trained personnel by the total number of personnel in the work center. When a work center has more than one AFSC, then the calculation consists of dividing the number of trained personnel in the AFSC that pertains to the work performed by the total number of personnel having that particular AFSC in the work center.
- Separate work centers by training level. Training level is defined as the percentage of trained personnel in the work center for a specific AFSC.

b. Determination of Maintenance Productivity

The procedure for determining the maintenance productivity of specific work centers starts with the choice of specific work unit codes (WUCs) to be examined. This choice was assisted considerably by the help of Honeywell, Inc. personnel who provided information on each maintenance simulator they make and the specific WUCs that each particular simulator represents. This data is attached in Appendix C.

Our primary interest was on the SAMTs, so initially we chose to request information only for WUCs associated with them. However, WUC 12000 was also chosen so we could examine data for a hardware trainer (Crew Station System -- canopy and seat).

Previously, in our research on the F-15/F-4 aircraft, we had used a standard output from the Air Force Maintenance Data Collection (MDC) system known as the WUC trend analysis report. However, a new system known as the Consolidated Data System (CDS) has been instituted for the F-16 that allows for more flexible and responsive maintenance data reporting. Both systems rely on maintenance information recorded by each work center on Air Force Form AFTO 349, "Maintenance Data Collection Record," which is entered in the MDC data base at each wing. CDS draws off the MDC data base to display whatever information is required. The advantage of CDS over MDC is the ability to aggregate maintenance data in a more usable form and with flexibility as to which information is displayed. The obvious information needed is what was worked on (WUC), what was done (action taken code), how long the action took (time), and who performed the action (work center).

After determining which WUCs are to be examined, a request to each wing for a specifically formatted report for a particular time period resulted in a large amount of information for use in analysis. We were assisted greatly in our data request and formats by representatives of the Tactical Air Command (TAC), located at their headquarters, as well as TAC personnel at the wing level who had been working with the CDS.

Our general procedure for determining work center maintenance productivity using the output data from the CDS is as follows.

- Request a WUC report that specifies the WUCs required for analysis. The time period requested was calendar year 1982. The report was requested for all work centers and for all action taken codes.

- After receipt of the WUC report from each wing, examine it for completeness. Then see which work centers have the appropriate AFSCs for the WUCs under consideration.

- Determine if sufficient WUC actions occur for a particular work center (to include action codes) to indicate a normal distribution (i.e., 30 or more actions).
- Separate and aggregate the WUCs by work center and action taken code. Then sum to get total hours for

  each work center/action taken code. At this point, the analysis of maintenance productivity must incorporate other variables; i.e., total number of actions taken by each worker (frequency) and level of work center training. Number of workers and training information is received from other wing data bases.

- The final analytical step is to make comparisons among work centers to see what effects training and other measurable variables, in this instance frequency, have on maintenance productivity.

c. Analytical Techniques

The term analytical technique means the integrated step-by-step process followed in analyzing the training and maintenance action data that we requested/received from three Air Force F-16 wings.

We used the following systems as our data sources:

- the Consolidated Data System (CDS) for F-16 maintenance, which provided maintenance information, and

- the training subsystem of the Maintenance Management Information and Control System (MMICS), which provided training information.

Special terms used in our analysis are defined below.

- Observation is a single completed work action.

- Frequency is the total nu`ber of observations divided by the total number of w. .ers that did the work:

$$\text{frequency} = \frac{\text{number of observations (or work actions)}}{\text{number of workers}}$$

- Productivity is total elapsed time (in hours) divided by frequency or worker-hours per observation.4/

$$\text{productivity} = \frac{\text{total elapsed time}}{\text{frequency}} =$$

$$\frac{\text{(number of workers)x(elapsed time)}}{\text{number of work actions}}$$

It is important to note that as the frequency figure decreases, productivity is increasing, since the measurement is worker-hours per observation and fewer hours spent on a work action is an increase in productivity.

We used three approaches to examine the data. These approaches were:

- examine productivity by action code,
- examine productivity by frequency, and
- use analysis of variance (ANOVA) techniques.

Each of these is discussed below.

(1) <u>Examination of Productivity by Action Code</u>

This approach involves:

- aggregating the elapsed time for a specific WUC by action taken code ("action taken") for each work center,
- dividing the total elapsed time by the frequency to get productivity,

4/We chose the standard industrial engineering definition for productivity (i.e., lower is better since it is time required to perform a task or produce an output) rather than the sometimes-used alternate definition (i.e., output per unit of time).

- consolidating productivity data by wing and by training level,
- plotting the resulting productivity data by individual action code, and
- examining the result considering training levels.

(2) Examination of Productivity by Frequency

This approach involves exactly the same steps listed above in "Examine Productivity by Action Code" except the productivity data is plotted by frequency per action code and training is not considered in the examination. We also fitted a regression line to the data to depict the impact on productivity. The slope of the regression denotes increasing or decreasing productivity (negative slope -- increasing).

(3) Use of ANOVA Techniques

This approach involves a statistical test of sample results to determine whether or not the results observed are statistically significant. The steps in this technique include:

- classification of all work center observations into "cells" in an ANOVA matrix;
- computation of average productivity figures within each ANOVA matrix;
- computation of variation statistics attributable to
  - training,
  - frequency, and
  - the error term; and
- performing an F-test for variable significance.

B. APPLICATION OF METHODOLOGY AND RESULTS

We used three analytical techniques during this phase. The first two are quite basic (productivity by action code and productivity by frequency). Statistical methods were used to compute the regression line for the second procedure and for the entire ANOVA procedure. This section discusses the following:

- Data and computations,
- Examination of Productivity by Action Code,
- Examination of Productivity by Frequency,
- Use of ANOVA Technique, and
- Observations.

1. Data and Computations

Before discussing our analytical techniques, we will explain the steps which were used in the selection of the WUCs and action taken codes for our analysis. In section III.A.1.c, we displayed 10 WUCs for the 11 simulators which make up an MTS. These WUCs are listed below.

NUMBER	NAME
12000	Crew Station System
14000	Flight Control
23000	Turbofan Power Plant
24000	Auxiliary Power Plant/Jet Fuel Starter
41000	Environmental Control System
42000	Electrical Power Supply
46000	Fuel System
51000	Flight Instruments
71000	Radio Navigation
75000	Weapons Delivery

First, we chose those WUCs associated with Honeywell simulators since we had detailed information on them. We added one WUC associated with a hardware simulator.

- Eliminate: 41000, 46000, and 75000

We then requested workload data on the remaining seven WUCs from three wings.

After receipt of the workload data from the wings, our second step was to examine the documents to find which WUCs had a sufficient number of observations for our initial analysis. One WUC was eliminated.

- Eliminate: 24000

Based on the preceding examination, we eliminated several action taken codes and subordinate-level WUCs. The remaining WUCs and action taken codes were then aggregated for further examination. These WUCs were: 12CA0, 12E00, 14A00, 14B00, 23Z00, 42A00, 42B00, 42C00, 51A00 and 51F00.

In the last step, we were able to accurately determine which WUCs and associated action taken codes had sufficient numbers of observations for analysis. This determination gave us WUC 14A00 with six action taken codes and WUC 23Z00 with three action taken codes. The WUCs we chose make up approximately 5% of total wing maintenance and represent a significant part of the total. As a result of our selection process, the following action codes were chosen:

14A00	23Z00	TITLE
P	P	Removed
	Q	Installed
R		Removed and Replaced
T		Removed for Cannibalization
U		Replaced after Cannibalization
X	X	Test-Inspection-Service
Y		Troubleshoot

We limited the number of WUCs which were investigated to those taught using simulators. This allowed us to establish a close relationship between maintenance training conducted using simulators and the work performed on the job. There are additional WUCs which are being worked on by the people in the work centers with the same AFSC. An analysis of this worker-time relationship showed that the WUCs we examined did not constitute the entire work accomplished by those specific work centers. This could bias the frequency value included in the present analyses because the number of people wholly devoted to the observations we examined is less than the total number of people in the work center. Our calculations assumed that all workers (with appropriate AFSCs) worked on the observations we examined. The computations of the frequencies for the two WUCs we looked at are contained in Appendix C.

The number of observations per worker, or frequency, was explained previously. The productivity figure we used for worker hours per observation allows for comparison of work centers of different sizes. As opposed to our frequency figure, where the higher the numeric value the better the result, our productivity figure exhibits the opposite characteristic -- the lower the numeric value the better the result (lower worker-hours per observation is "better"). The productivity computations for the two WUCs are contained in Appendix C.

In order to assure that the amount of time spent by work centers for the actions we examined was representative, we did a comparison of hours worked in WUC 14A00 and WUC 23Z00 to the total hours of work completed. There are 28 system level WUCs for the F-16. WUC 14000 was the highest manhour consumer in our sample (10.6%), WUC 23000 was fourth with 8.0%. There are seven subsystems within WUC 14000--WUC 14A00 was 32% of WUC 14000 or 3.4% of total wing manhours. There are 12 subsystems within WUC 23000--WUC 23Z00 was 24% of WUC 23000 or 2.0% of total wing manhours. Thus out of 113 subsystem WUCs, the two WUCs we examined (14A00 and 23Z00) are quite representative of total wing maintenance since they consume over 5% of total maintenance manhours in the sample we looked at.

2. Examination of Productivity by Action Code

This section discusses the productivity by action code technique. It is divided into two parts:

- Application, and
- Results.

a. Application

The examination of productivity by action code required the calculation of productivity data by work center. These calculations are provided in Appendix C. The application also required the training status of the individual work centers examined. The training status (percent trained) by work center, as well as the number of observations for each action code, are shown for the two WUCs we examined on Exhibits III-2 and III-3.

Using the computed work center and wing productivity, we plotted the data by action code for WUCs 14A00 and 23Z00. These exhibits (III-4 through III-10) also show the training and frequency information pertinent to each plot. The lines connecting the plotted points are strictly for interpretive purposes, such as noting trends or changes. Because three variables (productivity, training, and frequency) are all shown on the graphs, the frequency for each action code is given along with the percent of workers trained for each organizational entity. The charts are explained below.

- Wing-to-wing (Exhibits III-4 and III-5). These exhibits show any trends that may exist between bases, based on the percent of workers trained. At the same time, one can also see the values of the frequencies for each of the data points. In the ANOVA section, these two variables will be isolated and their impact discussed.

- High, medium, and low training (Exhibits III-6, -7, -8, -9, -10). These five exhibits each deal with one category of training, based upon the percent of trained individuals within each work center. Shown below is a display of the number of work centers for each WUC that falls into one of the three categories.

	HIGH (≥60%)	MEDIUM 60%>x>20%	LOW (≤20%)
14A00	1	8	2
23Z00	8	3	0

BASE	WORK CENTER	TRAINING STATUS		NUMBER OF OBSERVATIONS PER ACTION CODE[1/]					
		#TRND/TOT	%	P	R	T	U	X	Y
OVERALL	TOTAL	58/144	40	157	516	176	148	361	188
WING K	TOTAL	23/72	32	87	222	95	67	262	111
	K25	11/30	37	46	68	42	37	31	29
	K20	2/5	40	7	33	16	8	3	12
	K22	2/18	11	10	40	9	4	32	21
	K21	8/19	42	11	30	14	8	55	17
WING L	TOTAL	18/39	46	51	260	67	70	43	34
	L1	5/9	55	15	64	19	17	4	--
	L4	5/11	45	14	64	9	18	6	6
	L3	4/10	40	16	56	26	24	6	1
	L2	4/9	44	6	71	8	11	27	27
WING J	TOTAL	17/33	52	19	34	14	11	56	43
	J12	4/11	36	4	22	5	3	24	28
	J10	11/12	92	10	4	7	7	28	13
	J11	2/10	20	5	7	2	1	3	2

1/ "TOTALS" INCLUDE OBSERVATIONS NOT IN THE WORK CENTERS EXAMINED

Exhibit III-2. TRAINING STATUS AND NUMBER OF OBSERVATIONS (14A00)

BASE	WORK CENTER	TRAINING STATUS		NUMBER OF OBSERVATIONS PER ACTION CODE[1]		
		#TRND/TOT	%	P	Q	X
OVERALL	TOTAL	95/142	67	178	164	155
WING K	TOTAL	39/66	59	100	99	85
	K24	14/26	54	15	16	9
	K23	3/7	42	9	10	2
	K27	9/16	56	48	48	70
	K26	13/17	76	28	25	4
WING L	TOTAL	28/38	74	54	46	9
	L1	7/10	70	4	5	--
	L4	6/8	75	3	5	2
	L3	8/11	74	20	16	--
	L2	7/9	78	27	20	7
WING J	TOTAL	28/38	74	24	19	61
	J12	10/14	71	7	5	5
	J10	9/12	75	15	10	51
	J11	9/12	75	2	4	5

1/ "TOTALS" INCLUDE OBSERVATIONS NOT IN WORK CENTERS EXAMINED

Exhibit III-3. TRAINING STATUS AND NUMBER OF OBSERVATIONS (23ZOO)

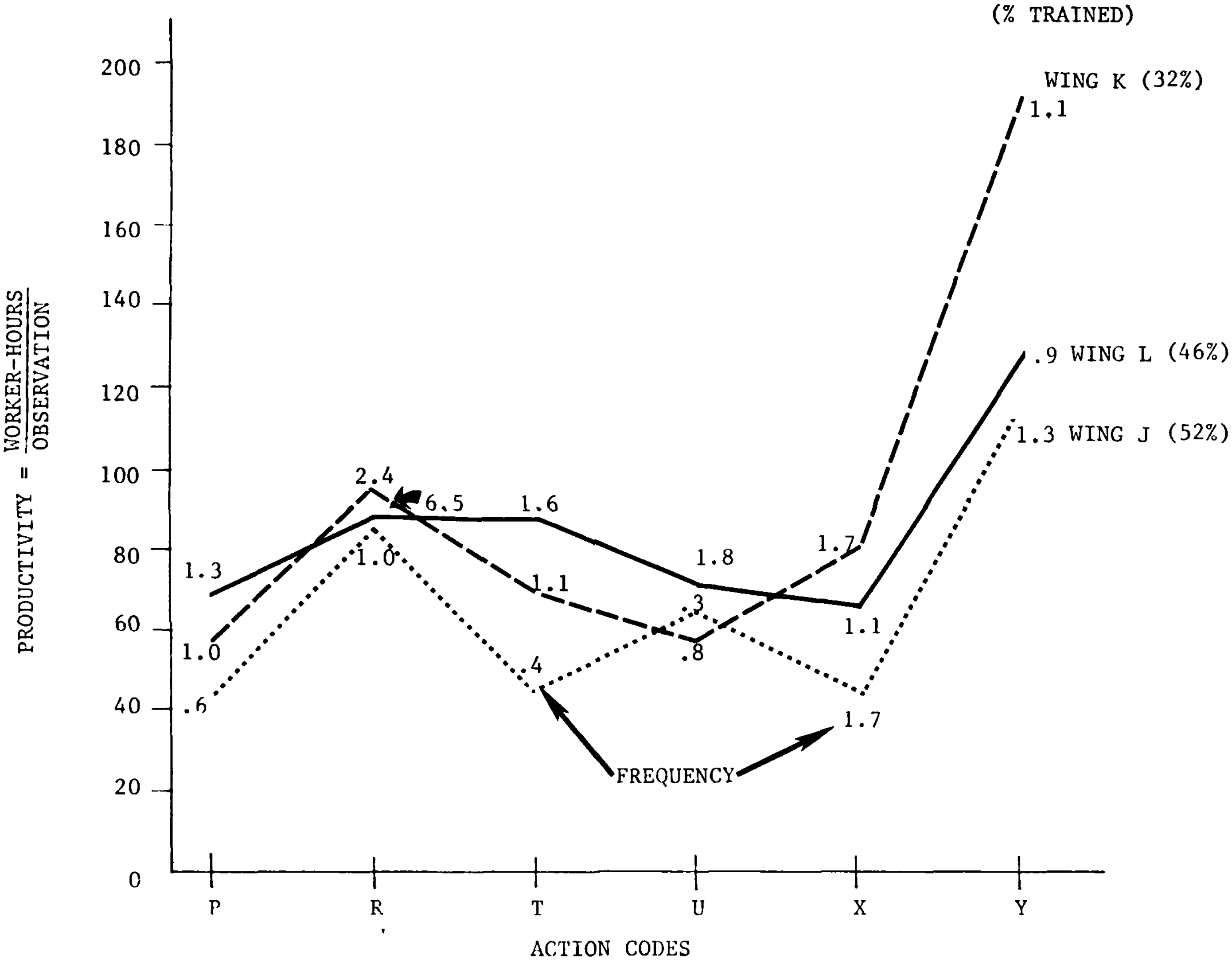


Exhibit III-4. TRAINING: WING-TO-WING (14A00)

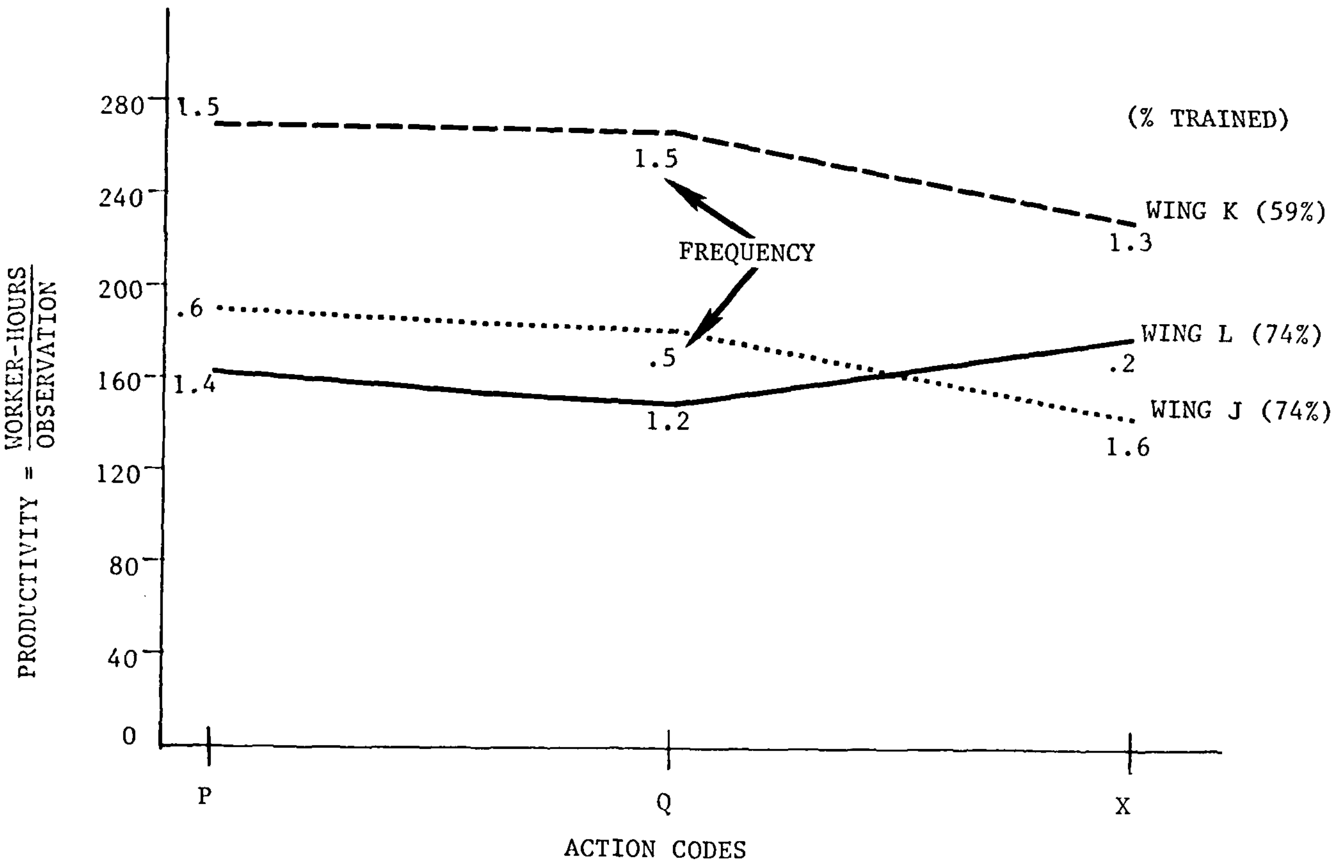


Exhibit III-5. TRAINING: WING-TO-WING (23ZOO)

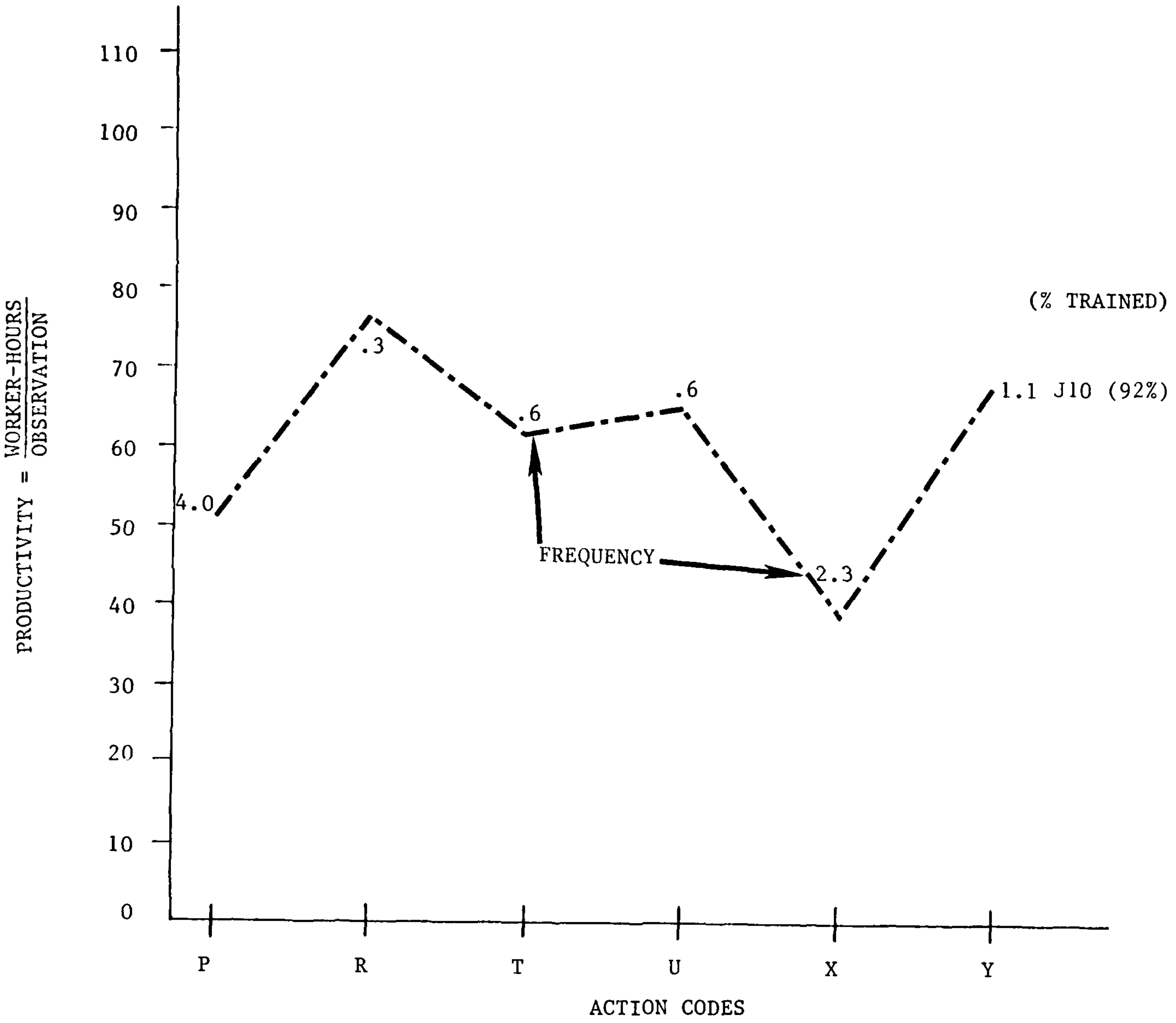


Exhibit III-6. TRAINING: HIGH (14AOO)

