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ABSTRACT

Concepts currently used in conveying technical information about the operation and maintenance of equipment in the U.S. Army were investigated. The objective was to develop a more cost effective maintenance program by reducing personnel costs through a more effective software link between the hardware and maintenance personnel. The study objectives were organized into seven major tasks: (1) To identify new concepts for maintenance that hold promise for reducing the cost of equipment ownership, (2) to analyze the new concepts in order to identify the fundamental elements responsible for their effect upon maintenance cost, (3) to match fundamental elements to particular Army situations, evaluate their validity, and make cost projections, (4) to review the fundamental elements against the commodity systems and project the cost of ownership which could accrue through use of these elements to produce all Army technical manuals, (5) to prepare a specification which includes all the fundamental elements tailored to appropriate Army situations, (6) to prepare a sample manual based on the specification, and (7) to prepare a plan for testing the sample manual. This report summarizes interim reports for each of the seven tasks. (Author/NJ)

STUDY AND PROPOSAL FOR THE IMPROVEMENT OF
[illegible] METHODS

Contract No. DAAD05-74-C-0783

FINAL REPORT

Prepared by:

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December 31, 1975

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In addition to naming these individuals we would like to express our appreciation to the many technical personnel in the Ordnance School who answered questions and provided equipment for analyses made in preparing the sample materials produced under the contract. Mr. Harold Oliver, Educational Advisor at the Ordnance School, made the arrangements for their help.

The panel members who provided their advice in reviewing work on the contract are prominent members in this field of research. They are, Dr. John P. Foley, Jr., Dr. Kay Inaba, Mr. Theodore Post and Mr. Harold Price.

There were key people in initiating this contract on Low Cost Ownership. Their attention to the need of the Army and their knowledge of means available for fulfilling those needs were essential for bringing the contract into being. Those singled out here are Dr. Thomas Rowan of the Logistics Management Institute, Mr. Paul Burns and Mr. Roger Graves, of the Army Materiel Command.

Finally, we wish to express appreciation and high regard for all of the research personnel who have developed the new concepts in all the services and industry over the past twenty years. Without them, there would be nothing to report, nor would the means be available for the Army to implement the Job Performance Manual and Job Performance Guide Specifications in pursuit of low cost ownership.

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This study reviews the new concepts for Technical Manuals which have been developed and tested over the past twenty years. The study focuses on those new concepts which have shown that personnel can perform better or with less training when using these new concepts. The processes and techniques used by these new concepts to obtain better job performance or less training are identified, analyzed, and summarized in a specification incorporating the best features of each. The test results obtained with the new concept

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20. Abstract

manuals are summarized and projected into the personnel costs of owning equipment. Projections of these figures indicate a reduction in the cost of ownership of appr. [illegible] million per year from adoption of the specification of the processes used in the new concepts. The specification, Draft MIL-M-632XX(TM) has two Parts, I and II. They represent an integration of Technical Manuals (Part I) and Training (Part II) into one package which can be used for self paced, self contained, on the job training while trainees produce useful job products. A sample manual was produced under the specification covering a turret subsystem of the M60A2 tank. A test plan for experimental and operational tests of JPMs was also developed. The draft specification, described above, and the sample manual are documented separately and provided under separate cover to this report. The latter is identified as:

SAMPLE TECHNICAL MANUAL

TM 9-2350-232-24-1

TM 9-2350-232-24-2

TM 9-2350-232-24-3

TM 9-2350-232-24-4

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BACKGROUND

The objective of this study is to develop a more cost effective maintenance program. It involves a comprehensive systematic investigation of information transmission techniques now used and proposed for use by equipment operators and maintainers. Information transmission techniques were evaluated within the parameters of environment, task and equipment complexity, personnel training and competence as they apply. This study developed an improved maintenance program which could result in lower maintenance costs, better reliability, and higher availability of Army materiel.

Today the cost of ownership of equipment is higher than the cost of procuring those items. There is a cultural lag in recognizing this state of affairs. In earlier days we could properly think of the hardware item as an expensive investment to be protected by careful maintenance and repair. Today the cost of maintenance personnel has gone up, and hardware items are so complex and have so many parts to wear out and fail, that many more maintenance personnel are required to care for them. One third of the personnel in the U. S. Armed Services are presently in full time maintenance work[1], and this does not include all the operators who do maintenance part time. The cost of these personnel is greater than the cost of equipment procurement in a year and is the major factor in cost of ownership.[2] Replacement parts are another cost of ownership, but they are relatively small in comparison with personnel costs, so that when we consider costs of ownership, we must consider the ways in which personnel costs can be changed.

Equipment can be better designed for ease of maintenance, but this study does not explore that approach. It traces what has been done that can change personnel costs directly.