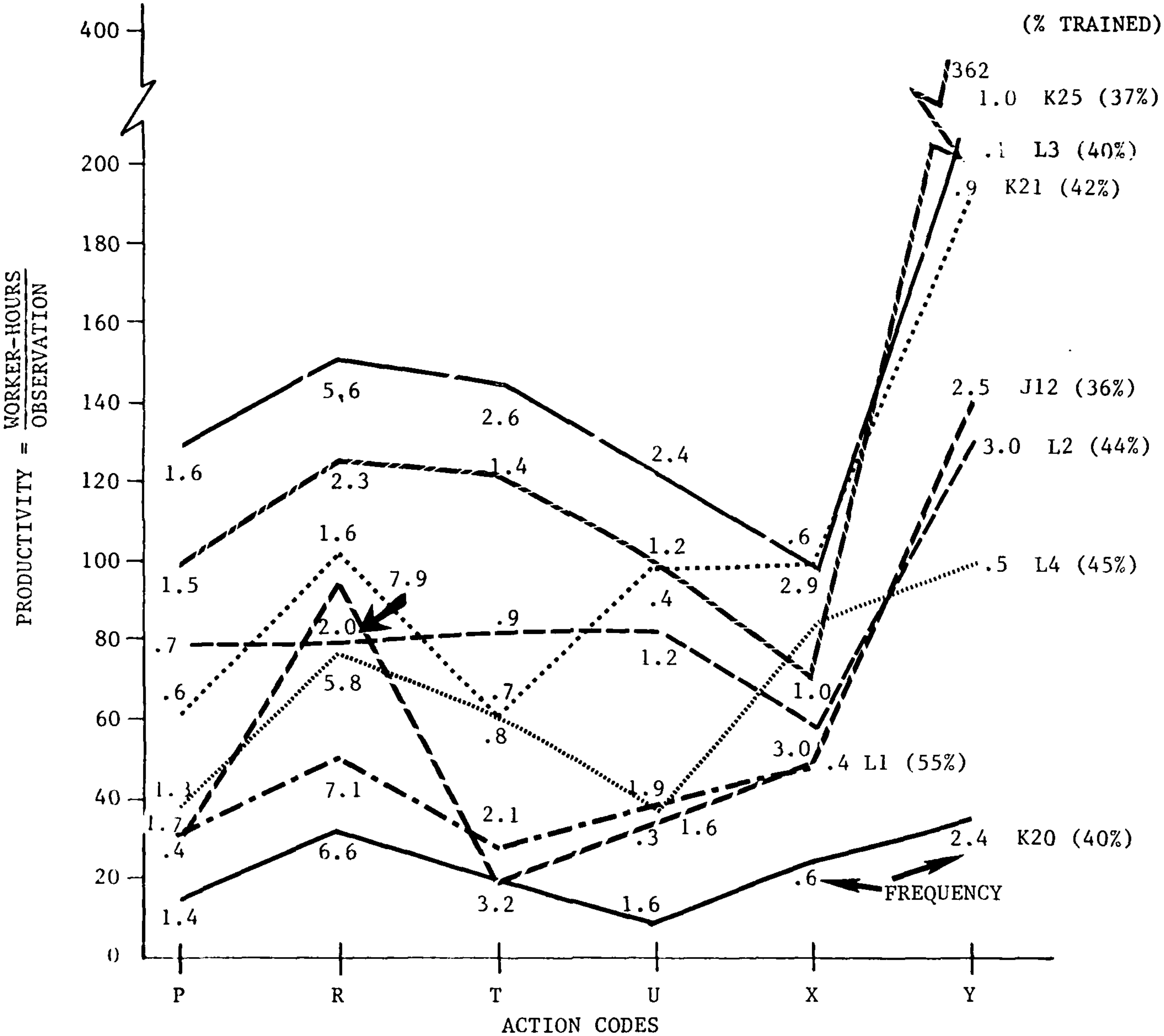


Exhibit III-7. TRAINING: MEDIUM (14A00)

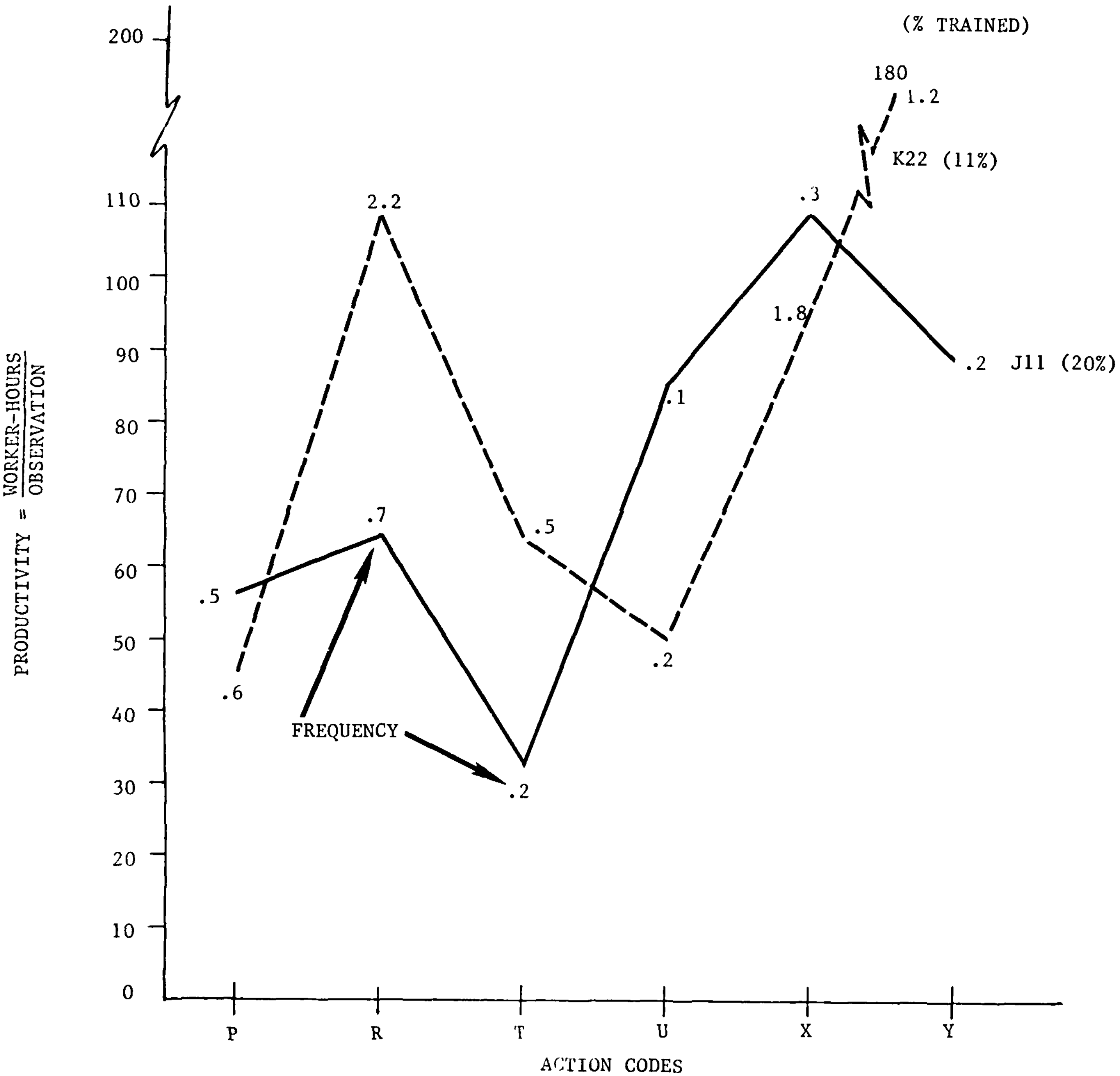


Exhibit III-8. TRAINING: LOW (14A00)

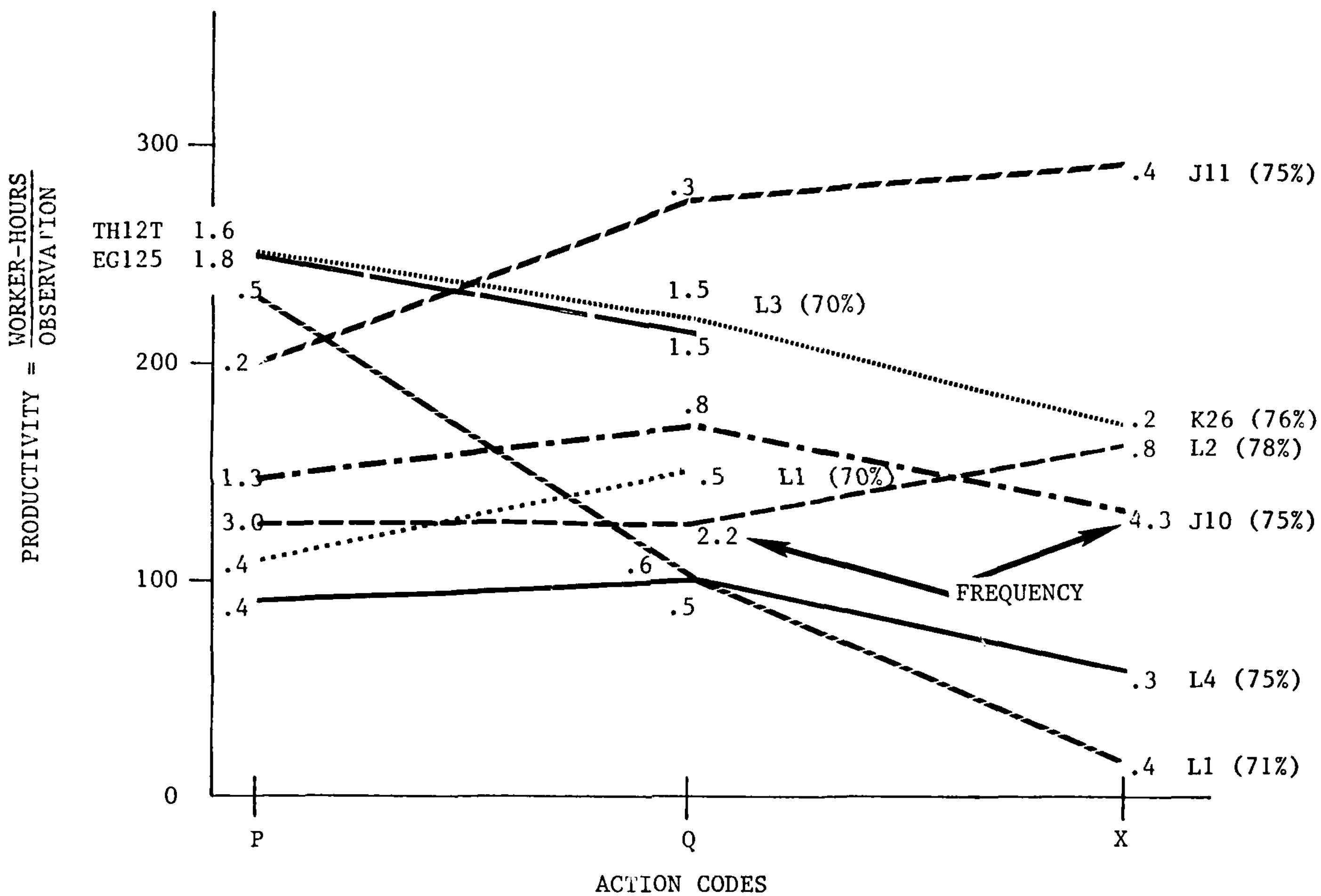


Exhibit III-9. TRAINING: HIGH (23ZOO)

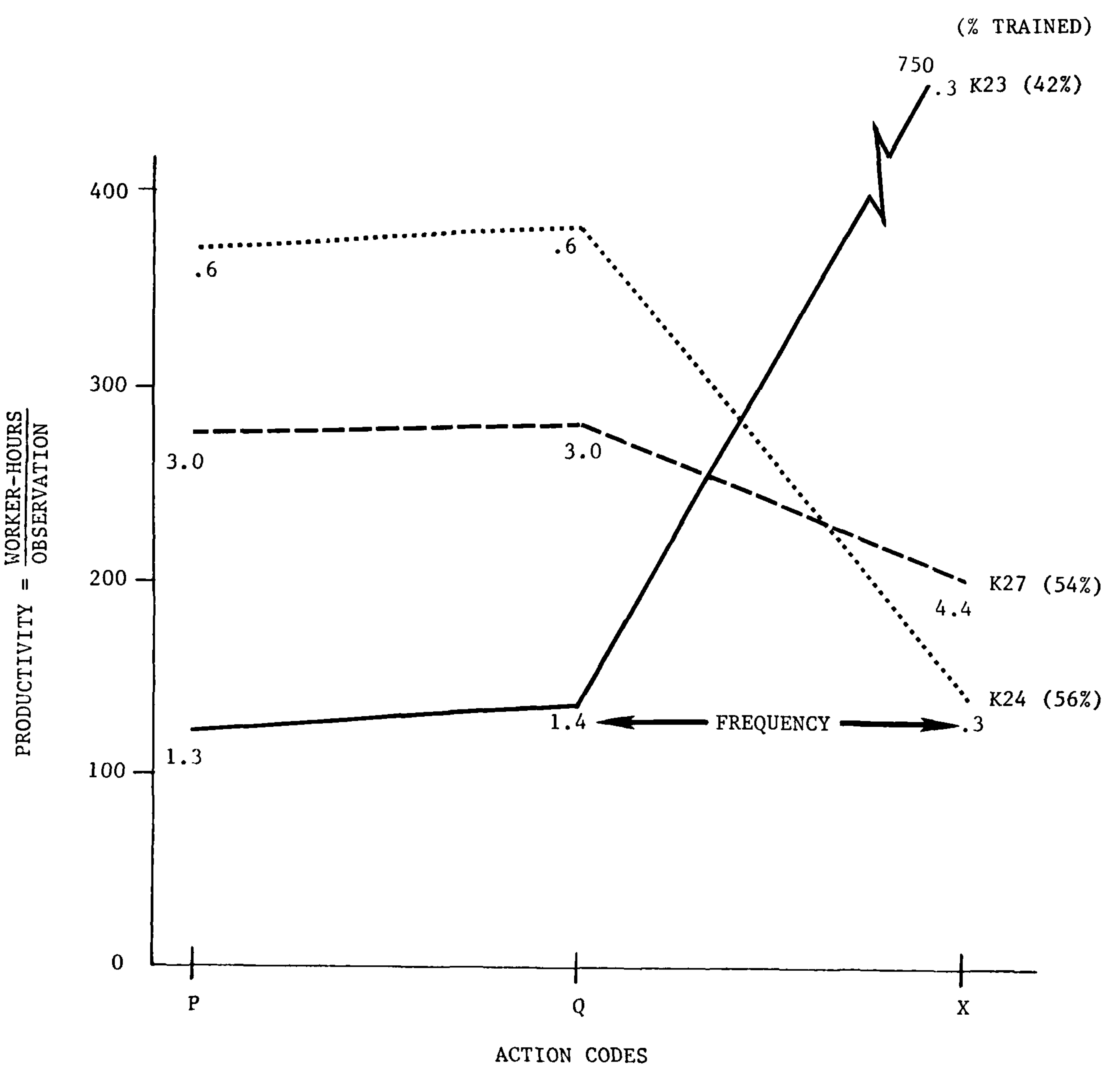


Exhibit III-10. TRAINING: MEDIUM (23ZOO)

b. Results

The graph on Exhibit III-4 allows us to make a comparison of the effect training has on productivity for WUC 14A00. We see examples of varying levels of training for the work centers at each of the three wings. The graph on Exhibit III-5 for WUC 23Z00 does not allow us to make as good a comparison since two of the wings have the same trained percentage (74%). However, both of these wings did significantly better than the wing with the lower trained percentage of 59%.

Our results are further discussed by WUC (14A00 and 23Z00) below.

- WUC 14A00
  - Wing-to-wing (Exhibit III-4). This chart shows what would normally be expected -- the greater the degree of worker training, the better the productivity.
  - High training (Exhibit III-6). Because there is only one work center in the high training category, no comparison can be made with other work centers
  - Medium training (Exhibit III-7). All eight work centers are relatively close in the percent of their personnel trained (36-55%), and follow a fairly consistent pattern with regard to productivity. In other words, the most productive work centers generally remain the most productive for all action codes.

    In this category, frequency does not appear to play a significant role. The eight work centers do not appear to follow any consistent pattern between high frequency and productivity. Therefore, in our medium training comparison, neither training nor frequency appear to have a relationship to productivity.

- Low training (Exhibit III-8). This comparison includes only two work centers, and does not exhibit any consistent patterns with respect to training or frequency and productivity. The better trained (20% vs. 11%) work center is more productive in three of the six action codes. The work center with the highest frequency is also only the most productive in three of the six action codes. It appears that, when a work center is essentially "untrained," being most productive is a hit-or-miss affair.

- In summary, although there are occasional consistent trends with regard to either training or frequency for a particular level of training, these trends do not hold for all the analyses.

• WUC 23Z00

- Wing-to-wing (Exhibit III-5). In this comparison, training appears to bear some relationship to productivity. The two highest trained bases, at 74%, were both more productive for each action code than the least trained base, at 59%. However, frequency does not appear to have a consistent relationship to productivity. In two of the three action codes, the least productive wing has higher frequencies than the two more productive. In comparing the two most productive bases in all three action codes, the base with the highest composite frequency is also the most productive. Thus, for this comparison, training may have an influence while frequency appears to have little consistent pattern.

- High training (Exhibit III-9). For WUC 23Z00, eight of the eleven work centers are in this category. Their training percentages are closely grouped between 70%-78% -- essentially all "equally trained." Although there is no absolute pattern between work centers with regard to their productivity standings, there are some fairly consistent groupings. With one exception, J12, the five most productive work centers remained so for all action codes. The three least productive remained the least productive. There was no consistent pattern with regard to frequency. For a particular action code, the work centers with the highest frequency were the least productive. Conversely, work centers with very low frequencies were the most productive. All in all, little can be learned from this comparison regarding a consistent relationship between productivity, training, and frequency.

- Medium training (Exhibit III-10). The remaining three work centers are in this category with training percentages of 42%, 54%, and 56%. As in the high training category, no consistent pattern emerges between training and productivity. The least trained work center is the most productive in two of the three action codes. The highest trained work center is the least productive in two of the three action codes. Frequency also appears to exhibit no consistent pattern. The work center with the highest frequency is in the middle for productivity. The work center with the lowest frequency is the least productive for two of the three action codes and the most productive in one. Here again, little can be said about a consistent relationship between productivity, training, or frequency.

- Low training. There were no work centers for WUC 23Z00 with low training.

- The results from the 23Z00 WUC analyses are very similar to those from 14A00. Within a particular level of training, there may be a consistent pattern for either training or frequency although these trends are not consistent for all levels of training.

The principle patterns that the comparison shows are those portrayed on Exhibits III-4 and III-5. There we see a definite relationship between training and productivity.

3. Examination of Productivity by Frequency

This section discusses the productivity by frequency technique. It is divided into two parts:

- Application, and
- Results.

a. Application

The analysis in this section will use the same productivity and frequency data from Appendix C as discussed previously. The exhibits, one for each action code, include the appropriate productivity and frequency figures for each work center. The data points for all relevant work centers were inputted into a computerized data base, and the charts were printed. A standard automated regression package was used on the data to obtain the slope and the intercept of the regression line through the plotted points.

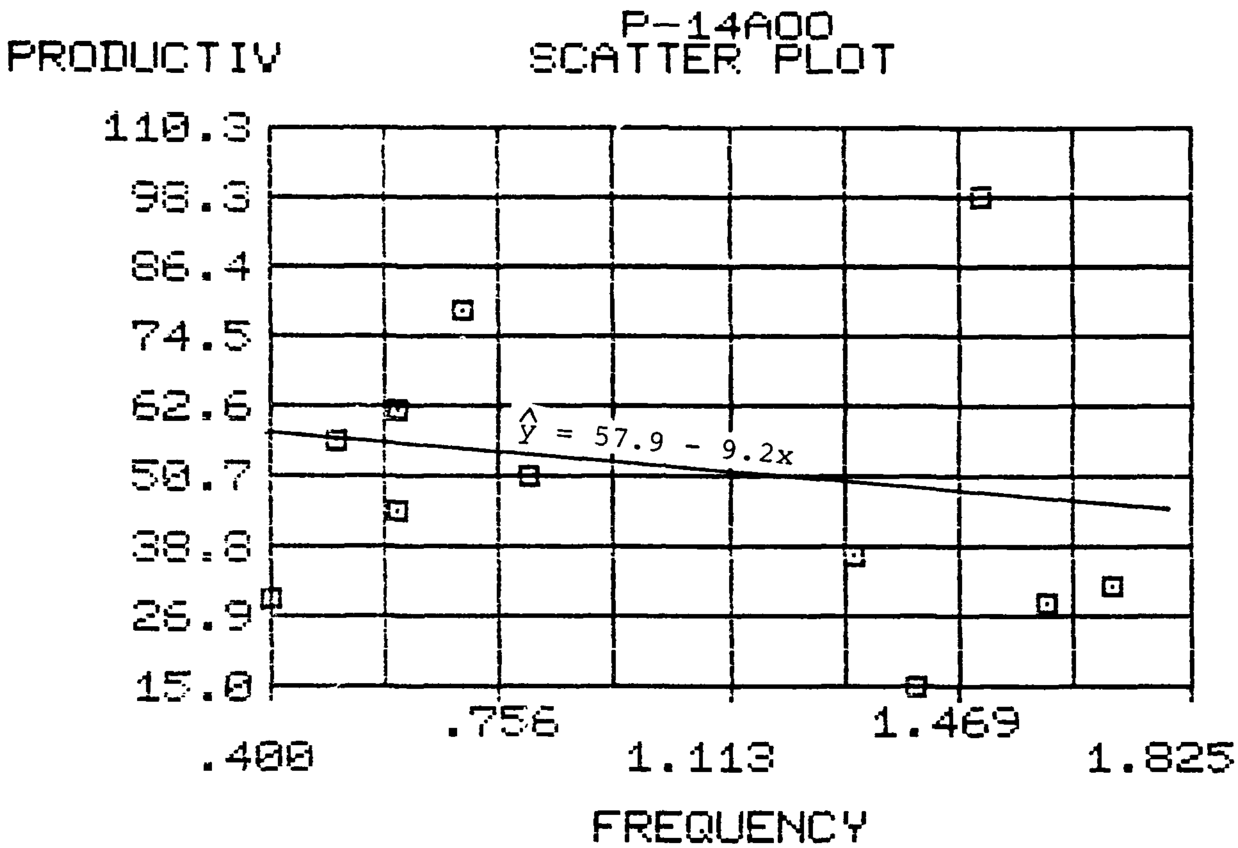
The negative value of a slope indicates a positive relationship between a change in productivity for each unit change in frequency. The greater the negative value (steeper slope), the greater is the impact of frequency on productivity. Conversely, a positive slope shows a negative correlation between productivity and frequency. Although the scales for the various charts are different, the equation of the line is given so the numeric value of the change can be seen. Thus, the sensitivity of frequency on productivity between action codes can be measured.

b. Results

This section will discuss the results of the analyses for WUCs 14A00 and 23Z00.

(1) Action Codes (14A00) (Exhibits III-11 to III-13)

Shown below is a matrix of values for the eight action codes and the values of a and b in the equation for



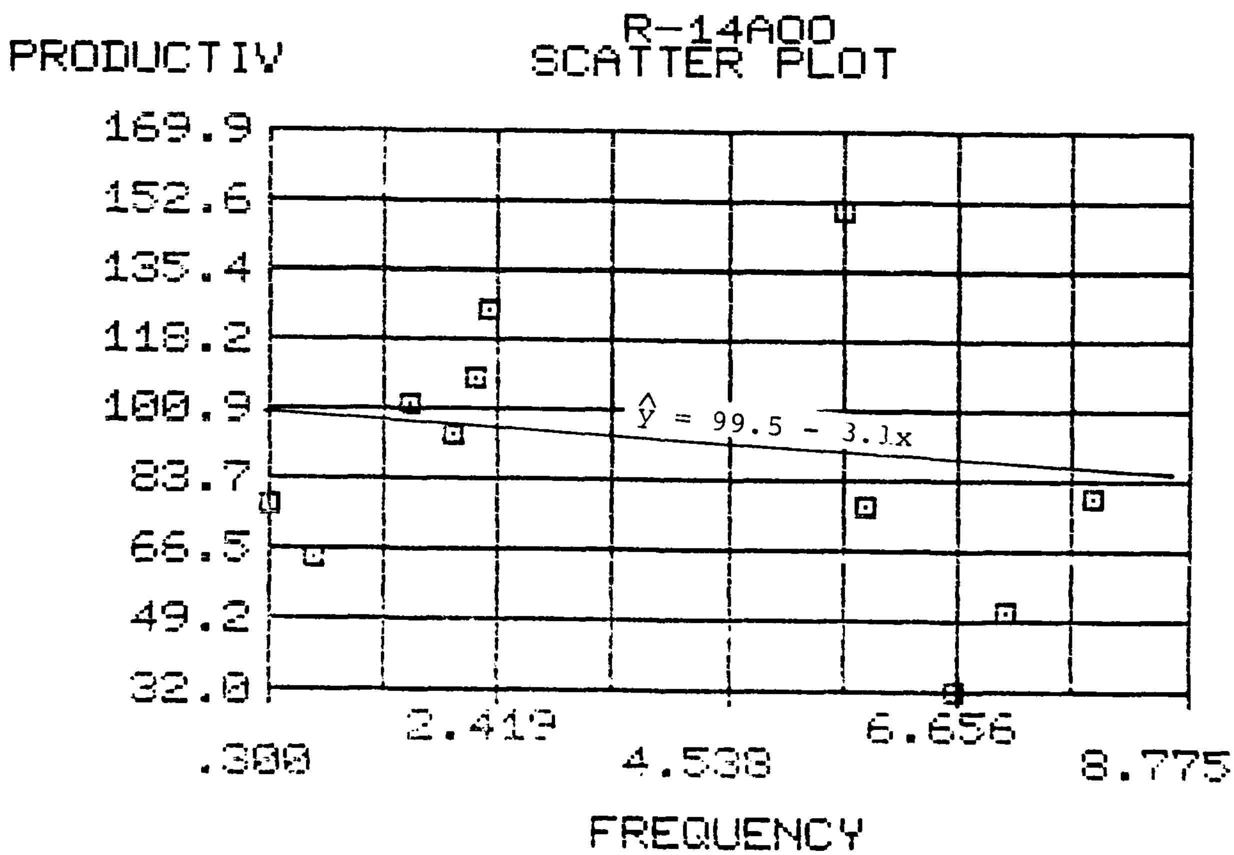
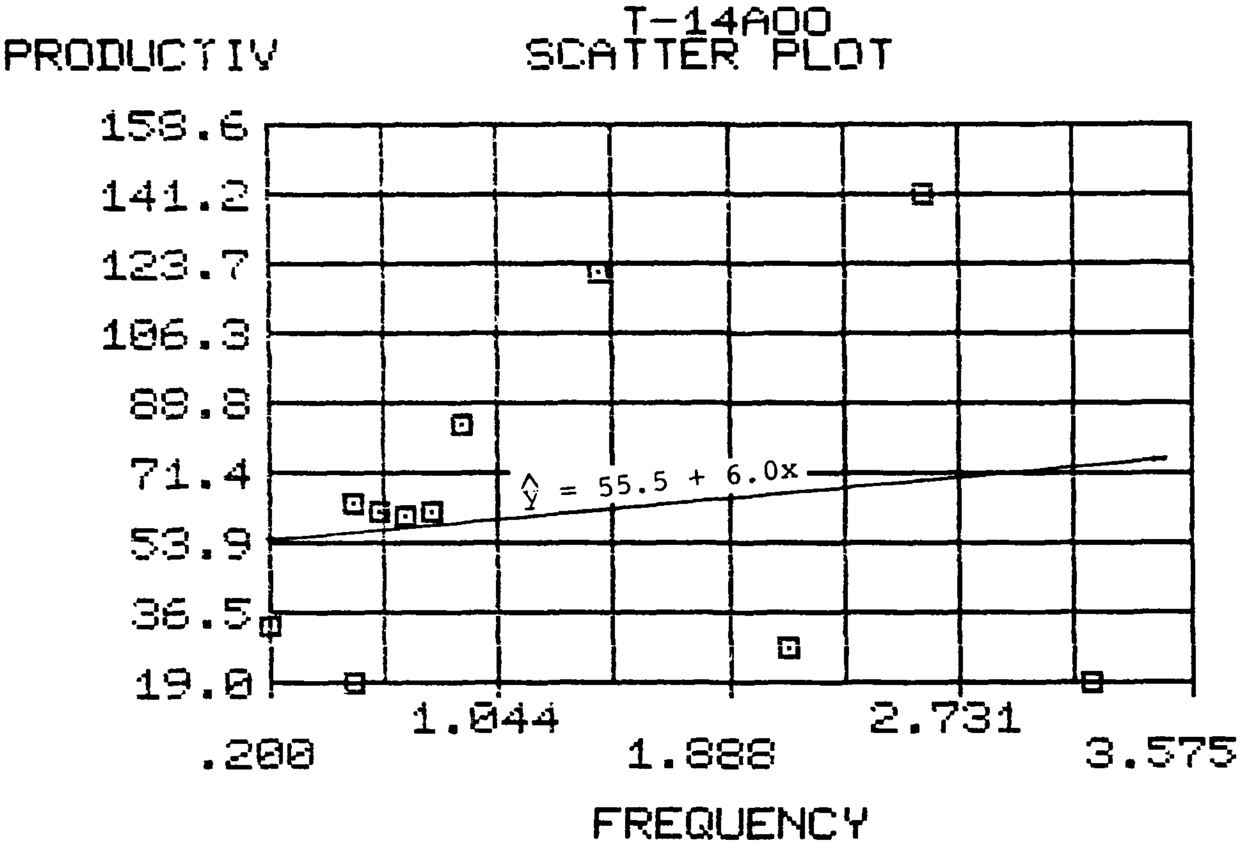


Exhibit III-11. ACTION CODES: P, R (14A00)



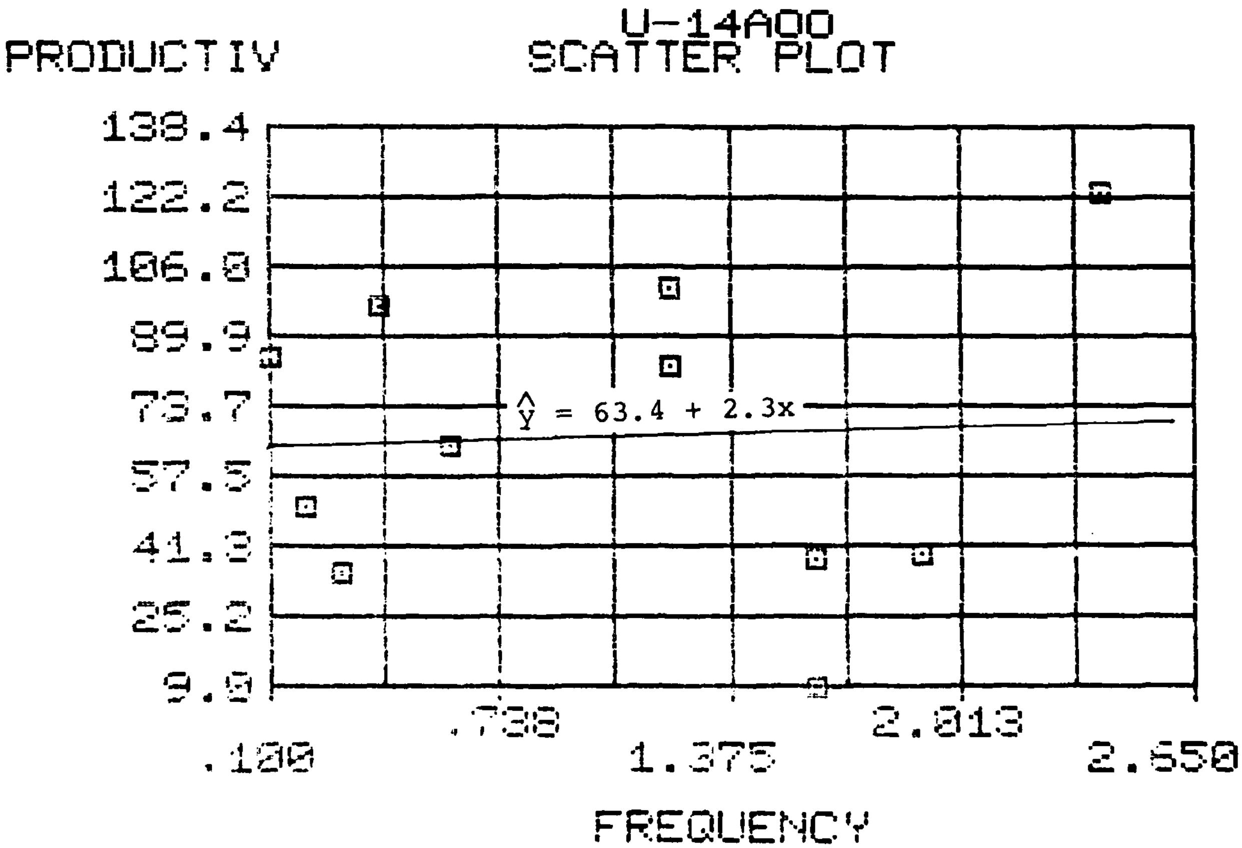
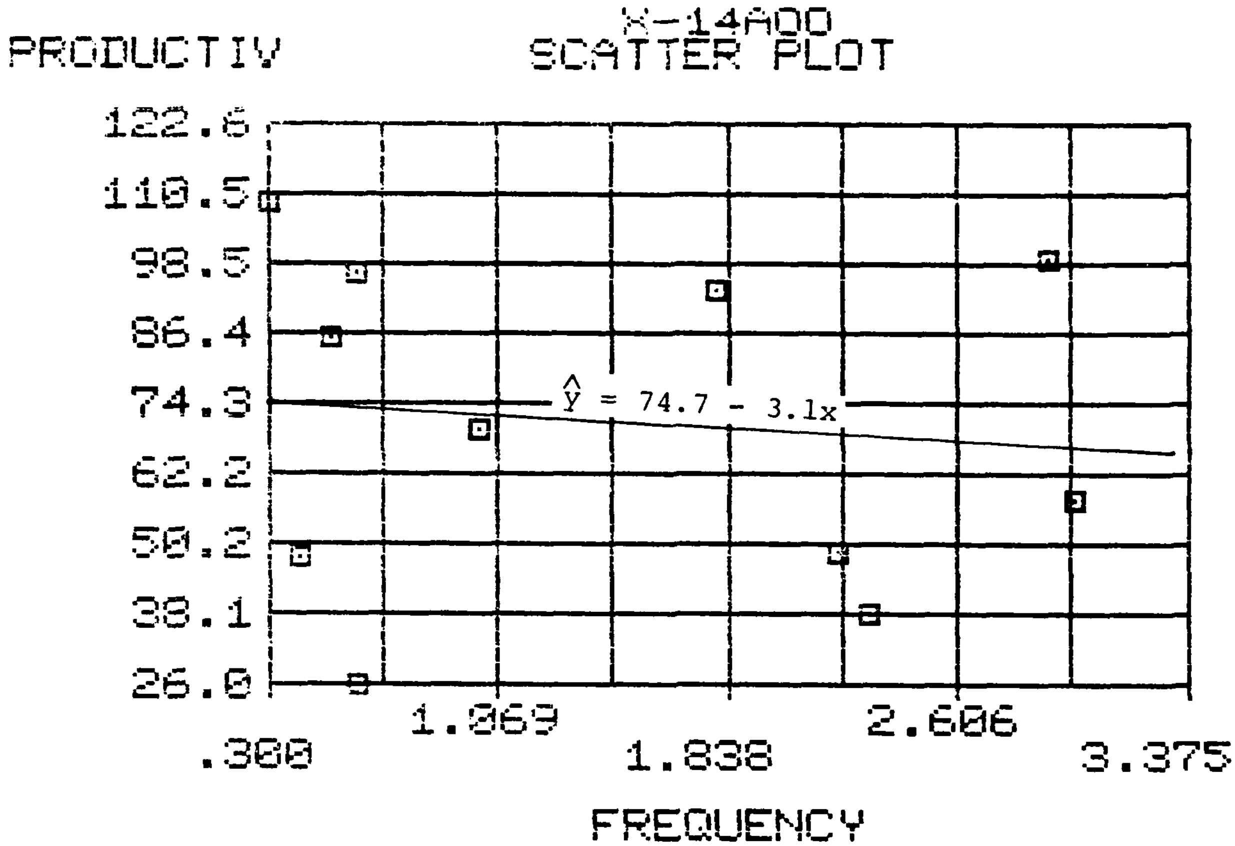


Exhibit III-12. ACTION CODES: T, U (14AOO)



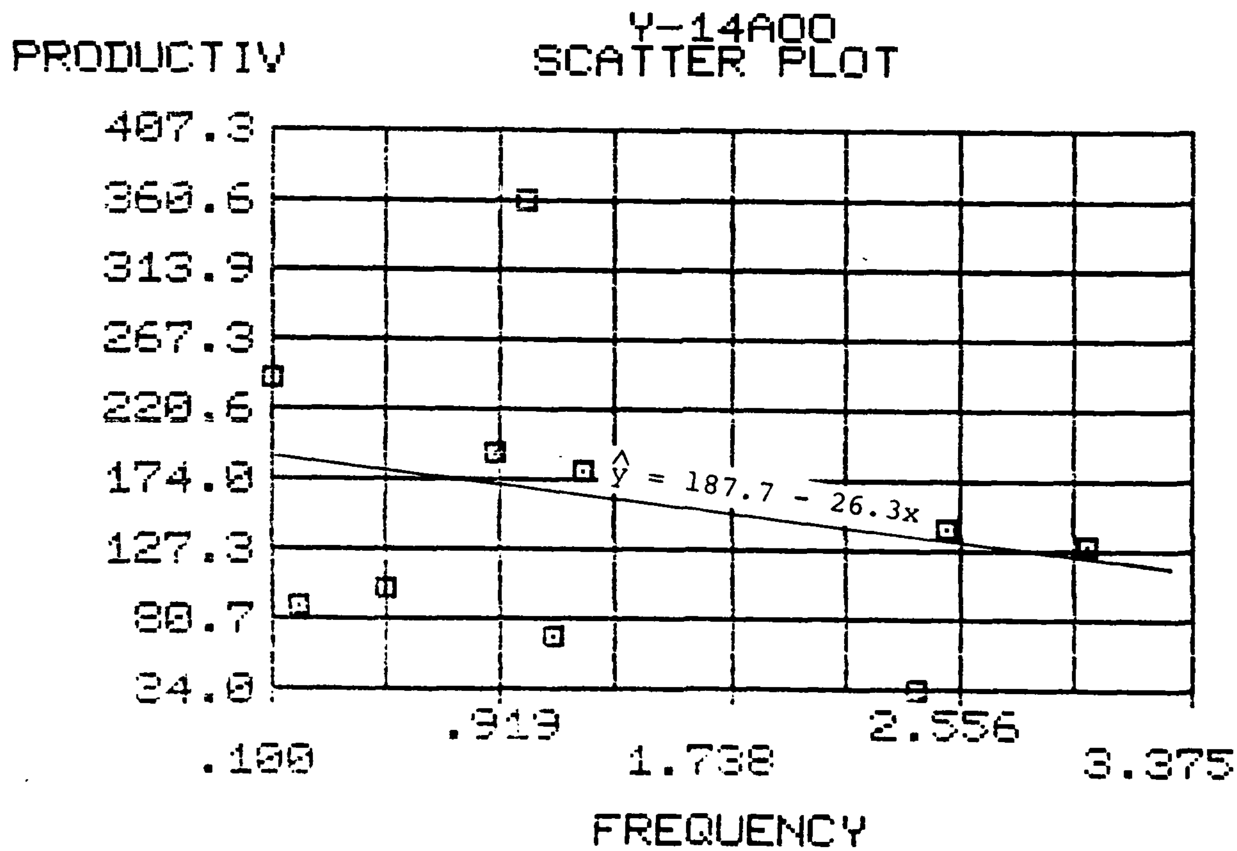


Exhibit III-13. ACTION CODES: X, Y (14AOO) the line fitted through the various data points: $y = a + bx$, where a is the value of the y intercept and b is the slope of the line.

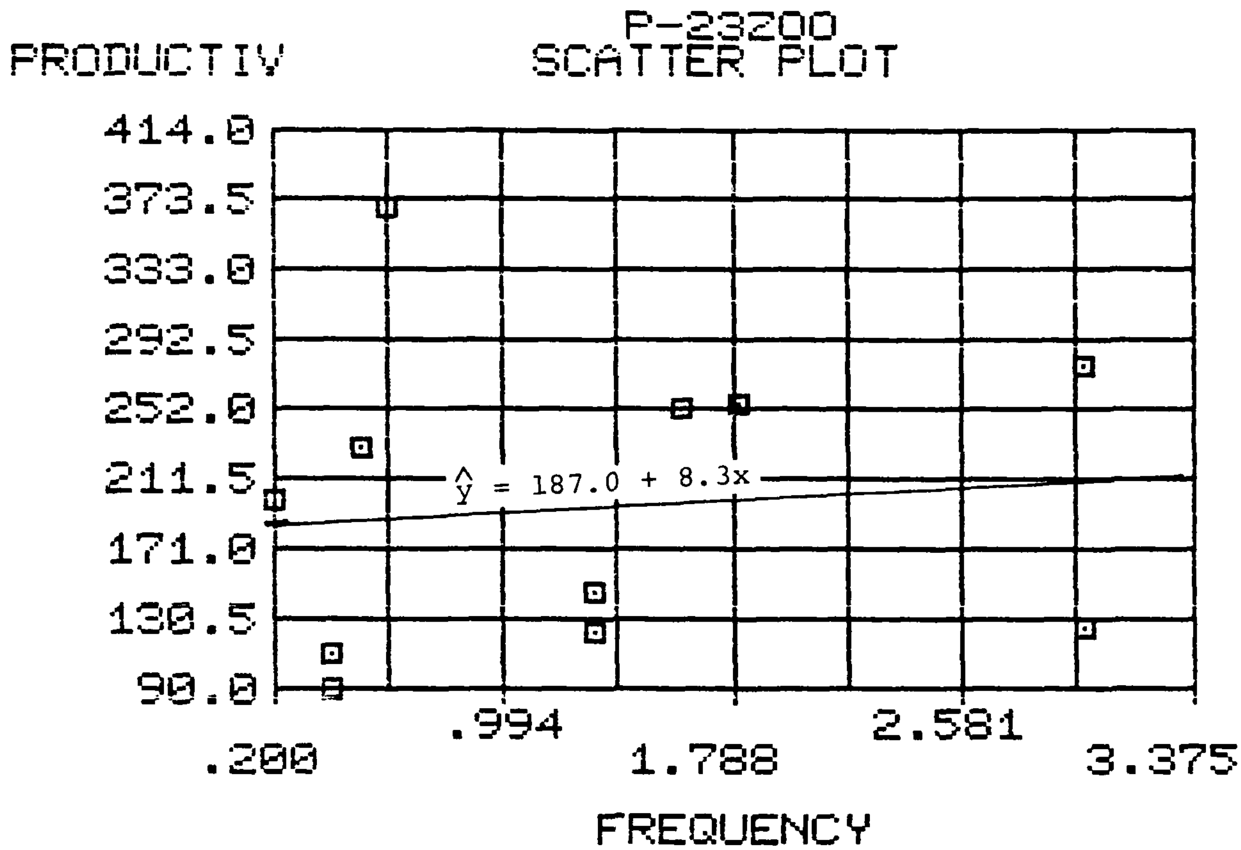
Title	Action Code	a	b
Removed	P	57.9	-9.2
Removed and Replaced	R	99.5	-3.1
Removed for Cannibalization	T	55.5	+6.0
Replaced after Cannibalization	U	63.4	+2.3
Test-Inspection-Service	X	74.7	-3.1
Troubleshoot	Y	187.7	-26.3

The slope of the regression line measures the sensitivity, or change, in productivity with a one unit change in frequency. For these six action codes, the slope varies from +6.0 (action code T) to -26.3 (action code Y). In addition to T, action code U also has a positive slope--which indicates a negative correlation between frequency and productivity for these two action codes. Therefore, of the six action codes, frequency has the greatest impact on productivity for action code Y, "Troubleshoot."

(2) Action Codes (23Z00) (Exhibit III-14 to III-15)

The values of "a" and "b" for the equation $y = a + bx$ are:

Title	Action Code	a	b
Removed	P	187.0	+8.3
Replaced	Q	184.9	+9.6
Test-Inspection-Service	X	235.2	-16.5



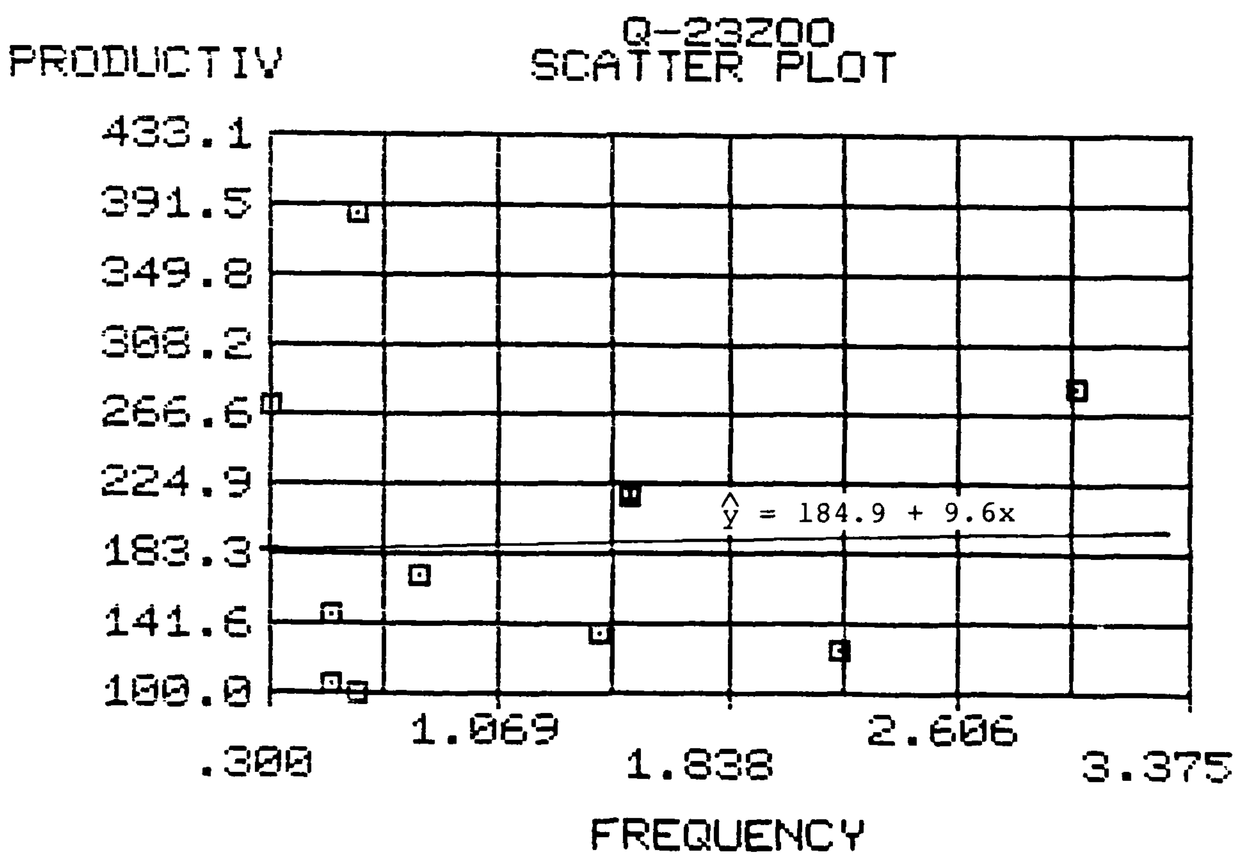


Exhibit III-14. ACTION CODES: P, Q (23200)

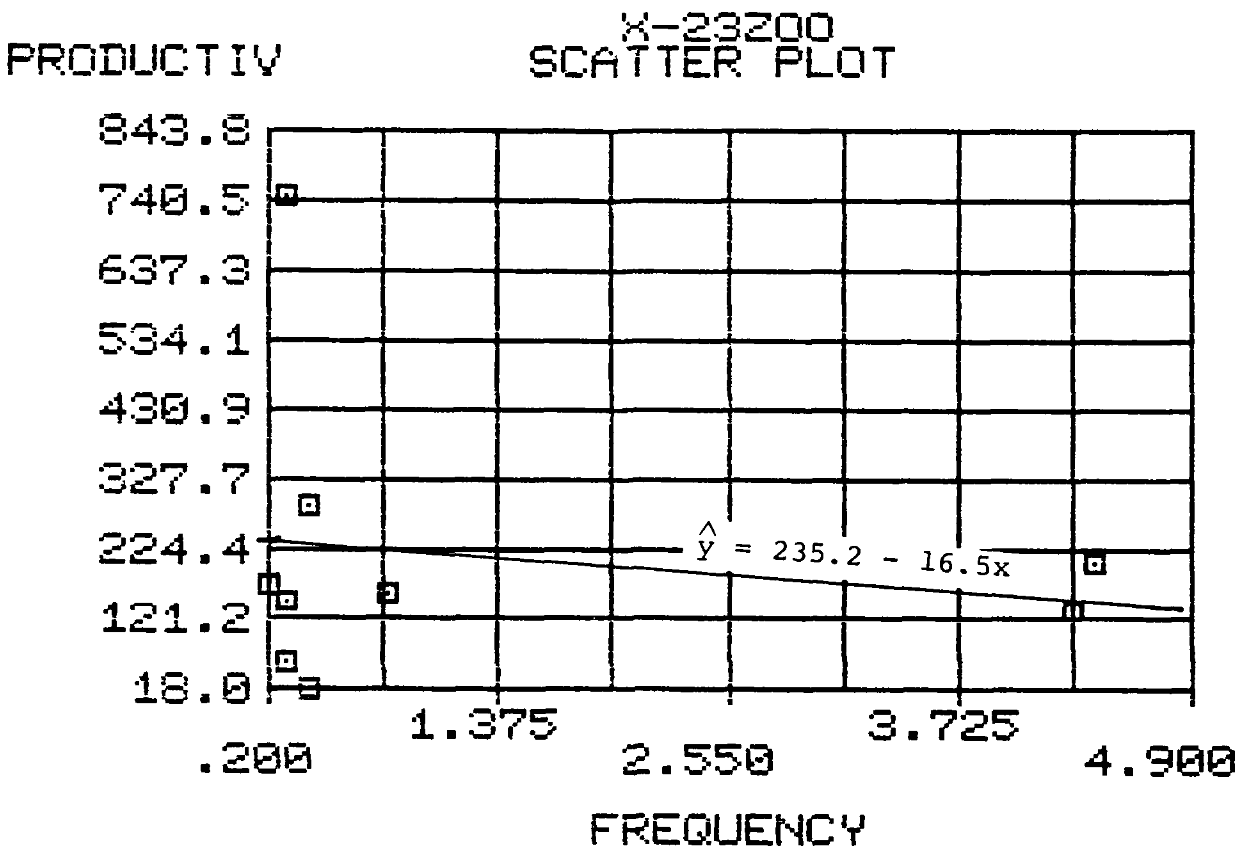


Exhibit III-15. ACTION CODE: X (23ZOO)

The slopes of the lines for action codes P and Q are positive with values of +8.3 and +9.6 respectively. This indicates a negative correlation between frequency and productivity and also indicates the effect of frequency on productivity is opposite of what was expected. Action code X, "Test-Inspection-Service," does have a negative slope -- value of -16.5 -- as would be expected.