There are three ways personnel costs can be changed:

1. By reducing non-productive hours spent in formal classrooms.

2. By reducing work force through improved performance on the job.

3. By reducing false removals through improved performance on the job.

There have been numerous "new concepts" advanced in the last twenty years for improving personnel performances and reducing formal training time. Most of these new concepts have been developed in the Psychological, Behavioral Science community rather than in the Engineering community. They focus on changes in the personnel subsystem rather than on engineering changes. Much of this research deals with the software link between the hardware and maintenance personnel. Traditionally, this software link has been the

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[1] Statistical Abstract of the United States, United States Department of Commerce, 91st Edition, 1970.

[2] Manpower costs have increased from 37% of the U. S. Defense Budget in 1962 to 47% in 1972 (Budget of the U. S. Government) and the percentage in 1975 is estimated at 55-60%.

Technical Manual. A certain group of the new concepts propose a new medium for this link; e.g., microfiche, tape, film records, etc. However, the medium used for this link has little or no effect on the cost of ownership. It is the content of information, not the medium of presentation, that changes performance on the job.

The new concepts of importance here are concerned with changing the information that flows across these links. It is by changing the information that the performance of maintenance personnel and the requirements for formal schooling can be changed. This in turn impacts the three factors listed above and consequently the costs of ownership. The present study is designed to examine all these new concepts, to identify elements of the concepts which have the greatest effect on changing performance.

It has been recognized that different situations may require different concept elements; it has also been suggested that some families of elements are suited to some situations and not others; nevertheless, the aim of this study is to examine different situations in the Army with the intention of tailoring a single new concept to fit all situations, with variations if required.

The objectives of this study were organized into seven tasks:

Task 1: To identify new concepts for maintenance that hold promise for reducing the cost of equipment ownership.

Task 2: To analyze the new concepts in order to identify the fundamental elements responsible for their effect upon maintenance cost.

Task 3: To match fundamental elements to particular Army situations, to evaluate their validity, and to make broad cost projections.

Task 4: To review the fundamental elements against the Commodity Systems, and project the cost of ownership which could accrue through use of these elements to produce all Army TMs.

Task 5: To prepare a specification which includes all the fundamental elements tailored to Army situations where they are appropriate.

Task 6: Prepare a sample manual based on the specification.

Task 7: Prepare a test plan for testing the sample manual.

Interim reports were prepared on each of the above tasks during the course of the contract. This report summarizes and replaces all of the interim task reports. The interim task reports are working papers each contributing to the next reports and the final report.

In addition, the study provides a gross estimate of the reduction in cost of ownership that adoption of this new Technical Manual specification should support. A more precise estimate would depend on factors which fluctuate and extrapolations from factors which do not justify such precision. In order for the potential reductions in cost of ownership to be realized, the personnel and training subsystems must be changed, but they cannot be changed without the change in information supplied through the Technical Manual link; we are, then, talking about a change in one system that will have an effect across other Army systems. This is one of the most difficult changes to accomplish because the separate systems do not formally "come together" below the level of the Chief-of-Staff of the Army. If changes in one command are to be coordinated with changes in other commands, high level coordination is required.

Though this coordination is not the subject of this study, the fact that the subject of low cost ownership cuts across commands is specifically recognized. It is a fact that has made change difficult in the past. This study is concerned with the technology for making the change possible. It does this by drawing together every relevant concept which has already been tested. In doing this, a single new technology is identified, which is an amalgamation of small scale studies in all of the services and industry. This provides the Army with the best of what has gone before, tailored to their situations. It provides the research community with a way of organizing in one study what has previously been discovered in separate studies, conducted for different purposes in different situations. In the process, it resolves old arguments and sets a new base from which to proceed. The questions that remain to be answered are those that can be approached only through larger scale implementations that have never been possible with the resources of the research community. The results of the present study provide the Army with the best possible specifications and evidence for implementation. The implementation itself must be coordinated primarily between AMC and TRADOC and should be accomplished with a concurrent research study to keep performance records. These records should provide the evidence for possible future reductions in work force based on improved performance. It will also provide evidence of possible increments in performance as school training is decreased, and personnel begin to perform more on the basis of information in the Technical Manual than on the basis of formal school instruction.

With this overview, the specific tasks and products of this study on low cost ownership are now presented.

CONCLUSIONS

1. The cost of owning equipment is more than the cost of procuring it. The cost of the personnel subsystem has risen from 3[illegible] of the Defense Budget in 1962 to more than 55-60 in mid 197[illegible].

2. There are approximately 169,000 personnel in the full time electronic and mechanical work force of the Army. This cost of ownership of equipment is approximately 5 billion dollars per year.

3. There are approximately 56,000 new Army personnel trained each year for full time maintenance jobs in formal schools averaging about 20 weeks each and contributing approximately 1.2 billion dollars annually to the cost of ownership.

4. There is ample evidence that a new approach to maintenance Technical Manuals can reduce these costs of ownership by about 1.7 billion dollars per year, and two billion dollars would not necessarily be the upper limit of this estimate.

5. The large reductions in cost come from a reduction in school training of about 75% and a 15% reduction in the size of work force. Some smaller reductions may also be achieved by reductions in the number of false removals and the supply perturbations they entail. No cost savings are seen for the manuals themselves, but their cost is only a very small fraction of the cost of training and work force.

6. The new approach is based on a change in conception and assumptions about technical manuals. Instead of using training to provide the new maintenance personnel with general information which is combined with specific equipment descriptions on the job, the new approach is to analyze all jobs and describe exactly what is to be done in the TM to maintain the equipment. The descriptions are presented in graphics and short words for a user with grade school reading skills.

7. The changes required to bring about these reductions in cost of ownership require coordination between major commands, particularly AMC and TRADOC.

8. The specification prepared in this study incorporates the fundamental elements from all new concepts which have proven their effectiveness in the Army, Navy, Air Force, Coast Guard, and industry over the past 18 years. It provides the Army with the best single approach for accomplishing reductions in cost of ownership.

RECOMMENDATIONS

It is recommended that:

1. DARCOM and TRADOC jointly implement the specification and personnel system changes described here on a pilot scale, e.g., on one or more new major items of equipment such as a tank or missile, and on one or more items of existing high density equipment in the Army inventory, e.g., tracked vehicles, selected communications or artillery computing equipment.

2. The pilot scale implementations should be conducted by Army personnel, but research personnel should also be involved in data collection and cost projections over a period of years in order to gain more precise estimates than are possible from the small scale studies conducted to date. This should be coordinated at a research level with similar pilot scale implementation being conducted by the Air Force.

3. Plans should be prepared for further larger scale implementation based on experience gained in the pilot scale programs. This would involve production of new Technical Manuals for many items of existing equipment and new equipment with the specifications being similar to those used in the pilot scale implementations.

4. Advance development research funds should be allocated to this effort as it will require some kinds of modification and improvement. As the scale of operations identifies new problems, e.g., reducing the number of MOSs as personnel can effectively perform a greater variety of jobs, and job relevant testing of personnel for advancement, new solutions will be needed to capitalize on these potentials. Also, such studies will be of value to other services and industry as well as for setting priorities and implementation schedules within the Army.

5. Personnel with research experience in this field should be retained to help guide pilot scale implementation effort. This should include help to the Army procuring agency and to the rest of industry which must learn new methods for meeting the new specifications.

TASK 1

A. General Discussion

New concepts that claim to improve transmission of maintenance information from manufacturer to user were identified in this study and analyzed. They range from ideas published in a company brochure to fully developed and tested techniques. The first analysis of new concepts was to identify those which dealt only with media (photographic and electronic techniques) and not the content of information transmitted over the media. This was the first analysis because the medium of transmission of information does not appreciably affect cost of ownership, the study objective. There can be no further analysis of media in terms of their effect on cost of ownership, because they have no effect on cost of ownership. The appropriateness of any transmission medium for Army situations depends on power and mobility characteristics of the equipment associated with the media, not cost of ownership. None of these new concepts which dealt with media had any test data to demonstrate any advantage over traditional paper technical manuals. Essentially all the techniques of information transmission that do affect cost of ownership can be used over any medium.

When the term new concepts in maintenance is used hereafter in the report it refers only to those that have a potential for affecting the major costs of ownership, the personnel subsystem.

All of these new concepts promise to improve maintenance through improved performance of maintenance personnel. There were no other criteria for inclusion in the survey. It is believed that the survey included virtually all the new concepts, and it certainly includes all the major ones. The survey portion of the present study did not uncover any important new concepts that had not already been identified by others.

The survey format is not adequate to provide a breakthrough in this field. Surveys merely describe, they do not create a structure for reducing all results to a common form which can be used to structure the next steps. Advances can only come from reducing existing data to some kind of common form.

Therefore, the survey portion of the present study is not the important step. It merely provides the groundwork for building a structure and reducing data to that structure.

From the survey it is clear that the inexperienced soldier is the focus of most new concepts. The new concepts involve job aids for the most part, though training is also included in some. When training is included, it is for a functional understanding of the equipment and not

for design level understanding. The focus is the new man on the job, who is assumed to be untrained or trained only at a functional level.

It is because of this focus that the new concepts have such a large impact on cost of ownership. The high costs of ownership are in the new man, his training and first year on the job. It is these costs that the new concepts have demonstrated a capability for changing. An experienced man's performance cannot be dramatically improved because he is already operating at a relatively high level. If the new concepts also help him, this must be considered as a side benefit. Desirable as this might be, it does not greatly affect the cost of ownership.