(3) Comment

Interestingly, the two action codes where frequency should have a strong effect, "Y" (14A00) and "X" (23Z00), is where we see strong relationships. This is intuitive and is proven by our data.

4. Use of ANOVA Technique

This section discusses the use of the ANOVA technique. It is divided into two parts:

- Application, and
- Results.

a. Application

In our present analysis, we have observed that different frequency levels and different levels of training lead to different productivity times. In particular, we have observed that the trend, as both frequency and training increase, is for productivity to increase. Although this trend is observed for the data that is included in this analysis, we are more interested in whether or not the result can be generalized (e.g., whether or not this trend is one that we would expect to see throughout the entire Air Force maintenance "population"). In order to make this kind of generalization, a statistical test is needed that will answer the following question:

> "Is there a statistically significant difference in the observed mean productivity times, or are the observed differences simply due to chance?"

The technique that will answer this question for the variables in this study is the analysis of variance (ANOVA) technique. ANOVA serves to test the statistical significance of sample level means, or (equivalently) to test the null hypothesis that the sample means are equal. In our analysis, this test is performed for both the frequency and training variables to determine their effect on productivity. A complete description of the ANOVA techniques and its applicability to our analysis is provided at Appendix C.

Observations from all action codes of our WUC 14A00 and WUC 23Z00 examinations were first classified into an ANOVA matrix. The row, column, and overall totals and averages were then computed for each ANOVA matrix. These matrices are shown as Exhibits III-16 and III-17.

Although the numbers that are the basis for these matrices are the same as the numbers that have been used throughout this analysis, they are combined, and thus used, in a very different fashion.

- Although each specific action code represents a very different maintenance job, even within the same WUC, the ANOVA matrices shown at Exhibits III-16 and III-17 include all of the action codes included in this analysis for both WUCs. This was done for two reasons. First,

TRAINING \ FREQUENCY	LOW (≤1)	MEDIUM (1 < x ≤ 2)	HIGH (>2)	ROW (TRAINING) AVERAGE	ROW (TRAINING) TOTAL
LOW (≤ 20%)	66.2	137.0	108.0	103.7	311.2
MEDIUM (20% < x < 60%)	82.2	74.7	84.0	80.3	240.9
HIGH (≥ 60%)	63.8	68.0	38.0	56.6	169.8
COLUMN (FREQUENCY) AVERAGE	70.7	93.2	76.7	OVERALL AVERAGE 80.2	
COLUMN (FREQUENCY) TOTAL	212.2	279.7	230.0	OVERALL TOTAL 721.9	

Exhibit III-16. ANOVA MATRIX FOR 14A00

FREQUENCY / TRAINING	LOW (≤ 1)	MEDIUM ($1 < x \leq 2$)	HIGH (> 2)	ROW (TRAINING) AVERAGE	ROW (TRAINING) TOTAL
LOW ($\leq 20\%$)	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]
MEDIUM ($20\% < x < 60\%$)	268	236	254	253	758
HIGH ($\geq 60\%$)	193	175	127	165	495
COLUMN (FREQUENCY) AVERAGE	231	206	191	OVERALL AVERAGE 209	
COLUMN (FREQUENCY) TOTAL	461	411	381	OVERALL TOTAL 1253	

1/No work centers in the low training category were present in this analysis.

Exhibit III-17. ANOVA MATRIX FOR 23Z00

no single action code included enough work center observations to adequately represent a sample population to which an ANOVA analysis could be applied. Secondly, the rationale for accomplishing this kind of statistical analysis is to make some kind of inference about the general relationship between both training and frequency to productivity. The inclusion of all action codes makes this a more general analysis.

- Averages computed for each "cell" in the matrices shown at Exhibits III-16 and III-17 can be combined to illustrate what are known as the "specific effects" of both training and frequency. These effects illustrate the change in the average productivity value as either training or frequency change. Because cell averages include all action codes for both WUCs in our analysis, the specific effects of training and frequency for WUCs provide an indication of productivity trends or either frequency or training change by themselves.

Before attempting rigorous statistical analyses of the numbers computed in the ANOVA matrices for the WUCs under examination, we translated the data into a graphical format to allow for intuitive analysis. Exhibits III-18 through III-21 show the general effects of training and frequency on productivity for both 14A00 and 23Z00 WUCs. All of these plots indicate (with the exception of a few points which contradict the trend) that the trend, for both WUCs, is toward increased productivity as either frequency or training increase. This is consistent with the results illustrated above (for specific action codes within each WUC), but is more illustrative because it includes all action codes for each WUC.

In addition, the specific effects of both training and frequency can be gleaned from the ANOVA matrices without any further computations. In fact, the specific effects are simply the averages included in the training (row) average and frequency

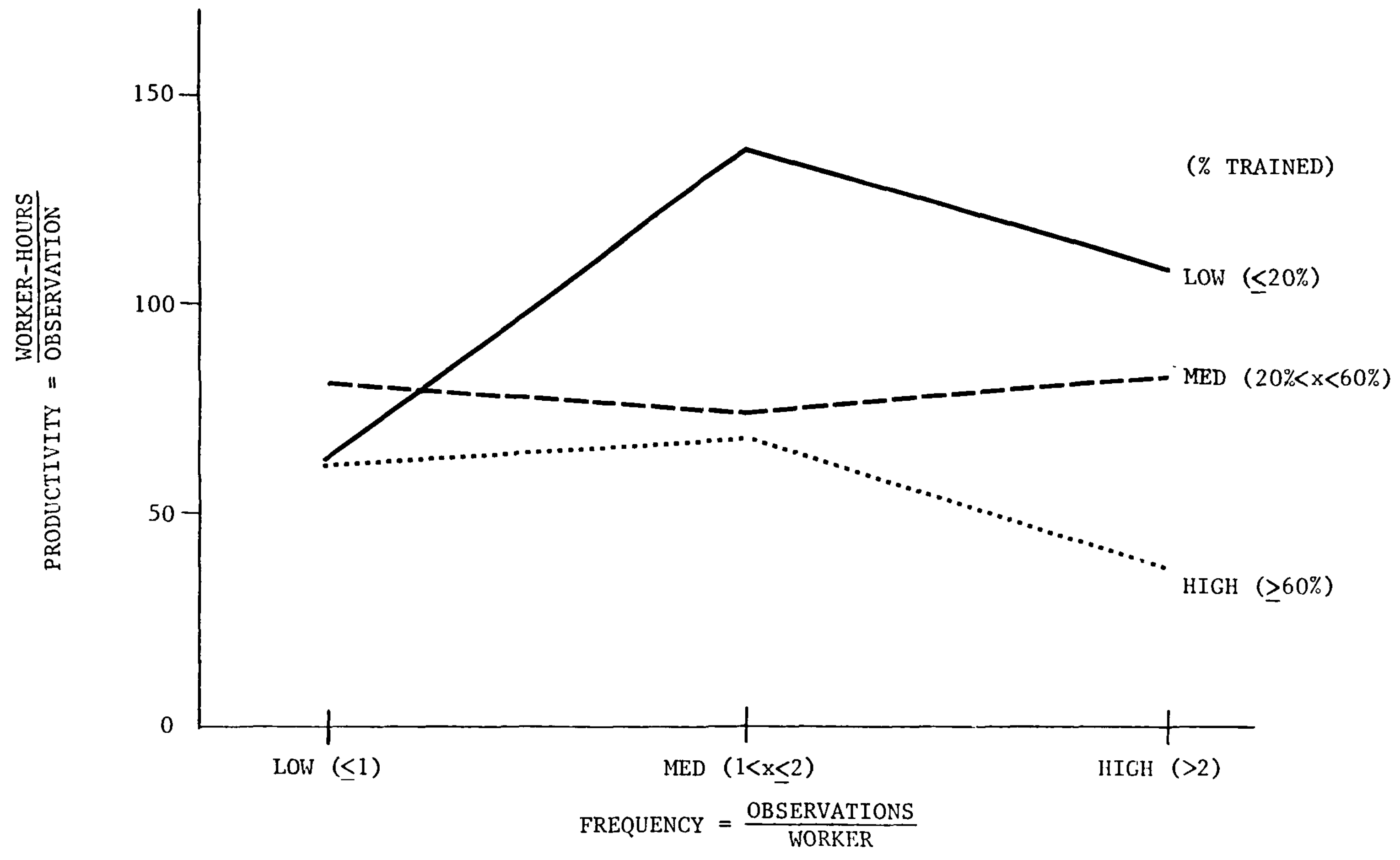


Exhibit III-18. ANALYSIS OF VARIANCE: TRAINING EFFECTS (14AOO)

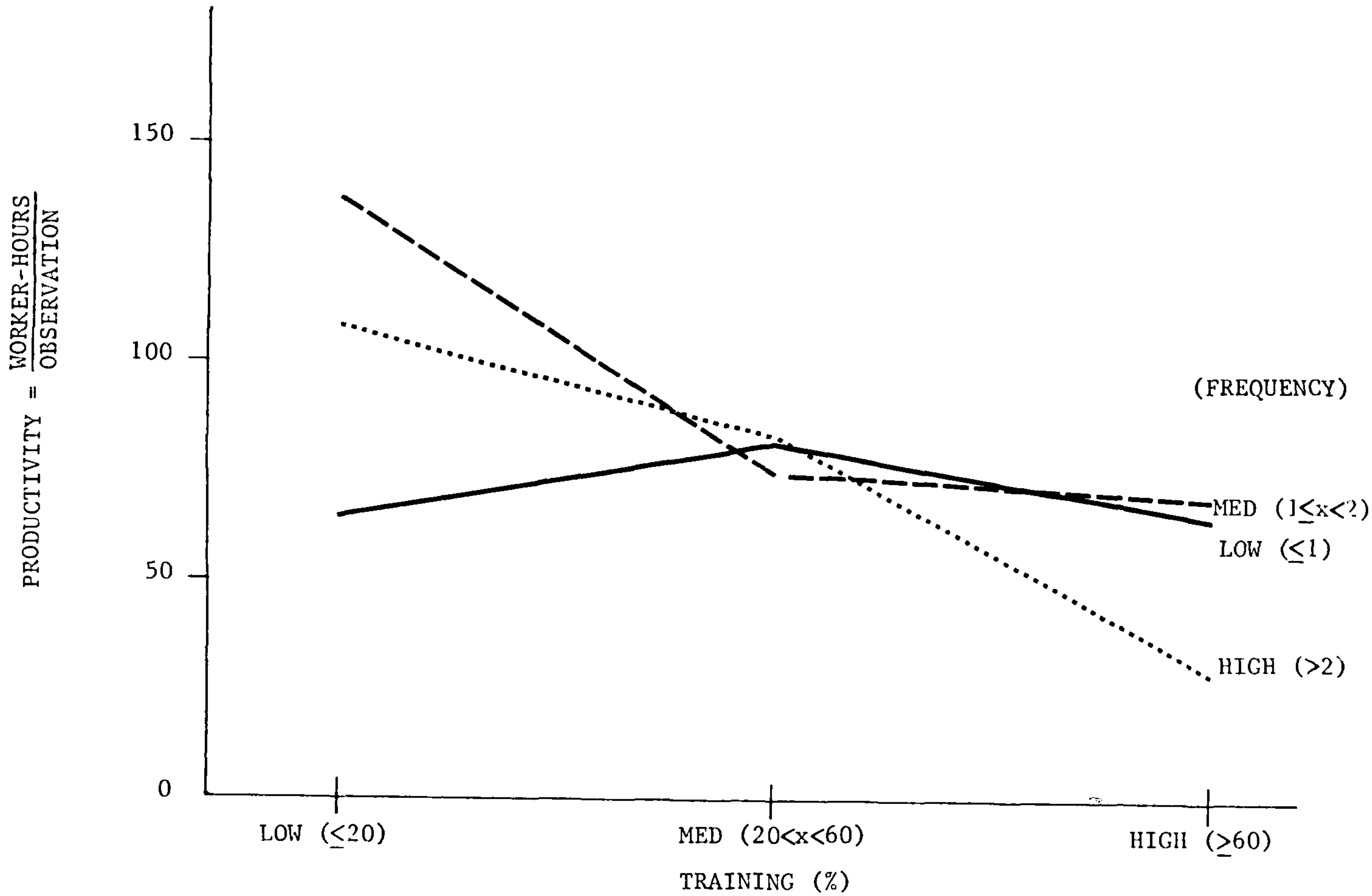


Exhibit III-19. ANALYSIS OF VARIANCE: FREQUENCY EFFECTS (14AOO)

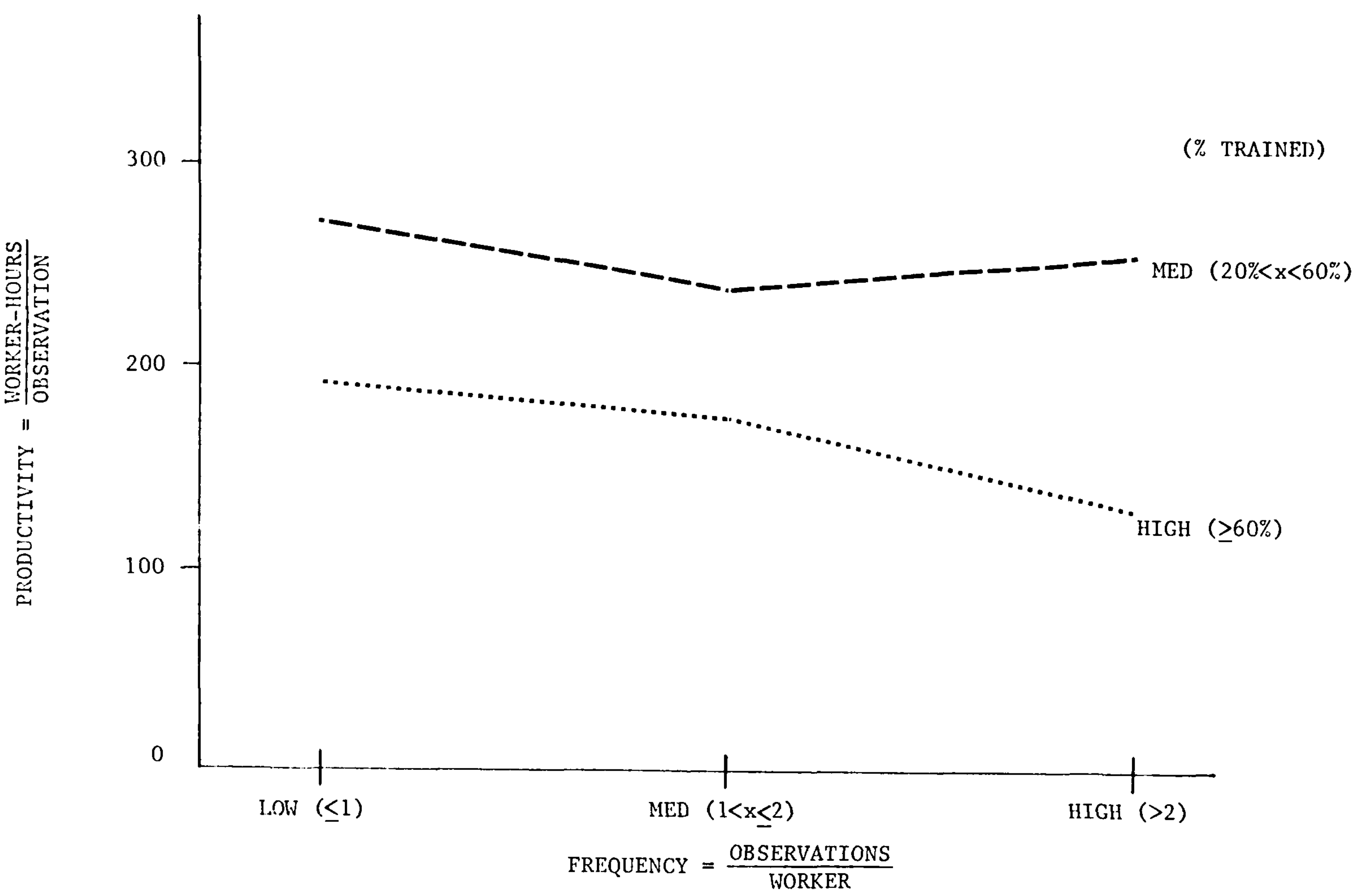


Exhibit III-20. ANALYSIS OF VARIANCE: TRAINING EFFECTS (23ZOO)

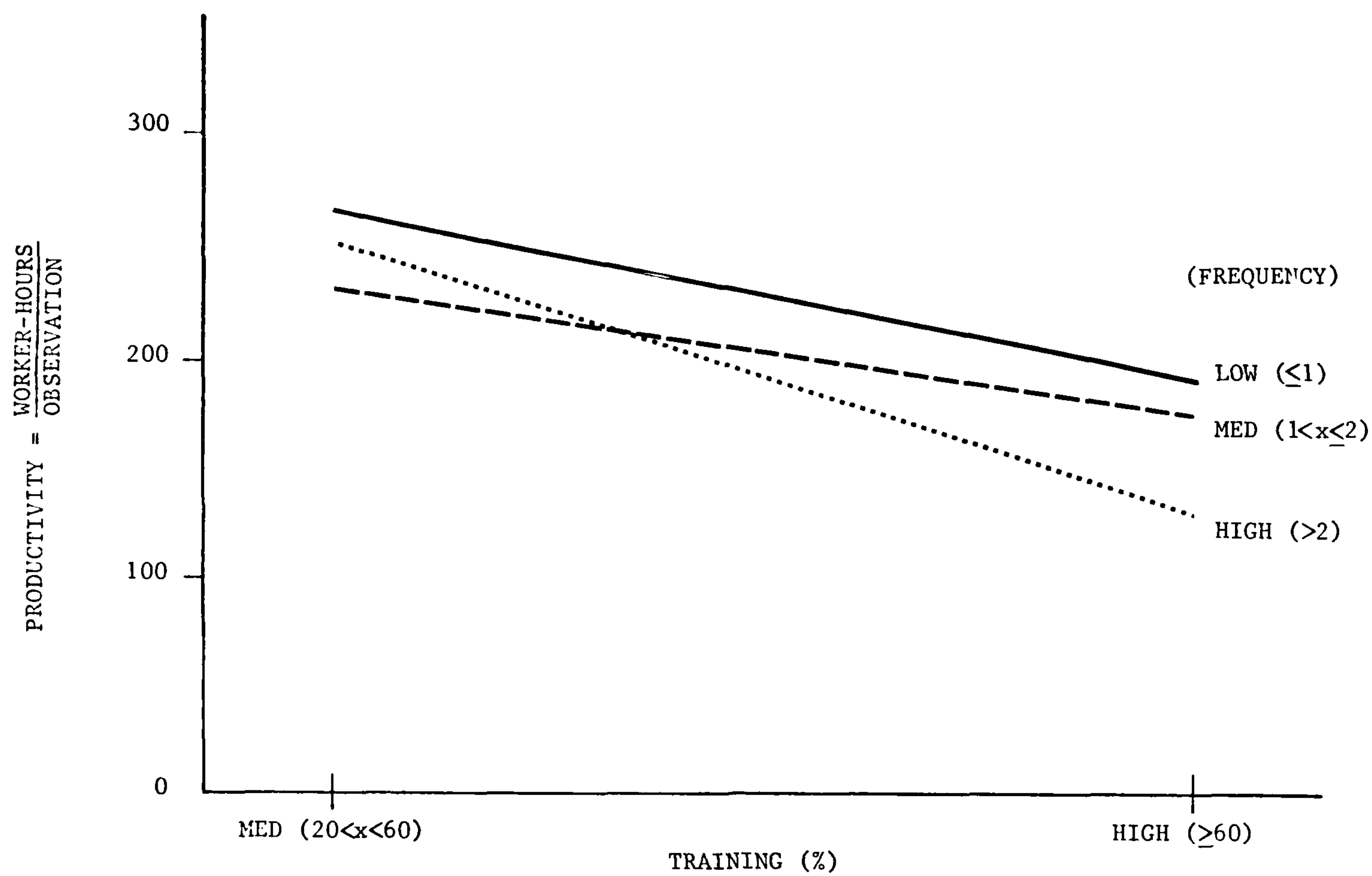


Exhibit III-21. ANALYSIS OF VARIANCE: FREQUENCY EFFECTS (23ZOO) (column) average cells in the ANOVA matrices. Examining these numbers indicates that the specific effect of training for both the 14A00 and 23Z00 WUC is positive (i.e., as training increases, productivity increases). The specific frequency effect for 23Z00 illustrates the same result. The specific frequency effect in the case of 14A00, however, is ambiguous. As frequency goes from the "low" range ($\leq$ 1 action/worker) to the "medium" range (1 < actions/worker $\leq$ 2), productivity decreases. As frequency increases to the high range (2 < actions/worker), productivity increases. Therefore, the productivity trend in this case is not clearcut. This result could lead one to conclude that frequency, at least as we have defined it, has little impact on productivity, or that one or more erroneous observations in the medium frequency range have thrown off our results.

b. Results

The observations described in the previous section with regard to our ANOVA technique of analysis, or our other analyses described previously, pertain only to the sample of Air Force maintenance work centers we examined. We cannot correctly state that the trends observed are indicative of the entire Air Force maintenance population without statistical justification. This justification is either proved or disproved by the complete application of the ANOVA technique (as described in Appendix C).

Exhibits III-22 and III-23 summarize the statistics associated with the ANOVA matrices for 14A00 and 23Z00. The pertinent comparative statistics in these two tables are the F-ratios for training and frequency. Comparing these ratios with a standard F-statistic, derived from the standard F-distribution at a specific level of confidence, allows us to draw conclusions as to the statistical validity of our analytical results. In particular, if the F-ratios shown in Exhibits III-22 and III-23 are <u>larger</u> than the appropriate F-statistics from the standard F-distribution, then we can conclude that the relationships that we have observed in this analysis are valid for Air Force maintenance in general. Training does lead to a general increase in productivity and frequency leads to a general increase in productivity.

The appropriate tests for both 14A00 and 23Z00 training and frequency variables are explicitly provided below:

<u>14A00</u>

- Training
  - F (training) = 2.9
  - F statistic (from F distribution, 90% confidence, 2 d.f. for training variance, 4 d.f. for error variance) = 4.32
  - 2.9 < 4.32, so the relationship between training and productivity observed in our 14A00 analysis <u>does not</u> indicate, at the 90% confidence level, that training has a positive impact on productivity.
- Frequency
  - F (frequency) = 0.7

VARIATION	DEGREES OF FREEDOM (D.F.)	MEAN SQUARES	F-RATIO
TRAINING V_T	2	1666 $\left(\hat{S}_T^2 = \frac{V_T}{D.F._T}\right)$	2.9 $\left(F_T = \frac{\hat{S}_T^2}{\hat{S}_E^2}\right)$
FREQUENCY V_F	2	400 $\left(\hat{S}_F^2 = \frac{V_F}{D.F._F}\right)$	0.7 $\left(F_F = \frac{\hat{S}_F^2}{\hat{S}_E^2}\right)$
ERROR V_E	4	574 $\left(\hat{S}_E^2 = \frac{V_E}{D.F._E}\right)$	

Exhibit III-22. ANOVA TABLE FOR 14AOO

VARIATION	DEGREES OF FREEDOM (D.F.)	MEAN SQUARES	F-RATIO
TRAINING V_T	1	11,528 $\left(\hat{S}^2_E = \frac{V_T}{D.F._T}\right)$	19.1 $\left(F_T = \frac{\hat{S}^2_T}{\hat{S}^2_E}\right)$
FREQUENCY V_F	2	817 $\left(\hat{S}^2_F = \frac{V_E}{D.F._F}\right)$	1.4 $\left(F_F = \frac{\hat{S}^2_F}{\hat{S}^2_E}\right)$
ERROR V_E	2	605 $\left(\hat{S}^2_E = \frac{V_E}{D.F._E}\right)$	

Exhibit III-23. ANOVA TABLE FOR 23ZOO

- F statistic (from F distribution, 90% confidence, 2 d.f., for frequency variance, 4 d.f. for error variance) = 4.32

- 0.7 < 4.32, so the relationship between frequency and productivity observed in our 14A00 analysis does not indicate, at the 90% confidence level, that frequency has a positive impact on productivity.

23Z00

- Training

  - F (training) = 19.1

  - F statistic (from F distribution, 90% confidence, 1 d.f. for training variance, 2 d.f. for error variance) = 8.53

  - 19.1 > 8.53, so the relationship between training and productivity observed in our 23Z00 analysis does indicate, at the 90% confidence level, that training has a positive impact on productivity.

- Frequency

  - F (frequency) = 1.4

  - F statistic (from F distribution, 90% confidence, 2 d.f. for frequency variance, 2 d.f. for error variance) = 9.0

  - 1.4 < 9.0, so the relationship between frequency and productivity observed in our 23Z00 analysis does not indicate, at the 90% confidence level, that frequency has a positive impact on productivity.

As described above, the statistical results of our analysis, provided by the application of the ANOVA technique, show in three out of four tests that our results are not indicative of the overall Air Force maintenance population. Several observations should be noted, however, that are not directly apparent from these statistical results.

- Training, in both WUC examinations, has a much larger impact on productivity than frequency. The F-ratio is a measure of "how much change" in the dependent variable (productivity) is attributed to an independent variable. The larger the F-ratio is, the more change can be attributed to the independent variable in question. In both the 14A00 and the 23Z00 examinations, the training F-ratio is much larger than the frequency F-ratio.

- The number of work center observations within each "cell" in the two ANOVA matrices were not equal; therefore, the cell averages shown in these two matrices are based on different numbers of observations. This statement is not, in itself, a qualifier of the results that we obtained; however, some statistics texts allude to the fact that this case could lead to a bias in the results that are calculated. The application of this technique, taking unequal observations into consideration, would require computer services that are unavailable to us at the present time. In future examinations, this capability may be available and more accurate results could show that both factors are statistically significant.

5. <u>Observations</u>

Our analysis used three techniques to examine productivity. Each of them produced some positive analytical results. The techniques used were: productivity by action code, productivity by frequency, and ANOVA.

The productivity by action code technique allowed us to examine the effect training had on productivity in a graphic form. The results appeared to show that for both of the WUCs examined (14A00 and 23Z00) the effect of training is significant in terms of productivity increases. This was obvious in our "wing-to-wing" comparisons. The attempt to group work centers by training status (high, medium, low), and thus infer some meaning concerning the effect of frequency, did not provide useful results. Any relationship, holding training relatively constant, between frequency and productivity was not obvious.

The productivity by frequency technique plotted frequency versus productivity. A regression line was fitted to each plot and the results for WUC 14A00 showed, in four out of six cases (six action codes), a positive correlation (negative slope) between frequency and productivity. The results for WUC 23Z00 were not clear. We examined three action codes and in two cases got a negative correlation between frequency and productivity. In one case we got a positive correlation. Overall, the technique appears to show a positive relationship between frequency and productivity.

The ANOVA technique allowed us to examine the impact of both frequency and training on maintenance productivity. The statistical results were mixed since in three out of four tests it was not indicated that these results were indicative of the overall Air Force maintenance population. However, it must be noted that training, in both WUC examinations, has a much larger effect on productivity than frequency. In the case of WUC 23Z00, there was a positive indication of a relationship between training and productivity at the 90% confidence level.

In order to assure ourselves that the amount of time spent by work centers on the actions we examined was representative, we did a limited comparison of actions we examined to total actions worked on. There are 28 system level WUCs for the F-16. WUC 14000 was the highest manhour consumer in our sample (10.6%), WUC 23000 was fourth with 8.0%. There are seven subsystems within WUC 14000--WUC 14A00 was 32% of WUC 14000 or 3.4% of total wing manhours. There are twelve subsystems within WUC 23000--WUC 23Z00 was 24% of WUC 23000 or 2.0% of total wing manhours. Thus out of 113 subsystem WUCs the two WUCs we examined (14A00 and 23Z00) are quite representative of total wing maintenance since they consume over 5% of total maintenance manhours in the sample we looked at.

Our intention was to show a relationship between maintenance productivity and installation-level training. We chose courses taught using simulators for our examination of training, but did not compare simulator training with non-simulator training.

IV. AN EXAMINATION OF THE IMPACT OF INSTALLATION-LEVEL TRAINING ON ARMY OPERATIONAL UNIT MAINTENANCE PRODUCTIVITY

This section discusses the impact of installation-level training on Army operational unit productivity. The analysis will develop a linkage between individual training conducted at the installation level and unit productivity.

Unlike the Air Force, the Army does not conduct formalized installation training. However, under the auspices of the U.S. Army Training and Doctrine Command (TRADOC), school-developed training materials are furnished to operational units to conduct their own training. TRADOC, through its Training Effectiveness Analysis (TEA) process, has a means of evaluating training. The TEA process is conducted by the TEA division of the TRADOC Systems Analysis Activity (TRASANA) located at White Sands Missile Range, New Mexico. TRASANA conducts specialized training effectiveness analyses, normally in conjunction with the fielding of new major weapons systems such as the M1 (ABRAMS) tank.

Individuals who are required to operate and maintain weapons systems reach the journeyman level through individual training conducted at the installation level. Service schools, by design, may not teach certain tasks, which then become a unit level responsibility. Many tasks are best taught at the installation level because job tasks vary greatly due to factors peculiar to a unit, such as models of equipment, and particular maintenance problems which are location-oriented. Therefore, installation schools are a key component in the individual training process.

An installation school can:

- assist the unit commander in solving his training problems;

- provide a valuable source of information to the command conducting the training; and

- serve as a vehicle to distribute the desired level of support for individual training at the unit.

The Army has locally-developed and -supported installation schools at most major troop locations. This training is funded out of operational resources rather than training resources. Because installation schools often take instructors from operational units, organizations are reluctant to divert personnel from operational units to serve as instructors. Therefore, an installation school may not receive a high priority for its manning requirements. One solution that the Army has used to alleviate this problem is the use of contract training. Contractor-provided training, supplementing formal training and used to specifically address installation/unit needs, is utilized in two different variants.

- Contractors provide training according to an installation-developed course of instruction, thus acting as civilian replacements for military instructors. Many local colleges or universities in the vicinity of military installations can provide this kind of service. For example, North Texas State University is under contract to provide instructors for certain courses (logistics; organizational maintenance) to Fort Carson, Colorado.

- Contractors provide training on equipment that their company manufactures. Training is geared to the needs of the units at the installation. To ensure that the latest equipment information is incorporated, the actual curriculum is developed by the contractor himself. An example of this type of training is the courses provided by Stewart Stevenson Power, Inc. for maintenance mechanics. Stewart Stevenson is a subsidiary of Detroit Diesel Allison, Inc., which manufactures the engines that are in a large number of the vehicles on which mechanics work.

An examination was made of operational units in which unit schools were present and for which accessible information concerning maintenance productivity was available. This latter information need required a means of measuring individual or team productivity within the unit. Therefore, a data source was required that provided this capability. Once this source was identified, the available data was linked with installation-level training data, and a unit level training/productivity analysis was developed.

This section contains three subsections:

- Skill Training Evaluation Approach,
- Skill Training Evaluation Results, and
- Overview of the Army Training Effectiveness Analysis Process.

Sections IV.A and IV.B, Skill Training Evaluation Approach and Skill Training Evaluation Results, discuss the examination of installation-level training at two different installations and the relationship of this training to unit productivity. Section IV.C, Overview of the Army Training Effectiveness Analysis Process, discusses the role TRASANA plays in examining Army training in the field and the general procedures they use in conducting evaluations.

Supporting data is presented in Appendix D, Training Effectiveness Analysis Background Materials.

A. SKILL TRAINING EVALUATION APPROACH

The focus of this study is the impact of training conducted at the installation level (either school training or contractor training) on maintenance job performance. The typical training path for Army enlisted maintenance personnel is shown on Exhibit IV-1. Enlistees attend basic training and advanced individual training (AIT) prior to assignment. During AIT, soldiers learn the basic skills required within their Military Occupational Specialty (MOS). After AIT, soldiers are assigned to a unit, where training is continued by OJT. OJT at the unit level is supplemented as needed by installation-level school training and/or contractor training.

This section discusses the following topics:

- individual training conducted by installation-level schools and contractor courses, and the relationship of this training to unit maintenance training needs;
- data sources which are available to provide maintenance performance data;
- unit selection; and
- MCR's Army skill training evaluation methodology.

1. Installation Level Individual Training

The primary functions of installation-level training include the following:

- to supplement the generalized training received in formal schools with equipment-specific training related to types of equipment located at that installation;
- to provide transition training to personnel whose previous experience has been on other models of equipment; and

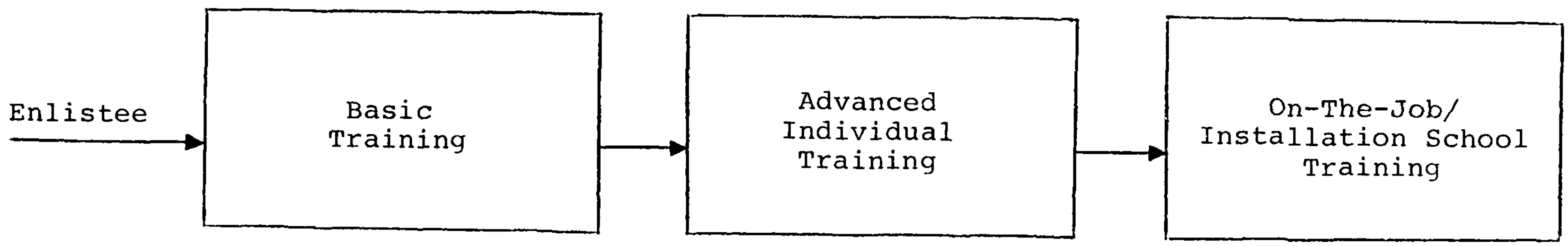


Exhibit IV-1. TYPICAL TRAINING PATH OF ARMY ENLISTED MAINTENANCE PERSONNEL

- to provide upgrade and refresher training.

In the Army, installation-level training is conducted by an installation-level school or by a contractor. Army installation-level schools are established by the installation using its own resources.

Contractor courses are also funded by the installation, using its own resources. Contract courses either augment or replace installation-level school courses where they are used.

The research documented by this technical report focuses on both installation-level school training and contractor training which support Army direct support (DS) maintenance battalions in two different mechanized infantry divisions. Direct support maintenance is the intermediate level in the Army's maintenance hierarchy. The three levels of maintenance for non-aircraft systems are discussed below.

- Organizational maintenance: this is the most direct level of maintenance in the Army. At this level, the operational unit itself performs maintenance actions such as tune-ups, oil changes, and other simple maintenance tasks.

- Direct support (DS) maintenance: this category consists of maintenance tasks of medium difficulty, such as replacing engine components, transmissions, or other such maintenance tasks. DS maintenance is usually performed by a separate maintenance battalion within a division.

- General support (GS) maintenance: this is the highest level of maintenance performed at the installation level in the Army. GS tasks include major engine overhaul, engine rebuilding, and other related maintenance tasks. GS maintenance is performed at an installation level GS shop, which receives GS jobs from all units that are assigned to the installation.

Within a specific DS unit, work is performed in several different companies which include soldiers with a variety of different MOSs. Team maintenance (two or more individuals performing a single maintenance task) is standard procedure in most DS units. Cross-skill maintenance (personnel who are trained in one skill area performing a maintenance task associated with a different skill area) is performed as required by workload and personnel shortages, particularly within the 63-series MOSs (vehicle mechanics).

2. Data Sources

Three different sources of maintenance performance data were examined in the present analysis:

- The Army Maintenance Management System (TAMMS);
- the Maintenance Performance System (MPS); and
- unit level records (DA Form 2407).

a. TAMMS

The Army Maintenance Management System is an equipment records system used for controlling the operation and maintenance of Army materiel. TAMMS captures certain maintenance information recorded on Army maintenance request forms, and the system produces a variety of different maintenance reports and summaries from this information. The general purpose of TAMMS is to provide the information needed to manage the maintenance of weapons and support equipment, the availability of spare parts, and other related functions.

b. MPS

The Maintenance Performance System is a training needs information system that has been developed by the Army Research Institute (ARI). The MPS is currently under test as a part of a research program in an Army-wide effort to improve maintenance. The stated purpose of the MPS is to "help identify problems related to lack of technical skills, poor utilization of training resources, and poor shop management."[5/] Maintenance performance data is integral to the accomplishment of this stated purpose.

c. Unit Level Records

DS maintenance units maintain records in each company shop office on maintenance actions performed. These records consist of copies of DA Form 2407, "Maintenance Request," that an operational unit is required to submit for maintenance work to be performed. In addition to including information on the equipment submitted for maintenance and the actual maintenance work performed on the equipment, the time for completing each maintenance action is also noted on this form. The information on this form is used in TAMMS.

3. Unit Selection

Unit selection was limited in the present study due to the fact that one of our data sources, the MPS, is currently a test system and is only available at two different locations.

5/Maintenance Performance System: User's Reference Manual, U.S. Army Research Institute for the Behavioral and Social Sciences, January 1981.

These locations are:

- Fort Carson, Colorado, and
- Fort Polk, Louisiana.

The identity of the installation is not relevant; hence, we have re-named them Fort R and Fort S. The two maintenance battalions are numbered R123 and S789, respectively. This alpha-numeric code is used throughout the analysis portion of this section to identify the units.

4. Methodology

The methodology that was followed in performing our Army skill training evaluation is shown in Exhibit IV-2 and explained in more detail below.

Step 1: Determine units to be examined in analysis.

Two installations were chosen as data sources for this study. DS maintenance units were chosen as the focus for this analysis for two reasons:

- DS maintenance personnel typically perform maintenance actions that could be taught to them through installation level training, and
- the MPS focused on DS units at the two installations chosen for data collection.

The DS maintenance units at the two installations chosen are:

- the 704th Maintenance Battalion at Fort Carson, and
- the 705th Maintenance Battalion at Fort Polk.

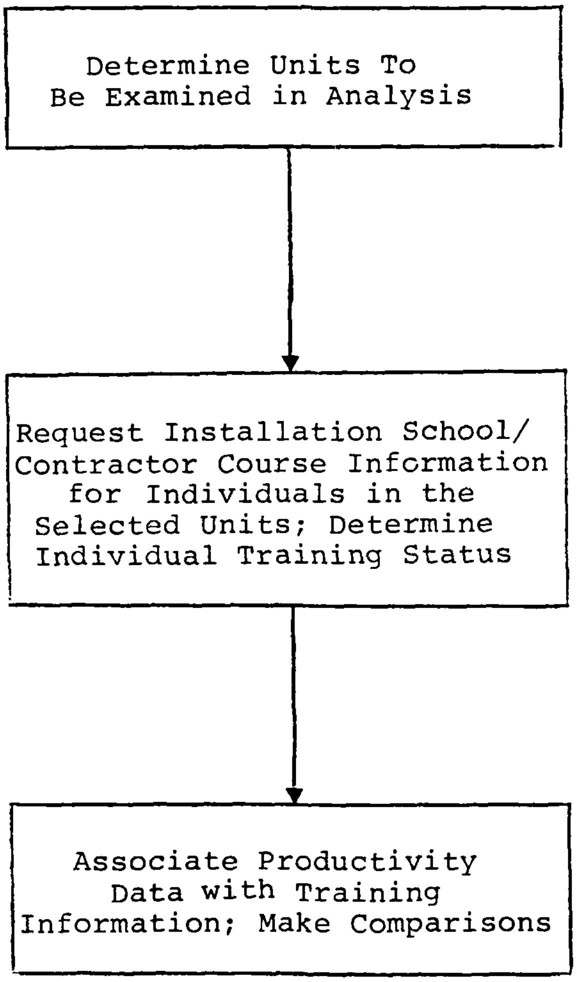


Exhibit IV-2. ARMY SKILL TRAINING EVALUATION METHODOLOGY

Step 2: Request installation school/contractor course information for individuals in the units selected for analysis; determine individual training status.

Once the units to be analyzed were identified, course information was required to determine the installation-level training status of maintenance individuals in each unit. DS maintenance battalions in a mechanized infantry division include a large number of vehicle mechanics, who do most of the maintenance for the unit. Course information requests were restricted to those courses which dealt with vehicle mechanics (63-series MOSs). This restriction was made to limit the amount of data that had to be requested.

Once course data was obtained, individuals in the 63-series MOSs in each unit were assigned a training status of either trained or untrained. For the purposes of this analysis, these determinations were defined as follows:

- trained -- an individual must have completed an installation level course pertaining to a 63-series MOS; and
- untrained -- all other individuals who have not completed a 63-series MOS course at the installation level.

Step 3: Associate productivity data with training information.

At this point, productivity data was to be linked with individual training status. Trained individuals and untrained individuals could be segregated, and productivity information for specific maintenance actions could be compared between the two groups using statistical techniques. As will be discussed in the next section, we were unable to accomplish this step due to a lack of appropriate data.

B. SKILL TRAINING EVALUATION RESULTS

This section discusses the following topics:

- application of the skill training evaluation methodology and limitations which affected the application of the methodology; and
- observations on improvements that can be made to allow for improved training/productivity linkage evaluations.

1. Application

The MCR project team gathered productivity data from Fort Carson and Fort Polk. Course data was requested from both installation level schools that pertained to 63-series MOSs, and on the Detroit Diesel Allison courses that are taught to individuals at Fort R (Fort S does not supplement installation-level school courses with contractor courses). We then attempted to process this data as described in our skill training evaluation methodology (Section IV.A.4). Problems with this application became apparent and so a full application of our methodology was not possible.

An analysis such as this is only as good as the data on which it is based. Unfortunately, none of the data sources that were identified as potentially useful for this study proved to be appropriate. Different shortcomings limited the use of each of the data sources identified.

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An analysis such as this is only as good as the data on which it is based. Unfortunately, none of the data sources that were identified as potentially useful for this study proved to be appropriate. Different shortcomings limited the use of each of the data sources identified.

a. TAMMS Data Limitations

A previous study has documented the inadequacies of TAMMS data for training effectiveness purposes.[6/] The TAMMS system was designed to provide information for purposes of maintenance and logistics; not for the purpose of evaluating maintenance performance by individuals. The biggest problem with this database for our purposes is that the names of individuals who perform maintenance actions are not maintained in the central data files. Because the ability to identify and track individuals is central to our methodology for relating maintenance performance to training, TAMMS data is not appropriate for our analysis.

b. MPS Data Limitations

In theory, the MPS database is an ideal source of data for any training/productivity analyses. MPS data includes information which directly identifies individuals that are performing specific maintenance tasks. Therefore individuals can be readily identified, training information can be associated with names, and performance can be tracked.

The MPS system is still being tested. However, at the two installations at which it is in operation, the current databases are very small. In addition, the DS level MPS test phase has been completed at Fort R and DS data was no longer input after 1 October 1982. These factors proved to be a problem

6/ Evaluating the Effectiveness of Maintenance Training by Using Currently Available Maintenance Data, IDA, August 1981.

when a training data/productivity data linkage was attempted. While trying to link training information with associated productivity data in the MPS databases, we discovered that most of the names on the training list were not included in the MPS databases. Specifically, we found the following.

- At Fort R, 45 names were received as 63-series MOSs from the S123d Maintenance Battalion who had been trained through the installation school or through the Detroit Diesel Allison contractor course in the past year. Of this list of names, only four (9%) were found to be included in the MPS database.

- At Fort S, 10 names were received as 63-series MOSs from the S789th Maintenance Battalion who were trained through the installation school in the past year. This sample size itself was so small as to bring to question the validity of any statistical analyses based on this data, and only one name (10%) was found to be included in the MPS database.

Therefore, the small size of the MPS databases at our source installations effectively prohibited an effective training/productivity linkage.

c. Unit Level Data Limitations

DA Form 2407, "Maintenance Request," records are retained by the DS unit for all maintenance actions performed at this level. However, certain shortcomings of the data included on these forms limit its use in the present study.

- "Work performed" information is very generic. Mechanics are required to account for the work they performed on the 2407, but such notation is most commonly made at the broadest level possible. For example, any work performed on an engine or its components, ranging from simple tasks to the most complex ones, are commonly represented as "engine work" on the 2407. Data at this generic level of detail is inappropriate for the type of analysis represented by this study.

- Data is not maintained for time productivity purposes; it is maintained to keep track of parts used, parts needed, etc. Therefore, time information that is recorded on the 2407 cannot be assumed to be truly accurate.

- Individual names of maintenance personnel are not shown on the form.

In addition to these intrinsic limitations of the 2407 data itself, there is another external factor that serves to limit the statistical applicability of this data.

- DS units maintain 2407 records for 90 days; data prior to 90 days is thrown out. The range of the data is thus very limited.

2. Observations

Data limitations discussed above limit the conclusions that could be made with respect to the results of this analysis. No specific, quantitative observations or conclusions can be advanced concerning the relationship between installation level maintenance training and productivity.

Subjectively, however, installation-level training does seem to have a positive impact on maintenance productivity. Interviews were conducted with several individuals (ranging from DS mechanics to staff officers at the division level) at Fort Carson. All of these individuals had the same impression of installation-level training: although the positive benefit of the training may not be quantifiable, the benefit does exist. Mechanics were able to "diagnose problems better" and "p form troubleshooting actions with more accuracy" as the result of installation-level training (in this case, Detriot Diesel Allison courses).

These subjective observations are all that can be said, at this time, concerning the relationship upon which this analysis has focused. Current databases from which information can be obtained for training/productivity analyses proved inadequate for a specific, quantitative analysis. Although the current databases are not appropriate for the kinds of analyses that we are attempting, this will not necessarily be the case in the future.

The Army is developing the systems to keep track of productivity information. When they are completed, the present type of analysis could be successful. In particular, the following data sources could provide appropriate information.

- The MPS. As was mentioned above, the MPS is currently in the test mode. As more data is collected by this system at Fort S, and if the system is expanded and data is collected at other Army installations, this system could prove to be a very effective training management tool, especially for the present type of analysis.

- The Standard Army Maintenance System (SAMS). The SAMS is an automated maintenance management system that will relace the current TAMMS system and encompass all levels of Army materiel maintenance. SAMS will improve upon the present TAMMS system in that a maintenance job will be "tracked" on an in-shop computer as it progresses through work stages, and each different stage of work will be be explicitly noted in the job record. Therefore, the records should be more accurate than those in TAMMS (which is automated at a much higher level) and include more detailed data on particular actions performed. Unfortunately, the SAMS system is also not designed for training analysis purposes; no information that identifies individuals is included in this system. The system, however, is still in preliminary implementation stages. Data elements could theoretically be added to the system if a strong rationale were given for their inclusion. Even if individual identification were not included in the system, the improvements in accuracy and level of detail over the TAMMS database could be of benefit for training/productivity analyses.

A "macro" level approach, which specifically identifies certain types of installation-level training with certain types of maintenance actions, would be much easier to accomplish if maintenance actions were identified more explicitly in an automated database. SAMS could provide this capability, whereas the current TAMMS does not.

C. OVERVIEW OF THE ARMY TRAINING EFFECTIVENESS ANALYSIS PROCESS

The focus of the MCR study is the impact of training conducted at the installation level on maintenance job performance. The information in this section concerning TRASANA was felt to be analogous to our efforts and thus worthy of explanation.

This section discusses the overall Army Training Effectiveness Analysis (TEA) process. More detailed information on the structure of the TEA process and on an example TEA for the M1 (ABRAMS) tank is in Appendix D, Training Effectiveness Analysis Background Materials.

The mission of TRASANA is to serve as an analytical center for combat and training developments and to conduct analyses. The TEA Division of TRASANA is the single agency for managing the TEA process and, as such, conducts TEAs and reviews TEA studies conducted by others. This section will discuss the goals and emphasis, support provided, and process used by the TEA Division.

1. Goals and Emphasis

Training effectiveness analysis is a process for which TRASANA's TEA Division is the proponent. The TEA Division has as its goals and areas of emphasis the following:

- contribute to the fielding of optimum training packages with the hardware;
- assist in the improvement of existing training packages;
- build a TEA data base; and
- emphasize Army Force Modernization by:
  - conducting more TEA on post-fielded systems;
  - conducting TEA early in the developmental phase; and
  - emphasizing the permeation of the TEA process throughout the Army.

The process is carried out through evaluations in four major categories: training, training devices, soldier/hardware interface, and evaluation of MOS selection criteria. The evaluations may include one or more of these categories. Cost analysis may also be included in the determination of efficiency.

2. <u>Support Provided</u>

The TEA Division supports TRADOC schools and training centers and provides input to Army field units. The TEA Division becomes involved in a study by one of two methods. The proponent (school, center, unit) submits a request to TRADOC or directly to the TEA Division to perform a study. If TRADOC determines the study is of merit and the TEA Division has resources available then it will be conducted. A list of major study reports completed by TEA Division is shown on Exhibit IV-3.

REPORT	ABBREV	NUMBER	DATE
Basic Rifle Marksmanship Cost and Training Effectiveness Analysis (CTEA)	BRM	TR-16-77	SEP 77
REDEYE Weapon Systems Training Effectiveness Analysis (WSTEA)	RE WSTEA	TR 21-77	NOV 77
M60A1 Modified WSTEA	M60A1	TR 7-78	JUN 78
REDEYE Weapon Systems Army Training Study (ARTS)	RE ARTS	TR 6-78	OCT 78
TEA Handbook	TEA Hbk	N/A	AUG 79
Marksmanship and Gunnery Laser Devise/Infantry Remoted Target System Training Developments Study (TDS)	MAGLAD/ IRETS	TEA 1-79	DEC 79
Multiple Launch Rocket System CTEA	MLRS	TEA 3-80	JUN 80
Infantry Fighting Vehicle Initial CTEA	IFV	TEA 4-80	MAR 80
Patriot Air Defense System CTEA	PATRIOT	TEA 8-80	OCT 80
VULCAN Weapons System Training Subsystem Effectiveness Analysis (TSEA)	VULCAN	TEA 23-80	OCT 80
Cavalry Fighting Vehicle Force Development Test and Experimentation (FDTE) Training Analysis	CFV	TEA 31-80	OCT 80
Armor Training Test Instruments and Selection Criteria Evaluation Study TEA	ATS	TEA 38-80	JAN 81
Plastic Ammunition TDS			
Application: Military Opns in Urban Terrain	PA: MOUT	TEA 41-80	JAN 81
Application: 5.56mm Rifle Marksmanship Sustainment	PA: 5.56mm	TEA 41-80	JAN 81
Firefinder TEA Operator Selection Criterion	FIREFINDER	TEA 4-81	JAN 81
TDS for MOULAGES	MOULAGES	TEA 5-81	FEB 81
Air Defense Accessions TEA	ADA ACC	TEA 7-81	MAR 81
Near-Term Scout Helicopter Preliminary CTEA	NTSH	TEA 10-81	APR 81
CHAPARRAL/REDEYE TSEA	CHAP/RE	TEA 12-81	JUN 81
Training Attrition Problem, Institute for Military Assistance TSEA	TAPIMA	TEA 13-81	MAR 81
M1 (ABRAMS) Main Battle Tank TEA	M1	TEA 37-81	SEP 81
Air Defense Accessions Update	ADA Update	TEA 40-81	OCT 81
TDS M1 (ABRAMS) Tank Unit-Conduct of Fire Trainer	M1 UCOFT	TEA 11-82	MAR 82
Multiple Integrated Laser Engagement System Air Ground Engagement Simulation/Air Defense CTEA	MILES AGES/ AD	TEA 12-82	MAR 82
ELSAP 2000 Tank Gunnery Turret Trainer TDS	ELSAP	TEA 13-82	MAR 82
M1 ABRAMS Tank Driver Trainer TDS	M1 DVR TNR	TEA 15-82	APR 82
PERSHING II TEA	PERSHING	TEA 17-82	MAR 82
UH-60 Flight Simulator TDS	UH60FS	TDS 19-82	APR 82
TDS-Bradley Fighting Vehicle Unit-Conduct of Fire Trainer	FV UCOFT	TEA 28-82	MAY 82
Corps Support Weapon System-Preliminary TEA	CSWS	TEA 23-82	JUN 82

Exhibit IV-3. MAJOR STUDY REPORTS COMPLETED BY TEA DIVISION

3. Process Used

The TEA Division collects information through several measurement methods: standardized tests such as the Armed Services Vocational Aptitude Battery (ASVAB), Select Adult Basic Learning Exam, Gates MacGinatie Reading Test, Lynn Achievement Motivation Scale, and Armed Forces Qualification Test (AFQT) Percentile Score. Also, the TEA Division uses special purpose tests such as the Skills and Knowledge (S/K) tests, and performance proficiency tests, better known as hands-on tests. The above listings are not exhaustive since additional sources of information may be included such as demographic surveys, force-on-force simulations, human factors analyses, and cost analyses.

Various statistical procedures are used by the TEA Division to evaluate data once it is compiled and organized. Several statistical measures are shown in Exhibits IV-4 and IV-5. Exactly which procedure is used is determined by the problem and the nature of the data.

	PARAMETRIC TESTS					NONPARAMETRIC TESTS			
	Z TEST	STUDENT'S T-TEST	ANALYSIS OF VARIANCE	MULTIPLE COMPARISONS SCHEFFE	LSD	CHI-SQUARE	FISHER'S EXACT PROBABILITY	WILCOXON	MANN-WHITNEY U
BRM			X		X		X		
RE WSTEA		X	X		X				
M60			X		X				
MAGLAD/IRETS		X	X	X					
MLRS		X	X						X
PATRIOT		X	X				X	X	X
VULCAN		X	X						
CFV		X				X			
ATS	X					X			
PA:MOUT		X	X			X			
PA:5.56mm		X	X	X					
FIREFINDER		X							
ADA ACC		X	X	X		X			
CHAP/RE		X	X		X				
TAPIMA			X		X	X			
M1	X		X					X	
ADA UPDATE		X				X			
M1 UCOFT	X	X				X		X	X
MILES AGES/AD		X					X		
PERSHING	X	X	X	X		X			
UH60FS		X	X				X		
M1 DVR TNR	X	X				X			
FV UCOFT		X				X			
35H & 35B						X		X	
BTMS						X	X		
MACE			X						

Exhibit IV-4. STATISTICS USED IN TEAS TO EVALUATE THE DIFFERENCE BETWEEN GROUPS

STUDY	PEARSON PRODUCT MOMENT	SPEARMAN RHO	REGRESSION
	CORRELATIONS		
BRM	X		X
RE WSTEA	X		
M60A1	X		X
RE ARTS	X		
MAGLAD/IRETS		X	X
PATRIOT		X	X*
VULCAN	X		
CFV		X	
ATS			X*
ADA ACC			X*
NTSH		X	
CHAP/RE		X	
TAPIMA	X		
M1	X		X
PERSHING		X	X*
M1 UCOFT	X		
FV UCOFT	X		

* This was discriminant analysis

Exhibit IV-5. STATISTICS USED IN STUDIES TO DETERMINE EXTENT TWO OR MORE VARIABLES ARE RELATED

APPENDIX A

REFERENCE SOURCES

TASK 1

A. DOCUMENTS

Equipment Maintenance: Maintenance Management, Air Force Regulation (AFR) 66-1, Headquarters, U.S. Air Force, 2 July 1980.

Equipment Maintenance: Maintenance Management Information and Control System (MMICS), Maintenance Personnel and Training Management Users Manual, AFM 66-278, Headquarters, U.S. Air Force, 1 February 1979.

Equipment Maintenance: Maintenance Management Information and Control System (MMICS) Guide for Maintenance Managers, Air Force Pamphlet (AFP) 66-10, Headquarters, U.S. Air Force, 1 April 1980.

Evaluating the Effectiveness of Maintenance Training by Using Currently Available Maintenance Data, IDA Paper P-1574, Institute for Defense Analyses, August 1981.

The Performance of Maintenance Technicians on the Job, IDA Paper P-1597, Institute for Defense Analyses, August 1981.

Report on Individual Skill Training--Maintenance Training in the Department of Defense, Office of the Assistant Secretary of Defense (Manpower, Reserve Affairs and Logistics), May 1982.

B. INTERVIEWS

Name	Organization	Telephone #
HQ Air Force Staff: Washington D.C.		(AV 22X-XXXX) or (202) 69X-XXXX
LtCol Larry Matthews	AF/LEYM	7-1431
Capt Freddie Graham	AF/LEYM	7-1493
Capt Alfred Rodriguez	AF/MPP	5-7321
TAC HQ: Langley AFB, VA		(AV 432-XXXX) or (804) 764-XXXX
LtCol William James	TAC/LGQT	3688/2102

Name	Organization	Telephone #
1st Tactical Fighter Wing: Langley AFB, VA		(AV 432-XXXX) or (804) 764-XXXX
LtCol George Barr	MAT	2280/3175
MSgt Fred Woodard	MAT	
TSgt James Brown	MAT	3175
MSgt Roger Hardwick	Analysis	3610/4390
Maj Ted Schramm	Quality Assurance	7085/7087
SMSgt Wilson Davis	Quality Assurance	
MSgt Thomas Hicks	Quality Assurance	
MSgt Ralph Roberts	Programs & Mobil-	5447
Sgt Barker	ity Manpower	
FTD 201: Langley AFB, VA		(AV 432-XXXX) or (804) 764-XXXX
SMSgt Svabek		7741
405th Tactical Training Wing: Luke AFB, AZ		(AV 853-XXXX) or (602) 856-XXXX
SMSgt Warren Smith	MAT	7048
58th Tactical Training Wing: Luke AFB, AZ		(AV 853-XXXX) or (602) 856-XXXX
MSgt Fancher	MAT	7355
35th Tactical Fighter Wing: George AFB, CA		(AV 353-XXXX) or (714) 269-XXXX
SMSgt James Paxton	MAT	2949
37th Tactical Fighter Wing: George AFB, CA		(AV 353-XXXX) or (714) 269-XXXX
LtCol Fred Wilson	MAT	2640
SSgt Randolph Herrera	MAT	
TSgt Paul Jones	MAT	
TSgt Ervin Holt	MAT	2206

TASK 2

A. DOCUMENTS

Equipment Maintenance: Maintenance Management, Air Force Regulation (AFR) 66-1, Headquarters, U.S. Air Force, 2 July 1980.

Equipment Maintenance: Maintenance Management Information and Control System (MMICS), Maintenance Personnel and Training Management Users Manual, AFM 66-278, Headquarters, U.S. Air Force, 1 February 1979.

Equipment Maintenance: Maintenance Management Information and Control System (MMICS) Guide for Maintenance Managers, Air Force Pamphlet (AFP) 66-10, Headquarters, U.S. Air Force, 1 April 1980.

Work Unit Code Manual: F-16A/B Aircraft, Air Force Technical Manual T.O. IF-16A-06, General Dynamics Corp., 1 February 1980 with 7 changes.

Course Training Standards and Plans of Instruction for AFSC 326X6, 326X7, 326X8, 423X0, 423X2, and 426X2; Headquarters Air Training Command, 1979-1982.

B. INTERVIEWS

Name	Organization	Telephone #
		(AV 22X-XXX) or (202) 69X-XXX
HQ Air Force Staff: Washington D.C.		
LtCol Larry Matthews	AF/LEYM	7-1431
Capt Alfred Rodriguez	AF/MPP	5-7321
TAC HQ: Langley AFB, VA		(AV 432-XXXX) or (804) 764-XXXX
LtCol William James	TAC/LGQT	2-3688
LtCol Ronald Clarke	TAC/LGY	2-3093
SMSgt Spreadbury	TAC/LGQP	2-4465
56th Tactical Training Wing: MacDill AFB, FL		(AV 968-XXXX) or (813) 830-XXXX
MSgt Warn Taylor	MAT	3212
Sgt Stetler	Analysis	4708
388th Tactical Fighter Wing: Hill AFB, UT		(AV 458-XXXX) or (801) 777-XXXX
SMSgt Robert Bassett	MAT	3835
Sgt Childers	Analysis	3529

B. INTERVIEWS (Cont'd)

Name	Organization	Telephone #
474th Tactical Fighter Wing: Nellis AFB, NV		(AV 682-XXXX) or (702) 643-XXXX
Maj David Crews	MAT	2213
MSgt Hobbs	Analysis	2208
Institute for Defense Analyses: Alexandria, VA		
Dr. Jesse Orlansky		(703) 845-2293
Honeywell Inc.: West Covina, CA		
Dr. Ruth Weinclaw		(213) 331-0011

TASK 3

A. DOCUMENTS

The Army Maintenance Management System, TM 38-750, Headquarters, Department of the Army, May 1981.

Evaluating the Effectiveness of Maintenance Training by Using Currently Available Maintenance Data, IDA Paper P-1574, Institute for Defense Analyses, August 1981.

Maintenance of Supplies and Equipment: The Army Maintenance Management System (TAMMS) Reports and Summaries Catalog, DARCOM-P 750-15, Headquarters, DARCOM, August 1981.

Maintenance Performance System: Guide for Individual Technical Training in Direct Support Units, U.S. Army Research Institute for the Behavioral and Social Sciences, January 1981.

Maintenance Performance System: Operator's Manual, U.S. Army Research Institute for the Behavioral and Social Sciences, January 1981.

Maintenance Performance System: Users Reference Manual, U.S. Army Research Institute for the Behavioral and Social Sciences, January 1981.

The Performance of Maintenance Technicians on the Job, IDA Paper P-1597, Institute for Defense Analyses, August 1981.

Report on Individual Skill Training--Maintenance Training in the Department of Defense, Office of the Assistant Secretary of Defense (Manpower, Reserve Affairs, and Logistics), May 1982.

TRADOC Training Effectiveness Handbook (First Draft), U.S. Army TRADOC Systems Analysis Activity, Undated.

Training Effectiveness Analysis, A Process in Evolution, U.S. Army TRADOC Systems Analysis Activity, October 1982.

TRASANA Report TEA 37-81, M1 (ABRAMS) Main Battle Tank, U.S. Army TRADOC Systems Analysis Activity, September 1981.

B. INTERVIEWS

Name	Organization	Telephone #
ARI: Alexandria, VA		(703) 274-XXXX
Mr. Doug Bobko	ARI	8694
Mr. Mike Drillings	ARI	8694
Mr. John Hayes	ARI	8694
4th Inf. Div (M): Ft. Carson, CO		(AV 691-XXXX) or (303) 579-XXXX
CPT Robert Coffman	Division G-3	2938
Mrs. Carol Koscove	Division G-3	2938
MAJ William Parker	Division G-4	3068
CPT Henry Brown	Division G-4	3068
MAJ Daniel Speck	704th Maint. Bn.	2018
SGT Giergic	704th Maint. Bn.	2018
SFC Byassee	704th Maint. Bn.	3107
CPT Wansersvi	Logistics School	5558
5th Inf. Div (M): Ft. Polk, LA		(AV 833-XXXX) or (318) 535-XXXX
CPT Peterson	705th Maint. Bn.	4180
SGT Schaefer	705th Maint. Bn.	4180
Mr. Sopo	Logistics School	6476
TRASANA, White Sands Missile Range, NM		(AV 258-XXXX) or (505) 678-XXXX
Mr. Lee Paris	TRASANA TEA Div.	5915
Detroit Diesel Allison, Indianapolis, IN		
Mr. Ron Eber	Main Office	(317) 242-3253
Mr. Larry Ritchey	Main Office	(317) 242-6112
Mr. Bob Pejeau	D.C. Office	(202) 775-5058

APPENDIX B

SUMMARY OUTPUTS FROM METHODOLOGICAL DATABASES

1 QA DATA: SUMMARY RESULTS

THERE WERE 0 PEOPLE IN SKILL LEVEL 1 WHO WERE UNTRAINED AND FAILED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 1 WHO WERE TRAINED AND FAILED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 1 WHO WERE OJT AND FAILED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 1 WHO WERE UNTRAINED AND PASSED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 1 WHO WERE TRAINED AND PASSED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 1 WHO WERE OJT AND PASSED THEIR QA EXAM
THERE WERE 16 PEOPLE IN SKILL LEVEL 3 WHO WERE UNTRAINED AND FAILED THEIR QA EXAM
THERE WERE 14 PEOPLE IN SKILL LEVEL 3 WHO WERE TRAINED AND FAILED THEIR QA EXAM
THERE WERE 7 PEOPLE IN SKILL LEVEL 3 WHO WERE OJT AND FAILED THEIR QA EXAM
THERE WERE 61 PEOPLE IN SKILL LEVEL 3 WHO WERE UNTRAINED AND PASSED THEIR QA EXAM
THERE WERE 28 PEOPLE IN SKILL LEVEL 3 WHO WERE TRAINED AND PASSED THEIR QA EXAM
THERE WERE 55 PEOPLE IN SKILL LEVEL 3 WHO WERE OJT AND PASSED THEIR QA EXAM
THERE WERE 52 PEOPLE IN SKILL LEVEL 5 WHO WERE UNTRAINED AND FAILED THEIR QA EXAM
THERE WERE 21 PEOPLE IN SKILL LEVEL 5 WHO WERE TRAINED AND FAILED THEIR QA EXAM
THERE WERE 29 PEOPLE IN SKILL LEVEL 5 WHO WERE OJT AND FAILED THEIR QA EXAM
THERE WERE 112 PEOPLE IN SKILL LEVEL 5 WHO WERE UNTRAINED AND PASSED THEIR QA EXAM
THERE WERE 62 PEOPLE IN SKILL LEVEL 5 WHO WERE TRAINED AND PASSED THEIR QA EXAM
THERE WERE 153 PEOPLE IN SKILL LEVEL 5 WHO WERE OJT AND PASSED THEIR QA EXAM
THERE WERE 6 PEOPLE IN SKILL LEVEL 7 WHO WERE UNTRAINED AND FAILED THEIR QA EXAM
THERE WERE 15 PEOPLE IN SKILL LEVEL 7 WHO WERE TRAINED AND FAILED THEIR QA EXAM
THERE WERE 22 PEOPLE IN SKILL LEVEL 7 WHO WERE OJT AND FAILED THEIR QA EXAM
THERE WERE 9 PEOPLE IN SKILL LEVEL 7 WHO WERE UNTRAINED AND PASSED THEIR QA EXAM
THERE WERE 25 PEOPLE IN SKILL LEVEL 7 WHO WERE TRAINED AND PASSED THEIR QA EXAM
THERE WERE 32 PEOPLE IN SKILL LEVEL 7 WHO WERE OJT AND PASSED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 9 WHO WERE UNTRAINED AND FAILED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 9 WHO WERE TRAINED AND FAILED THEIR QA EXAM
THERE WERE 2 PEOPLE IN SKILL LEVEL 9 WHO WERE OJT AND FAILED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 9 WHO WERE UNTRAINED AND PASSED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 9 WHO WERE TRAINED AND PASSED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 9 WHO WERE OJT AND PASSED THEIR QA EXAM

57 QA DATA SUMMARY RESULTS

THERE WERE 0 PEOPLE IN SKILL LEVEL 1 WHO WERE UNTRAINED AND FAILED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 1 WHO WERE TRAINED AND FAILED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 1 WHO WERE OJT AND FAILED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 1 WHO WERE UNTRAINED AND PASSED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 1 WHO WERE TRAINED AND PASSED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 1 WHO WERE OJT AND PASSED THEIR QA EXAM
THERE WERE 9 PEOPLE IN SKILL LEVEL 3 WHO WERE UNTRAINED AND FAILED THEIR QA EXAM
THERE WERE 6 PEOPLE IN SKILL LEVEL 3 WHO WERE TRAINED AND FAILED THEIR QA EXAM
THERE WERE 1 PEOPLE IN SKILL LEVEL 3 WHO WERE OJT AND FAILED THEIR QA EXAM
THERE WERE 27 PEOPLE IN SKILL LEVEL 3 WHO WERE UNTRAINED AND PASSED THEIR QA EXAM
THERE WERE 9 PEOPLE IN SKILL LEVEL 3 WHO WERE TRAINED AND PASSED THEIR QA EXAM
THERE WERE 10 PEOPLE IN SKILL LEVEL 3 WHO WERE OJT AND PASSED THEIR QA EXAM
THERE WERE 9 PEOPLE IN SKILL LEVEL 5 WHO WERE UNTRAINED AND FAILED THEIR QA EXAM
THERE WERE 33 PEOPLE IN SKILL LEVEL 5 WHO WERE TRAINED AND FAILED THEIR QA EXAM
THERE WERE 17 PEOPLE IN SKILL LEVEL 5 WHO WERE OJT AND FAILED THEIR QA EXAM
THERE WERE 31 PEOPLE IN SKILL LEVEL 5 WHO WERE UNTRAINED AND PASSED THEIR QA EXAM
THERE WERE 42 PEOPLE IN SKILL LEVEL 5 WHO WERE TRAINED AND PASSED THEIR QA EXAM
THERE WERE 24 PEOPLE IN SKILL LEVEL 5 WHO WERE OJT AND PASSED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 7 WHO WERE UNTRAINED AND FAILED THEIR QA EXAM
THERE WERE 3 PEOPLE IN SKILL LEVEL 7 WHO WERE TRAINED AND FAILED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 7 WHO WERE OJT AND FAILED THEIR QA EXAM
THERE WERE 3 PEOPLE IN SKILL LEVEL 7 WHO WERE UNTRAINED AND PASSED THEIR QA EXAM
THERE WERE 4 PEOPLE IN SKILL LEVEL 7 WHO WERE TRAINED AND PASSED THEIR QA EXAM
THERE WERE 8 PEOPLE IN SKILL LEVEL 7 WHO WERE OJT AND PASSED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 9 WHO WERE UNTRAINED AND FAILED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 9 WHO WERE TRAINED AND FAILED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 9 WHO WERE OJT AND FAILED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 9 WHO WERE UNTRAINED AND PASSED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 9 WHO WERE TRAINED AND PASSED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 9 WHO WERE OJT AND PASSED THEIR QA EXAM

405 QA DATA: SUMMARY RESULTS

THERE WERE 0 PEOPLE IN SKILL LEVEL 1 WHO WERE UNTRAINED AND FAILED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 1 WHO WERE TRAINED AND FAILED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 1 WHO WERE OJT AND FAILED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 1 WHO WERE UNTRAINED AND PASSED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 1 WHO WERE TRAINED AND PASSED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 1 WHO WERE OJT AND PASSED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 3 WHO WERE UNTRAINED AND FAILED THEIR QA EXAM
THERE WERE 13 PEOPLE IN SKILL LEVEL 3 WHO WERE TRAINED AND FAILED THEIR QA EXAM
THERE WERE 3 PEOPLE IN SKILL LEVEL 3 WHO WERE OJT AND FAILED THEIR QA EXAM
THERE WERE 3 PEOPLE IN SKILL LEVEL 3 WHO WERE UNTRAINED AND PASSED THEIR QA EXAM
THERE WERE 90 PEOPLE IN SKILL LEVEL 3 WHO WERE TRAINED AND PASSED THEIR QA EXAM
THERE WERE 49 PEOPLE IN SKILL LEVEL 3 WHO WERE OJT AND PASSED THEIR QA EXAM
THERE WERE 35 PEOPLE IN SKILL LEVEL 5 WHO WERE UNTRAINED AND FAILED THEIR QA EXAM
THERE WERE 129 PEOPLE IN SKILL LEVEL 5 WHO WERE TRAINED AND FAILED THEIR QA EXAM
THERE WERE 217 PEOPLE IN SKILL LEVEL 5 WHO WERE OJT AND FAILED THEIR QA EXAM
THERE WERE 29 PEOPLE IN SKILL LEVEL 5 WHO WERE UNTRAINED AND PASSED THEIR QA EXAM
THERE WERE 186 PEOPLE IN SKILL LEVEL 5 WHO WERE TRAINED AND PASSED THEIR QA EXAM
THERE WERE 281 PEOPLE IN SKILL LEVEL 5 WHO WERE OJT AND PASSED THEIR QA EXAM
THERE WERE 8 PEOPLE IN SKILL LEVEL 7 WHO WERE UNTRAINED AND FAILED THEIR QA EXAM
THERE WERE 25 PEOPLE IN SKILL LEVEL 7 WHO WERE TRAINED AND FAILED THEIR QA EXAM
THERE WERE 9 PEOPLE IN SKILL LEVEL 7 WHO WERE OJT AND FAILED THEIR QA EXAM
THERE WERE 11 PEOPLE IN SKILL LEVEL 7 WHO WERE UNTRAINED AND PASSED THEIR QA EXAM
THERE WERE 51 PEOPLE IN SKILL LEVEL 7 WHO WERE TRAINED AND PASSED THEIR QA EXAM
THERE WERE 79 PEOPLE IN SKILL LEVEL 7 WHO WERE OJT AND PASSED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 9 WHO WERE UNTRAINED AND FAILED THEIR QA EXAM
THERE WERE 1 PEOPLE IN SKILL LEVEL 9 WHO WERE TRAINED AND FAILED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 9 WHO WERE OJT AND FAILED THEIR QA EXAM
THERE WERE 0 PEOPLE IN SKILL LEVEL 9 WHO WERE UNTRAINED AND PASSED THEIR QA EXAM
THERE WERE 3 PEOPLE IN SKILL LEVEL 9 WHO WERE TRAINED AND PASSED THEIR QA EXAM
THERE WERE 1 PEOPLE IN SKILL LEVEL 9 WHO WERE OJT AND PASSED THEIR QA EXAM

SUMMARY DATA FROM WUC TO REPORTS

STATISTICS FROM THE 37TH TFW

TOTAL NUMBER OF COMPARISONS WITHIN THIS WING=79
BETTER TRAINED WKCTRS PERFORMED FASTER 58.2278481% OF THE TIME FOR ALL OBSERVATIONS
AVERAGE TRAINED PERCENTAGE OF BETTER-TRAINED WKCTRS=55.4936709%
AVERAGE TRAINED PERCENTAGE OF LESS-TRAINED WKCTRS=34.1898734%
AVERAGE DIFFERENCE IN TRAINING=21.3037975%
BETTER TRAINED WKCTRS PERFORMED WORK, ON THE AVERAGE, IN 99.7313675% OF THE TIME IT TOOK LESS-TRAINED WKCTRS

SUMMARY DATA FROM WUC TA REPORTS

STATISTICS FROM THE 1ST TFW

TOTAL NUMBER OF COMPARISONS WITHIN THIS WING=17
BETTER TRAINED WKCTRS PERFORMED FASTER 58.82352995% OF THE TIME FOR ALL OBSERVATIONS
AVERAGE TRAINED PERCENTAGE OF BETTER-TRAINED WKCTRS =66.2352941%
AVERAGE TRAINED PERCENTAGE OF LESS-TRAINED WKCTRS=25.1764706%
AVERAGE DIFFERENCE IN TRAINING=41.0588235%
BETTER TRAINED WKCTRS PERFORMED WORK, ON THE AVERAGE, IN 95.6964159% OF THE TIME IT TOOK LESS-TRAINED WKCTRS

STATISTICS FROM THE 405 TTW

TOTAL NUMBER OF COMPARISONS WITHIN THIS WING=119
BETTER TRAINED WKCTRS PERFORMED FASTER 56.302521% OF THE TIME FOR ALL OBSERVATIONS
AVERAGE TRAINED PERCENTAGE OF BETTER-TRAINED WKCTRS=75.5714286%
AVERAGE TRAINED PERCENTAGE OF LESS-TRAINED WKCTRS=54.4369748%
AVERAGE DIFFERENCE IN TRAINING=21.1344538%
BETTER TRAINED WKCTRS PERFORMED WORK, ON THE AVERAGE, IN 100.518645% OF THE TIME IT TOOK LESS-TRAINED WKCTRS

STATISTICS FROM INTER-WING COMPARISONS

TOTAL NUMBER OF INTER-WING COMPARISONS=62
IN COMPARING THE 1ST AND THE 405TH TOGETHER, THE 1ST TFW HAD WKCTRS THAT PERFORMED FASTER AND WERE BETTER TRAINED 24.1935484% OF THE TIM
IN COMPARING THE 1ST AND THE 405TH TOGETHER, THE 405TH HAD WKCTRS THAT PERFORMED FASTER AND WERE BETTER TRAINED 48.3870968% OF THE TIME,
AVERAGE TRAINED PERCENTAGE OF BETTER-TRAINED WKCTRS(IN INTER-WING COMPARISON)=71.8064517%
AVERAGE TRAINED PERCENTAGE OF LESS-TRAINED WKCTRS(IN INTER-WING COMPARISON)=40.7419355%
AVERAGE DIFFERENCE IN TRAINING=31.0645162%
BETTER TRAINED WKCTRS PERFORMED WORK, ON THE AVERAGE, IN 96.3555436% OF THE TIME IT TOOK LESS-TRAINED WKCTRS

OVERALL STATISTICS, ALL COMPARISONS

TOTAL NUMBER OF COMPARISONS=198
BETTER TRAINED WKCTRS PERFORMED FASTER 61.6161616% OF THE TIME
AVERAGE TRAINED PERCENTAGE OF BETTER-TRAINED WKCTRS=73.5909091%
AVERAGE TRAINED PERCENTAGE OF LESS-TRAINED WKCTRS=47.6363637%
AVERAGE DIFFERENCE IN TRAINING=25.9545455%
BETTER TRAINED WKCTRS PERFORMED WORK, ON THE AVERAGE, IN 98.8010181% OF THE TIME IT TOOK LESS TRAINED WKCTRS

APPENDIX C

BACK-UP DATA

This Appendix contains the following information:

- Information on SAMTs received from Honeywell,
- Analysis of variance technique, and
- Productivity and frequency calculations.

INFORMATION ON SAMTs
RECEIVED FROM HONEYWELL
(Included in the handwritten form
provided to MCR)

<u>LEVELS OF REALISM FOR WUC PARTS ON SAMTs</u>

TFE - Ø2 Flight Control Systems

Subsystems:
- Pitot Static Systems
- FC Trim System
- Automatic FC System
- BIT System
- CADC Systems + Instruments
- FC Systems

WUCs Part and Number	Visual Realism	Spatial Realism	Auditory Realism	Kinesthetic Realism	Temporal Realism	Extent of Simulation
1. 14AAØ Computer Assy, FC	S/Gr					
2. 14ABØ Controller Assy, Stick	A/C					
3. 14ADØ Panel Assy, FC	A/C					
4. 14AEØ Panel Assy, Manual Trim	A/C					
5. 14AFØ Accelerometer Assy, Normal/Lateral	G					
6. 14AGØ Rate Gyro Assy, FC	G					
7. 14BAØ Integrated Servo Actuator, Rudder	G					
8. 14BBØ Integrated Servo Actuator, Horiz Tail	G					
9. 14BCØ Integrated Servo Actuator, Flaperon	G					
10. 14CAØ Rudder Assy	G					
11. 14CBØ Horizontal Stabilizer Assy	G					
12. 14CCA - E Flaperon Assemblies	G					
13. 14DØØ Leading Edge Flaps	G					
14. 14DAA Drive Unit, Power	G					
15. 14DAB Motor, Hydraulic	G					
16. 14DHØ Brake, Assymetry, LE Drive	G					
17. 14DJØ Indicator, Leading Edge Flap	A/C					
18. 14DKØ Switch, Limit, LE Flap Position	G					
19. 14DLØ Leading Edge Flap, LH	G					
20. 14DMØ Leading Edge Flap, RH	G					
21. 14FBØ Electronic Component Assy	G					
22. 14FCØ Pneumatic Sensor Assy	G					

WUCs Part and Number	Visual Realism	Spatial Realism	Auditory Realism	Kinesthetic Realism	Temporal Realism	Extent of Simulation
23. 14FDØ Transmitter, Angle of Attack	S					
24. 14FGØ Tube, Pitot - Static	G					
25. 14FHØ Manifold, Pneu Sensor Assy	G					
26. 51AAØ Indicator, Airspeed/Mach	A/C					
27. 51ABØ Altimeter, Servoed	A/C					
28. 51ACØ Indicator, AOA	S					
29. 51ADØ Indicator, Vertical Velocity	A/C					
30. 51BAØ Indicator, Horizontal Situation	G					
31. 51BBØ Indicator, Altitude Director	G					
32. 51CCØ Light Assy, Indexer, AOA	A/C					
33. 51DAØ Indicator, Standby Altitude	G					
34. 51DBØ Compass, Magnetic	G					
35.* 51FAØ Computer, Central Air Data	G					
36.						
37.						
38.						
39.						

LEVELS OF REALISM FOR WUC PARTS ON SAMTs

TFE - Ø3 NAV/ECM Systems

ILS
TACAN
A/G IFF

Subsystems

• definitely look at

WUCs Part and Number	Visual Realism	Spatial Realism	Auditory Realism	Kinesthetic Realism	Temporal Realism	Extent of Simulation
1. 63ADØ Panel Assy, Antilce/Anti Sel	A/C					
2. 63AEØ Selector, Antenna	A/C E Gr					
3. 64AØØ Intercommunications Set	Lab.					
4. 65AAØ Receiver-Transmitter	Grd A/C					
5 71AAØ Receiver-Transmitter, TACAN	G					
6. 71ABØ Adapter, Receiver Transmitter	G					
7 71ACØ Mount, TACAN	G					
8 71ADØ Panel, TACAN Control	A/C					
9. 71AEØ Antenna, TACAN, Upper	G					
10. 71AFØ Antenna, TACAN, Lower	G					
11 71BAØ Receiver, ILS	G					
12. 71BCØ Control, ILS Receiver	A/C					
13 71BDØ Antenna, Marker Beacons	G					
14. 71BEØ Diplexer	G					
15.						
16.						
17.						
18.						
19.						
20.						
21.						
22.						
23.						
24.						
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30.						
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33.						
34.						
35.						
36.						
37.						
38.						
39.						

LEVELS OF REALISM FOR WUC PARTS ON SAHTs

TFE - ϕ4 Electrical Systems

Subsystems:
- AC Generator System
- Battery System
- Transformer - Rectifier System
- Power Indicators
- Master Warning Indicators
- Emergency Power Unit

WUCs Part and Number	Visual Realism	Spatial Realism	Auditory Realism	Kinesthetic Realism	Temporal Realism	Extent of Simulation
1. 24ACϕ Generator, Emergency 5 KVA	SC/					
2. 24CAϕ Panel Assy, EPU Selector Switch	AC/					
3 24CCϕ Control Unit, Generator, 5 KVA	SC/SC					
4. 24CFA Switch, Safety	SC/					
5 42AAϕ Constant Speed Drive	SC/					
6 42ABϕ Generator, 4ϕ KVA	SC/					
7 42BAϕ Generator Control Unit	SC/					
8. 42 BCA Receptacle, Ground Test	/					
9. 42 CAϕ Panel Assy, Electrical Pwr, Pilot's	AE/SC					
10 42DAA Contactor, AC Pwr, 4ϕ KVA	SC/SC					
11. 42DBA Contactor, AC Pwr, ESS Bus.	/					
12. 42DCϕ Panel, Pwr-AC, ECM	SC/SC					
13. 42DDϕ Panel, Pwr-AC, Fwd Area.	/S					
14. 42DEϕ Panel Pwr-AC, RH Strake	/S					
15 42EAϕ Monitor, External Pwr	SC/					
16 42EBA Receptacle, External Pwr	SC/S					
17. 42 FBϕ Converter 5ϕϕ Watts, 12ϕϕ Hz	SC/					
18 42GAA Battery, Aircraft	/SC					
19 42GBϕ Charger, Aircraft Battery	/SC					
20. 42HAϕ Panel Assy, Pwr-DC, Aft Equip Bay-S	/					
21. 42HBϕ Panel Assy, Pwr-DC, RH Strake - S	/					
22.						

AC Panel / DC Panel

WUCs Part and Number	Visual Realism	Spatial Realism	Auditory Realism	Kinesthetic Realism	Temporal Realism	Extent of Simulation
23.						
24.						
25.						
26.						
27.						
28.						
29.						
30.						
31.						
32.						
33.						
34.						
35.						
36.						
37.						
38.						
39.						

LEVELS OF REALISM FOR WUC PARTS ON SAHTS

TFE - 1Ø Engine Start

WUCs Part and Number	Visual Realism	Spatial Realism	Auditory Realism	Kinesthetic Realism	Temporal Realism	Extent of Simulation
1. 24DAØ Starter Assy, Jet Fuel	G					
2. 24DBA Control Assy, Fuel	G					
3. 24DBB Valve, Start Fuel	G					
4. 24DBC Valve, Main Fuel	G					
5. 24DBD Valve, Max Fuel	G					
6. 24DBE Filter, Fuel Inlet	G					
7. 24DCA Controller, Jet Fuel Starter	G					
8. 24DDJ Valve, Hydr, Door Control	G					
9. 24DDK Actuator, Hydr, Door	G					
10. 24DDL Valve, Hydr Relief	G					
11. 24DDN Fuse Assy, Hydr	Lab					
12. 24DDQ Valve, Check, JFS Door	G					
13. 24DEA Motor, Hyd, Start	G					
14. 24DFA Exciter, Ignition	G					
15. 24DFB Plug, Ignitor	G					
16. 24DGØ Manifold Assy, Hydraulic	G					
17. 24DGA Valve, Hydr Relief	G					
18. 24DGB Valve, Hydr Check	G					
19. 24DGC Valve, Hydr Dump	G					
20. 24DGD Valve, Hydr Solenoid	G					
21. 24DGE Manifold, Hydr	G					
22. 24EAØ Gearbox, Accessory Drive	G					

WUCs Part and Number	Visual Realism	Spatial Realism	Auditory Realism	Kinesthetic Realism	Temporal Realism	Extent of Simulation
23.						
24.						
25.						
26.						
27.						
28.						
29.						
30.						
31.						
32.						
33.						
34.						
35.						
36.						
37.						
38.						
39.						

LEVELS OF REALISM FOR WUC PARTS ON SAMTs

TFE -11 Engine Diagnostics

① / ②

WUCs Part and Number	Visual Realism	Spatial Realism	Auditory Realism	Kinesthetic Realism	Temporal Realism	Extent of Simulation
1. 23ØØØ Turbofan Pwr Plant	G/G					
2. 23AAM Thermocouple, Immersion TT2, Sensor	G/					
3. 23AAP Control & Cylinder, Var. Vane, Comp. Inlet	lab/					
See also // 23QA7 4. 23AAQ Cylinder-Actuating, Linear, VV, Comp. Inlet	lab/					
5. 23AAR Sensor, Electric N1, Dual	lab/					
6. 23GCØ Pump Assy, Main Oil	lab/					
7. 23GEØ Filter Assy, Oil	/S					
8. 23GEB Element, Filter, Oil	/G					
9. 23HAA Control, Unified Oil, Turbine Engine	G/G					
10. 23HAB Control, Engine Electronic	?/G					
11. 23HAD Pump, Fuel, Main	/G					
12. 23HAE Pump, Fuel, Augmenter	lab/					
13. 23HAG Sensor, Hydromechanical, N2	lab/					
14. 23HAK Thermocouple, Immersion, Fan, Turb. ITS	lab/					
15. 23HAM Probe, Augmentor Pressure, PT6	lab/G					
16. 23HAN Valve, Fuel Pressure & Dump	lab/					
17. 23HAQ Valve, Solenoid, Fuel Denrichment	lab/					
18. 23KAB Igniter, Spark, Gas Turbine Eng, Main	G/					
19. 23KAD Exciter, Ignition, Dual	G/					
20. 23KAE Exciter, Ignition, Single	G/					
21. 23KAH Stator, Generator	G/					
22. 23KAJ Rotor, Generator	G/					

WUCs Part and Number	Visual Realism	Spatial Realism	Auditory Realism	Kinesthetic Realism	Temporal Realism	Extent of Simulation
23. 23KAR Box, Interconnecting	G/G					
24. 23PAB Control, Exhaust Nozzle, Convergent	ab/					
25. 23PAC Regulator, Air Press. Exhaust Nozz. Cont	lab/					
26. 23PAK-L Shaft, Flex, Prim. Act. Converg Nozz, Rt/Rt	lab/					
27. 23PAN Control - Push Pull, AJ Request	lab/					
28. 23QA4 Recorder, Events History	lab/					
29. 23QA6 Cylinder - Act, Lin, VV, Rear Compressor	lab/G					
30. 23QA7 Cylinder - Act, Lin, Compress. Bleed	lab/					
31. 23QA8 Valve, Anti-Icing, Eng. Inlet	/G					
32. 231AA Indicator, Tachometer	/At					
33. 231AB Indicator, Fan TIT	/At					
34. 231AD Indicator, Oil Pressure	/At					
35. 231AF Indicator, Nozzle Position	/At					
36. 231AP Transmitter, Oil Press, Eng.	/G					
37. 231BH Panel Assy, Eng/Jet Start	/At					
38. 231BJ Grip Assy, Throttle, Fwd, Aft	/S					
39.						

ANALYSIS OF VARIANCE TECHNIQUE

ANALYSIS OF VARIANCE (ANOVA) TECHNIQUE

Step 1:

Assign all work center observations (training/frequency/productivity combinations) to a "cell" in an ANOVA matrix. Training and frequency are the independent varibles. This examination attempts to explain the statistical weight of their impact on the dependent variable (productivity).

TRAINING \ FREQUENCY	LOW	MEDIUM	HIGH	ROW (TRAINING) AVERAGE
LOW				
MEDIUM				
HIGH				
COLUMN (FREQUENCY) AVERAGE				TOTAL AVERAGE

Based on an analysis of the spread of work center observations included in our analysis, the following definitions were adopted for the different training/frequency categories:

LOW TRAINING -- Work center with $\leq$ 20% of their personnel trained in the appropriate skill;

MEDIUM TRAINING -- Work center with > 20% but < 60% of their personnel trained in the appropriate skill;

HIGH TRAINING -- Work center with $\geq$ 60% of their personnel trained in the appropriate skill;

LOW FREQUENCY -- Work center with an action frequency of $\leq$ 1 (less than/equal 1 action/worker in the examination period);

MEDIUM FREQUENCY -- Work center with an action frequency > 1 but $\leq$ 2 (greater than 1 but less than/equal to 2 actions/worker in the examination period).

HIGH FREQUENCY -- Work center with an action frequency > 2 (greater than 2 actions/worker in the examination period).

STEP 2:

Once all work center observations are classified in the appropriate cell in an ANOVA matrix, a "cell average" productivity figure is computed in the following manner:

$$\text{CELL AVERAGE} = \frac{\sum \text{All Productivity Numbers for Work Centers in the Cell}}{\text{Number of Work Centers in the Cell}}$$

Similarly, a "Row/Column average" productivity figure is computed for each row/column in the ANOVA table. Row average productivity figures are computed in the following manner:

$$\text{ROW AVERAGE} = \frac{\sum \text{Cell Average Productivity Figures Within a Row}}{\text{Number of Cells in a Row}}$$

This average, in our analysis, provides a measure of the impact of a specific level of training across different frequency levels. Analogously, column average productivity figures are computed as follows:

$$\text{COLUMN AVERAGE} = \frac{\sum \text{Cell Average Productivity Figures Within a Column}}{\text{Number of Cells in a Column}}$$

This average provides a measure of the impact of a specific level of frequency across different training levels.

In addition, a "row/column total" productivity figure is computed for each row/column in the ANOVA matrix. These totals are simply defined:

ROW/COLUMN TOTAL = All Cell Average Productivity Figures in Each Row/Column.

Finally, an "overall average" productivity figure is computed in the following manner:

$$\text{OVERALL AVERAGE} = \frac{\sum \text{All Cell Average Productivity Figures}}{\text{Number of Cells}}$$

This number provides a measure of the average productivity observed in our sample.

As with the row/column computations, an overall total productivity figure is also computed. This total is:

OVERALL TOTAL = All Cell Average Productivity Figures.

STEP 3:

Once all averages and totals have been computed, variation figures must be computed for the analysis. The following variation figures (provided with their mathematical definitions) are computed:

$$V\text{, Total Variation} = \Sigma(\text{Cell Average Productivity Figures})^2 - \frac{(\text{Overall Total})^2}{(\text{Number of Rows})(\text{Number of Columns})}$$

$$V_T\text{, Training Variation} = \frac{\Sigma(\text{Row Total Average Productivity Figures})^2}{(\text{Number of Columns})} - \frac{(\text{Overall Total})^2}{(\text{Number of Rows})(\text{Number of Columns})}$$

$$V_F\text{, Frequency Variation} = \frac{\Sigma(\text{Column Total Average Productivity Figures})^2}{(\text{Number of Rows})} - \frac{(\text{Overall Total})^2}{(\text{Number of Rows})(\text{Number of Columns})}$$

$$V_E\text{, Error Variation} = V\ (\text{Total Variation}) - V_T\ (\text{Training Variation}) - V_F\ (\text{Frequency Variation})$$

These statistics describe the variation of the observed work center productivity figures around an overall mean productivity value. The formats are standard statistical variation formats, and so no explanation of their structure will be offered here.

In our analysis of the impact of training and frequency on productivity, these variation figures are crucial. If it can be shown that the variation attributed to frequency/training is larger than the error variation by a certain amount, then we can conclude that those factors <u>do</u> have a positive impact on productivity.

STEP 4

Calculate "mean square" values for the specific variations computed in Step 3. This is a simple procedure where V_T, V_F, and V_E are divided by their associated "degrees of freedom" to come up with a mean square value:

MS_T (Mean Square Training) = $\dfrac{V_T}{D.F._T}$ (Degrees of Freedom for Training Variable)

MS_F (Mean Square Frequency) = $\dfrac{V_F}{D.F._F}$ (Degrees of Freedom for Frequency Variable)

MS_E (Mean Square Error) = $\dfrac{V_E}{D.F._E}$ (Degrees of Freedom for Error Variable)

STEP 5

Use the "mean square" values calculated in Step 4 to calculate an "F-Ratio" for both training and frequency. The F-Ratio is a statistic that serves to measure the explanatory power of an independent variable on a dependent variable. The ratio is computed in the following form:

$$\text{F-Ratio} = \frac{\text{Mean Square Variance Attributed to a Specific Independent Variable}}{\text{Mean Square Error Variance}}$$

A large F-Ratio intuitively says that the independent variable tested has a much larger impact on the dependent variable than simple random chance, or, in a statistical sense, the independent variable is "significant."

STEP 6

Once the F-Ratios for training and productivity have been computed, the actual determination of the significance of those two variables on productivity can be made. In order to perform this determination of significance, two different hypotheses have to be advanced:

H_o: Row (Column) Average_1 = Row (Column) Average_2 = Row (Column) Average_3

(In words, this hypothesis states that training/frequency differences do not lead to statistical differences in productivity).

and

H_1: Row (Column) $\text{Average}_1 \neq$ Row (Column) $\text{Average}_2 \neq$ Row (Column) Average_3

(Training/frequency differences do lead to statistical differences in productivity).

To make a determination as to which hypothesis should be accepted, the F-Ratios for both training and frequency computed in Step 5 should be compared against a value of the F-Distribution at a specific level of confidence. If the F-Ratio (computed) > F-Distribution (at a specific level of confidence), then H_0 is rejected and H_1 is accepted. In effect, this conclusion says that the independent variable being tested (training or frequency) does have a statistically measurable impact on productivity at a specific level of confidence.

PRODUCTIVITY AND FREQUENCY CALCULATIONS

PRODUCTIVITY = $\frac{\text{HOURS}}{\text{FREQUENCY}}$

(14A00)

BASE AND WORK CENTER	% TRAINED	ACTION CODES P	R	T	U	X	Y
OVERALL (Σ avg base hours - 3)	40	$\frac{176}{3}$ 59	$\frac{883}{3}$ 294	$\frac{234}{3}$ 78	$\frac{197}{3}$ 66	$\frac{286}{3}$ 95	$\frac{473}{3}$ 158
WING K	32	$\frac{233}{1.0}$ ~~233~~ 57	$\frac{902}{2.4}$ ~~376~~ 94	$\frac{304}{1.1}$ ~~276~~ 69	$\frac{184}{.8}$ ~~230~~ 58	$\frac{543}{1.7}$ ~~319~~ 80	$\frac{833}{1.1}$ ~~757~~ 190
K25	37	$\frac{148}{1.5}$ 98	$\frac{290}{2.3}$ 126	$\frac{169}{1.4}$ 121	$\frac{121}{1.2}$ 101	$\frac{70}{1.0}$ 70	$\frac{362}{1.0}$ 362
K20	40	$\frac{22}{1.4}$ 15	$\frac{212}{6.6}$ 32	$\frac{61}{3.2}$ 19	$\frac{14}{1.6}$ 9	$\frac{16}{.6}$ 26	$\frac{81}{2.4}$ 34
K22	11	$\frac{27}{.6}$ 45	$\frac{237}{2.2}$ 108	$\frac{32}{.5}$ 64	$\frac{10}{.2}$ 50	$\frac{169}{1.8}$ 94	$\frac{217}{1.2}$ 180
K21	42	$\frac{37}{.6}$ 62	$\frac{163}{1.6}$ 102	$\frac{42}{.7}$ 60	$\frac{39}{.4}$ 97	$\frac{288}{2.9}$ 99	$\frac{173}{.9}$ 192
WING L	46	$\frac{364}{1.3}$ ~~280~~ 70	$\frac{2285}{6.5}$ ~~352~~ 88	$\frac{560}{1.6}$ ~~350~~ 88	$\frac{529}{1.8}$ ~~294~~ 73	$\frac{294}{1.1}$ ~~267~~ 67	$\frac{463}{.9}$ ~~514~~ 129
L1	55	$\frac{54}{1.7}$ 32	$\frac{364}{7.1}$ 51	$\frac{58}{2.1}$ 28	$\frac{74}{1.9}$ 39	$\frac{19}{.4}$ 48	---
L4	45	$\frac{48}{1.3}$ 37	$\frac{449}{5.8}$ 77	$\frac{49}{.8}$ 62	$\frac{61}{1.6}$ 38	$\frac{43}{.5}$ 86	$\frac{50}{.5}$ 100
L3	40	$\frac{207}{1.6}$ 29	$\frac{848}{5.6}$ 151	$\frac{379}{2.6}$ 141	$\frac{295}{2.4}$ 123	$\frac{58}{.6}$ 97	$\frac{24}{.1}$ 240
L2	44	$\frac{55}{.7}$ 79	$\frac{624}{7.9}$ 79	$\frac{75}{.9}$ 83	$\frac{99}{1.2}$ 83	$\frac{175}{3.0}$ 58	$\frac{390}{3.0}$ 130
WING J	52	$\frac{81}{.6}$ ~~135~~ 45	$\frac{259}{1.0}$ ~~259~~ 86	$\frac{53}{.4}$ ~~133~~ 44	$\frac{58}{.3}$ ~~193~~ 64	$\frac{228}{1.7}$ ~~134~~ 45	$\frac{446}{1.3}$ ~~343~~ 114
J12	36	$\frac{12}{.4}$ 30	$\frac{191}{2.0}$ 95	$\frac{9.5}{.5}$ 19	$\frac{11}{.3}$ 35	$\frac{108}{2.2}$ 49	$\frac{355}{2.5}$ 142
J10	92	$\frac{41}{.8}$ 51	$\frac{23}{.3}$ 77	$\frac{37}{.6}$ 62	$\frac{39}{.6}$ 65	$\frac{87}{2.3}$ 38	$\frac{74}{1.1}$ 68
J11	20	$\frac{28}{.5}$ 56	$\frac{45}{.7}$ 64	$\frac{6.5}{.2}$ 33	$\frac{85}{.1}$ 85	$\frac{33}{.3}$ 109	$\frac{18}{.2}$ 90

*The total base-wide hours (numerator) are divided by the base-wide frequency (denominator) to get the base-wide productivity. However, in order to get a base productivity number comparable to the individual work center numbers, the result is then divided by the appropriate number of work centers at each base (i.e., 233-4 = 58).

$$\text{FREQUENCY} = \frac{\text{NO. OF OBSERVATIONS}}{\text{NO. OF WORKERS}}$$

(14A00)

BASE AND WORK CENTERS	NUMBER OF WORKERS	ACTION CODES					
		P	R	T	U	X	Y
OVERALL	144	144/144 1.0	459/144 3.2	157/144 1.1	138/144 1.0	219/144 1.5	156/144 1.1
WING K	72	74/72 1.0	171/72 2.4	81/72 1.1	57/72 .8	121/72 1.7	79/72 1.1
K25	30	46/30 1.5	68/30 2.3	42/30 1.4	37/30 1.2	31/30 1.0	29/30 1.0
K20	5	7/5 1.4	33/5 6.6	16/5 3.2	8/5 1.6	3/5 .6	12/5 2.4
K22	18	10/18 .6	40/18 2.2	9/18 .5	4/18 .2	32/18 1.8	21/18 1.2
K21	19	11/19 .6	30/19 1.6	14/19 .7	8/19 .4	55/19 2.9	17/19 .9
WING L	39	51/39 1.3	255/39 6.5	62/39 1.6	70/39 1.8	43/39 1.1	34/39 .9
L1	9	15/9 1.7	64/9 7.1	19/9 2.1	17/9 1.9	4/9 .4	---
L4	11	14/11 1.3	64/11 5.8	9/11 .8	18/11 1.6	6/11 .5	6/11 .5
L3	10	16/10 1.6	56/10 5.6	26/10 2.6	24/10 2.4	6/10 .6	1/10 .1
L2	9	6/9 .7	71/9 7.9	8/9 .9	11/9 1.2	27/9 3.0	27/9 3.0
WING J	33	19/33 .6	34/33 1.0	14/33 .4	11/33 .3	56/33 1.7	43/33 1.3
J12	11	4/11 .4	22/11 2.0	5/11 .5	3/11 .3	24/11 2.2	28/11 2.5
J10	12	10/12 .8	4/12 .3	7/12 .6	7/12 .6	28/12 2.3	13/12 1.1
J11	10	5/10 .5	7/10 .7	2/10 .2	1/10 .1	3/10 .3	2/10 .2

PRODUCTIVITY = $\frac{\text{HOURS}}{\text{FREQUENCY}}$

(23Z00)

BASE AND WORK CENTER	% TRAINED	ACTION CODES		
		P	Q	X
OVERALL (Σ AVG BASE HOURS ÷ 3)	67	$\frac{746}{3}$ 249	$\frac{672}{3}$ 224	$\frac{556}{3}$ 185
WING K*	59	$\frac{1616}{1.5}$ $\cancel{1077}$ 269	$\frac{1595}{1.5}$ $\cancel{1063}$ 266	$\frac{1200}{1.3}$ $\cancel{923}$ 231
K24	54	$\frac{221}{.6}$ 368	$\frac{231}{.6}$ 385	$\frac{43}{.3}$ 145
K23	42	$\frac{160}{1.3}$ 123	$\frac{192}{1.4}$ 137	$\frac{225}{.3}$ 750
K27	56	$\frac{832}{3.0}$ 277	$\frac{842}{3.0}$ 281	$\frac{897}{4.4}$ 204
K26	76	$\frac{403}{1.6}$ 252	$\frac{330}{1.5}$ 220	$\frac{35}{.2}$ 175
WING L	74	$\frac{913}{1.4}$ $\cancel{652}$ 163	$\frac{731}{1.2}$ $\cancel{609}$ 152	$\frac{145}{.2}$ $\cancel{725}$ 181
L1	70	$\frac{44}{.4}$ 110	$\frac{73}{.5}$ 146	---
L4	75	$\frac{36}{.4}$ 90	$\frac{60}{.6}$ 100	$\frac{17}{.3}$ 57
L3	74	$\frac{457}{1.8}$ 254	$\frac{324}{1.5}$ 216	---
L2	78	$\frac{376}{3.0}$ 125	$\frac{274}{2.2}$ 125	$\frac{128}{.8}$ 160
WING J	74	$\frac{343}{.6}$ $\cancel{572}$ 191	$\frac{270}{.5}$ $\cancel{540}$ 180	$\frac{691}{1.6}$ $\cancel{432}$ 144
J12	71	$\frac{115}{.5}$ 230	$\frac{52}{.5}$ 104	$\frac{7}{.4}$ 18
J10	75	$\frac{188}{1.3}$ 145	$\frac{136}{.8}$ 170	$\frac{568}{4.3}$ 132
J11	75	$\frac{40}{.2}$ 200	$\frac{82}{.3}$ 273	$\frac{116}{.4}$ 290

*The total base-wide hours (numerator) are divided by the base-wide frequency (denominator) to get the base-wide productivity. However, in order to get a base productivity number comparable to the individual work center numbers, the result is then divided by the appropriate number of work centers at each base (i.e., 1077÷4 = 269).

$$\text{FREQUENCY} = \frac{\text{NO. OF OBSERVATIONS}}{\text{NO. OF WORKERS}}$$

(23Z00)

BASE AND WORK CENTERS	NUMBER OF WORKERS	ACTION CODES					
		P		Q		X	
OVERALL	142	$\frac{178}{142}$	1.3	$\frac{164}{142}$	1.2	$\frac{155}{142}$	1.1
WING K	66	$\frac{100}{66}$	1.5	$\frac{99}{66}$	1.5	$\frac{85}{66}$	1.3
K24	26	$\frac{15}{26}$	.6	$\frac{16}{26}$	.6	$\frac{9}{26}$	.3
K23	7	$\frac{9}{7}$	1.3	$\frac{10}{7}$	1.4	$\frac{2}{7}$	.3
K27	16	$\frac{48}{16}$	3.0	$\frac{48}{16}$	3.0	$\frac{70}{16}$	4.4
K26	17	$\frac{28}{17}$	1.6	$\frac{25}{17}$	1.5	$\frac{4}{17}$	.2
WING L	38	$\frac{54}{38}$	1.4	$\frac{46}{38}$	1.2	$\frac{9}{38}$	.2
L1	10	$\frac{4}{10}$	.4	$\frac{5}{10}$	.5	---	
L4	8	$\frac{3}{8}$	.4	$\frac{5}{8}$	.6	$\frac{2}{8}$	.3
L3	11	$\frac{20}{11}$	1.8	$\frac{16}{11}$	1.5	---	
L2	9	$\frac{27}{9}$	3.0	$\frac{20}{9}$	2.2	$\frac{7}{9}$	.8
WING J	38	$\frac{24}{38}$	.6	$\frac{19}{38}$	.5	$\frac{61}{38}$	1.6
J12	14	$\frac{7}{14}$	.5	$\frac{5}{14}$	.4	$\frac{5}{14}$	.4
J10	12	$\frac{15}{12}$	1.3	$\frac{10}{12}$	.8	$\frac{51}{12}$	4.3
J11	12	$\frac{2}{12}$	.2	$\frac{4}{12}$	.3	$\frac{5}{12}$	.4

APPENDIX D

TRAINING EFFECTIVENESS ANALYSIS BACKGROUND MATERIALS

APPENDIX D

TRAINING EFFECTIVENESS ANALYSIS BACKGROUND MATERIALS

This Appendix provides additional information about TRASANA's TEA process. Information is presented in two sections:

- the TRADOC TEA Handbook, and
- the TEA for the M1 (ABRAMS) Main Battle Tank.

A. <u>THE TRADOC TRAINING EFFECTIVENESS ANALYSIS (TEA) HANDBOOK</u>

The TRADOC TEA Handbook was developed by TRASANA to be used as a guidance document for planning, conducting and documenting TEA studies. The handbook is still in draft and is an evolving document. The present description is a summary of what is contained in the handbook. The handbook covers three broad areas which are discussed in the subsections that follow:

- TEA system overview,
- types of TEA, and
- guidance for TEA study planning.

1. <u>TEA System Overview</u>

The TEA system is a management tool for developing and assessing the effectiveness of training subsystems that are related to hardware-oriented systems. The TRADOC TEA system can be defined as a series of systematic studies in hardware-oriented systems conducted to assess the impact of training on system effectiveness, and to insure development and implementation of cost effective training subsystems.

There are two ways of classifying TEAs. The primary way is to divide them according to the phase of the life cycle with which a given TEA is associated. This means on developing hardware-oriented systems or on fielded systems or on both. The second way has to do with whether the relation of cost and effectiveness is examined.

2. Types of TEA

The five different types of TEAs are discussed below.

- Cost And Training Effectiveness Analysis (CTEA): A systematic, continuous evaluation process conducted during the acquisition cycle of a hardware-oriented system focusing on training subsystem development and training inputs to the Cost and Operational Effectiveness Analysis. This analysis addresses soldier capability to operate the hardware.

- Initial Screening Training Effectiveness Analysis (ISTEA): A systematic study conducted on a fielded hardware-oriented system to determine if there is a significant gap between the Design Effectiveness (E_D) and the Actual Effectiveness (E_A) of the hardware-oriented system.

- Training Subsystem Effectiveness Analysis (TSEA): A systematic study conducted to determine if the existence of a significant performance gap is partly or entirely due to the training subsystem.

- Training Developments Study (TDS): A systematic study conducted to develop a fix for a training subsystem found to be deficient and/or too expensive and to develop training devices.

- Total System Evaluation (TSE): A systematic evaluation of the hardware, logistics support, and personnel support subsystems of a fielded hardware-oriented system. A TSE is conducted when it has been determined that the training subsystem is neither the sole nor primary cause of a significant performance gap.

Each of these is described in the subsections below.

a. <u>CTEA</u>

The CTEA purposes are:

- comparing the cost and effectiveness levels of various training subsystem alternatives;

- selecting the training subsystem alternative which best supports and minimizes the cost associated with the Army's training mission for a specified hardware subsystem, while at the same time insuring that performance standards of soldiers are at the highest levels consistent with soldiers' capabilities; and

- providing training subsystem data inputs for consideration at all decision points during the acquisition cycle.

A CTEA has the following essential parts:

- study objective,
- definition of essential elements of analysis (EEA),
- measures of training effectiveness (MOTE),
- data collection plan,
- data collection instruments, and
- data analysis plan.

Thus, the CTEA evaluates the cost and effectiveness of alternative training approaches as they are being formulated to support the developing total hardware-oriented system. The CTEA is a continuous evaluative process that provides the basis for comparing and retiring alternative training methods.

b. <u>ISTEA</u>

The ISTEA purposes are to:

- determine if a significant performance gap exists for a fielded hardware subsystem, and

- provide baseline data of soldier capabilities to support CTEA on newly developing hardware systems.

An ISTEA has the same basic parts as the CTEA.

The ISTEA is primarily a quality control mechanism in the TRADOC TEA system. The basic function is to determine if the actual effectiveness of a fielded hardware system is significantly lower than its design effectiveness. Furthermore, the results of an ISTEA provide the basis for any other follow-on TEAs.

c. TSEA

The TSEA purpose is to examine the training subsystem in detail to determine if an existing performance gap is caused totally or in part by the training subsystem. A TSEA has the same basic parts as the CTEA.

The TSEA is usually conducted when an ISTEA finds a significant performance gap. The TSEA then determines if the performance gap is caused entirely or in part by the training subsystem. A TSEA can be initiated in the absence of an ISTEA when there is other evidence of a performance gap such as:

- widespread low Skill Qualification Test (SQT) scores for system operators and maintainers,
- low annual service practice scores/operational readiness test scores,
- large numbers of weapons qualification failures, or
- unsatisfactory scores Army-wide on Army Training Evaluation Program (ARTEP) tasks for units operating a certain hardware subsystem.

d. TDS

The TDS purpose is to:

- develop a fix (change or modification) for a training subsystem deficiency,

- develop a more cost effective way to train,
- develop a system-related training device for either a developing or a fielded system, and
- develop a non-system related training device.

A TDS has the same basic parts as the CTEA.

The TDS is basically designed to fix a training subsystem found to be deficient and/or too expensive.

e. TSE

TSEs are conducted on fielded systems when it is determined by a TSEA that the training subsystem is neither the sole or primary cause of a performance gap. When the TSEA has identified factors other than training that directly or indirectly degrade the effectiveness of the total system, thereby causing a performance gap, a TSE is initiated. These factors are typically elements of one or more of the following subsystems: hardware, logistics support, or personnel support. A TSE involves the assessment and analysis of the foregoing subsystems to determine why and how these suspect factors contribute to a performance gap. The goal is to arrive at cost effective solutions that will eliminate the performance gap.

At the present time the TSE planning logic and methodology are still being developed. Thus the TSE description is not completed in the TEA handbook.

3. Guidance for TEA Study Planning

This section is a discussion of each of the elements or steps that comprise a TEA, regardless of type. These steps are:

- study design,
- data collection,
- data analysis, and
- results or data interpretation.

a. Study Design

Study design normally consists of the following sequence of events before arriving at the determination of how the study will be performed:

- state the study question,
- state the EEA,
- determine the sample,
- determine the treatment,
- decide what statistical treatment is to be used, and
- determine the research design.

The study question is the overall objective of the study. The EEA are the clear questions that must be answered to meet the study objective. They should express a relationship between two observables (variables) that lend themselves to some form of measurement. The sample is a subset of the total population which is representative, in a statistical fashion, of the population. The treatment is the type of instrument used to measure some variable (e.g., SQT scores). The statistical treatment will depend upon the question to be answered and the nature of the data. The research design is determined by whether there is a control group and whether a pre-test and a post-test are used in developing data.

b. Data Collection

Data collection is not governed by any specific set of rules other than the advice to collect all that is needed and use all valid data. Data collection can be improved by using experienced persons and by examining previous studies. The only rules that are rigorously applied are to insure that:

- all necessary data is collected,
- collection forms are usable, and
- the data can be easily coded for computer use.

c. Data Analysis

Data analysis varies from one study to another. The planning and control of studies, however, will necessitate the following:

- data collation, or how to aggregate the information in a useful manner;
- check of data characteristics, which requires an understanding of the descriptive statistics associated with the data;
- selection of appropriate statistics, depending upon the data characteristics, research design and other study characteristics;
- selection of computer program/coding; and
- processing of the data.

Once the data analysis is completed, results can be developed.

d. Data Interpretation

Provided that a good design is accomplished, good quality control of data collection is provided and use of appropriate statistics is completed, then answers can be provided to the EEA. Exhibit D-1 shows the TEA planning process.

B. THE TEA FOR THE M1 (ABRAMS) MAIN BATTLE TANK

MCR requested the M1 TEA from TRASANA because it is the Army's largest newly fielded weapon system and because the TEA addresses maintenance MOSs which are the primary interest of our study. The report presents the results of the TEA of new equipment training to transition M60A1 tank operators and maintainers to become M1 tank qualified. Data analyzed included demographic, aptitude, attitude, and instruction scores which are related to pre-training, course-imbedded, and post-training hands-on test scores. Major proficiency problems were discovered in the operator and turret mechanic training programs. The only deficiency noted for the tracked vehicle mechanic was that of troubleshooting using the test set. In order to narrow the scope of our discussion, which is for illustrative purposes only, the part of the TEA pertaining to the tracked vehicle mechanic is addressed in the following subsections:

- objectives and EEA,
- methodology and test design,
- data collection,
- data analysis, and
- results or findings.

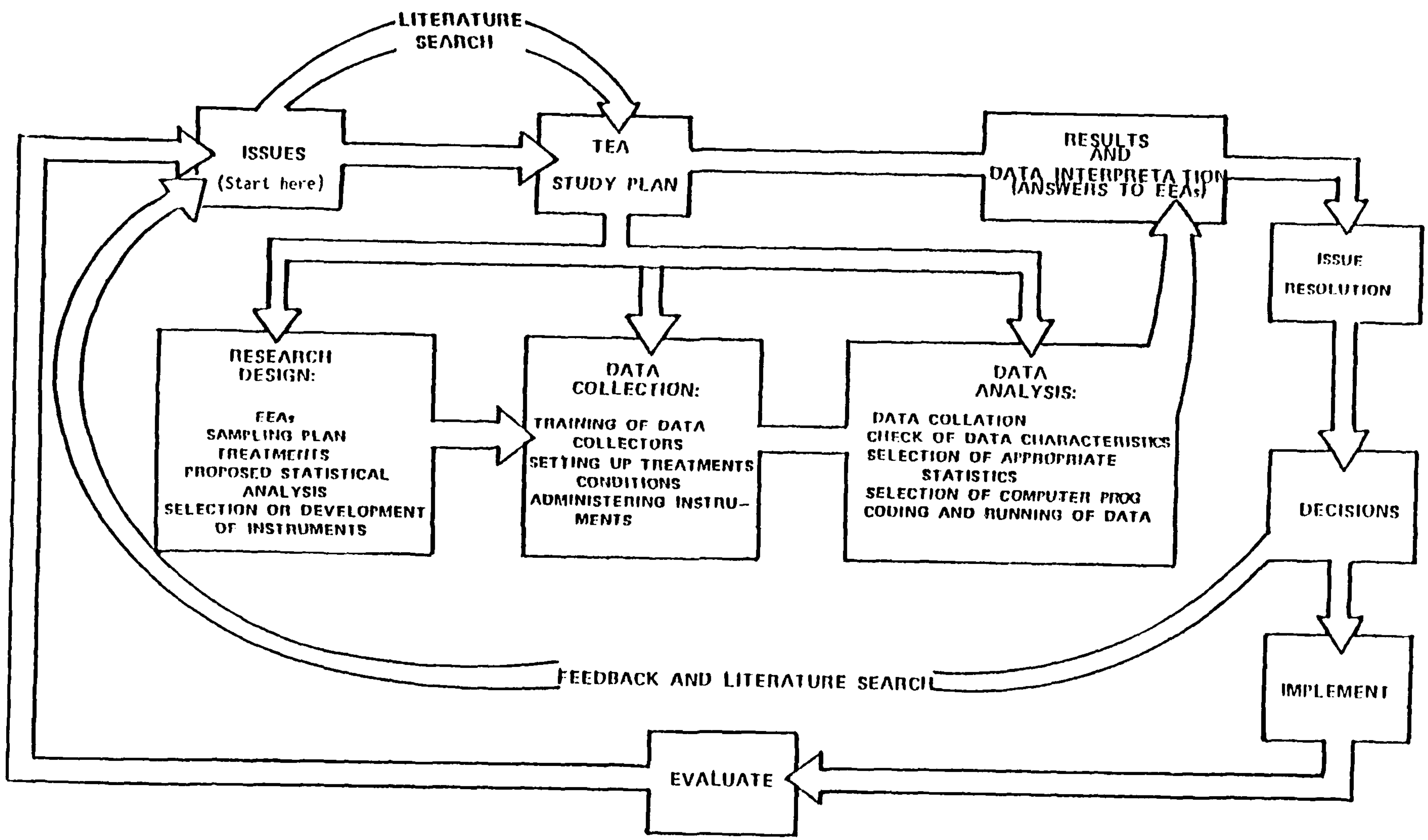

Exhibit D-1. TEA PLANNING PROCESS

1. Objectives and EEA

The objectives of the TEA were to:

- assess the effectiveness of transition training programs for M60A1 personnel to become proficient M1 personnel, and
- project the potential of these programs when they are fielded with the M1 tank.

The EEA stated in the study plan are listed below.

- What are the M1 tank-specific critical tasks for maintenance?
- What are the pre-training proficiencies of personnel?
- What are the tasks and levels of effort included in the training program?
- What level of proficiency is shown by trainees during the training program?
- What is the demonstrated post-training proficiency of personnel?
- What performance deficiencies were found in post-training exercises?
- What are the soldier profiles (personal characteristics) of trainers, students, and potential users of the training program?
- What are the attitudes and perceptions of the students/trainers of the training and hardware subsystem?

2. Methodology/Test Design

The test design is a pre-test, training, and post-test design. The pre-test gathered demographic, attitude, and pre-training aptitude data. The training phase provided the training program test results using hands-on tests. The post-training phase provided the after-training proficiency and attitude data.

3. Data Collection

Data collection took place in four parts shown below.

- Pre-training--Questionnaires and surveys which established demographic, attitude, motivation, and aptitude characteristics of each soldier to be trained were administered and hands-on testing of M60A1 skills required for admission to the transition training program was accomplished.

- Training--Hands-on tests which assessed each student's performance at the end of each major topic in the program were administered.

- Post-training--Hands-on and written tests of M1 skills, and written attitude questionnaires were completed. Additional post-training data was obtained through the administration of the post-training written test, questionnaires to determine attitude changes, and administration of a task criticality survey.

4. Data Analysis

The data was collected using an attitude survey, motivation questionnaire, post-training hands-on test, post-training written test, and a task criticality test. A statistical analysis using a multiple regression equation was attempted; however, due to the number of predictive variables, no predictors of proficiency were found for the MOS 63E (tracked vehicle mechanic). The TEA did find from the hands-on test results that the training was effective for all tasks except one (use of the STE/M1 test set for transmission troubleshooting).

5. Results of Findings

The training program was effective in all areas except that of troubleshooting using the STE/M1 test set. Since the soldiers were a representative sample of the Army-wide MOS 63E population, one would expect this same result if the same program were given to other representative samples.