B. Procedure

The procedures for collecting data on the new concepts were as follows:

1. Copies of reports of new concepts in company files were first collected. This produced about 85% of the total list.

2. Requests were made to the Defense Documentation Center (DDC) and National Technical Information Service (NTIS) to provide information by subject matter. This produced relatively little new data (about 2% of total).

3. DDC and NTIS were requested to provide information by author. This required prior knowledge of what authors to request. It updated information but provided no new concepts (0% of total).

4. Partial lists of new concepts included in about ten other reports were examined. Most of the items in these lists included unverified sources given in previous reports. Original copies of reports were requested from all originators for which no material was on file. This provided information on some new concepts (about 8% of total).

5. Personal contact was made with personnel who have worked in the field (5% of total).

6. There remains a short list of new concepts which have been reported by name in other reports but on which we were unable to collect any information. Telephone calls and letters did not reach the sources given in other reports. The sources, therefore, remain unverified.

No research results are included in this survey that did not come from a verified source. It should be added that this criterion did not exclude any data. No reports cited any data from unverified sources - only the existence of a new concept. Therefore, it may safely be assumed that all data on the new concepts has been collected for this report.

There have been several previous surveys of this field. The earliest were by Shriver and Trexler in 1966[1], and a compendium of concepts prepared by the SMC Equipment Manuals Field Office (EMFO) at Letterkenny Army Depot in 1965[2].

More surveys have followed. But all have described the concepts without reducing them to the fundamental elements responsible for their results. The present study uses the survey only as a small first step. The important steps are described in the tasks which follow. Without those steps the survey phase can be said to be misleading rather than enlightening. It identifies so many seemingly conflicting formats and intentions that any reader must say the field is not yet ready for implementation. The results of many studies indicate important potential. But there is no single clear action that will achieve the potential effects. Surveys perpetuate this indecision. They cannot clarify, they only add a few more items to a clutter of seemingly different concepts.

A list of these concepts appears as Appendix A.

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[1] Shriver, E. L., and Trexler, R. D. A Description and Analytic Discussion of Ten New Concepts for Electronics Maintenance. Technical Report 66-23, Human Resources Research Office, George Washington University, Alexandria, Virginia, December 1966.

[2] Technical Report SMC EMFO 11, Improved Maintenance Data Techniques. Improvements Branch, Guidance Division, SMC Equipment Manuals Field Office, Letterkenny Army Depot, Chambersburg, PA., 15 August 1965.

TASK 2

A. General Discussion

The purpose of Task 2 was to analyze the various new concepts identified in the survey, and identify fundamental elements which would account for the results obtained from using those concepts. An initial set of fundamental elements was identified in the project proposal, and each new concept was initially defined in terms of those elements; when a concept was found which could not be described by the fundamental elements in the initial list, a new element was tentatively defined to describe it, or an old one was redefined. This was done through iterating entries in a matrix of concepts by fundamental elements.

In the performance of this task, the initial list of fundamental elements was expanded, primarily as a result of redefining or reorganizing the original elements, rather than of adding new elements. This definition is referred to as "changing the boundary conditions" of the fundamental elements. For instance, the original fundamental element of "Plain English" was redefined as "Intelligibility", thus including information given in graphic form as well as in written words.

In performing this iteration of fundamental elements, each of the new concepts was defined in a set of common terms.

The iteration process was accomplished with a matrix of fundamental elements by new concepts. The entries were iterated several times. A matrix was prepared which represents a description of each of the new concepts in terms of the fundamental elements used to make them effective.

At one point it was thought that the concept which embodied the greatest number of fundamental elements would be found to be the most effective. As the matrix was iterated, this was found to be a naive idea: the mere presence of a fundamental element did not ensure that it was efficiently developed. For example, every concept uses "Plain English" to some degree, but its intelligibility may be severely limited. One concept studied is intended to provide information in "Plain English" for the experienced man. The information consists of concise readings at key points in the system, and the notation for special settings for contents for certain test conditions. There are no procedures to tie the readings and the settings together. To the experienced man, the data is plainly and concisely presented in "Plain English", but to the inexperienced man, the data is unintelligible. In another concept the procedures for using such data are included in the documentation and are intelligible on any level. Both concepts can legitimately be described as using some form of "Plain English", but the first is intelligible only to a limited audience.

When decisions arising from such dilemmas had to be made as to whether or not an element was sufficiently "present" to be placed in the matrix, it was recognized that it was not the presence of many elements which made a concept effective, but the thorough development of a few. When an originator sets out to improve technical documentation, he may do so in the name of "readability", or "understanding" or "full proceduralization". In all cases this means developing that element more than has traditionally been done. Every Technical Manual has some degree of proceduralization, every one provides some understanding, some Plain English, some content analysis, etc., but the really successful new concepts were found to have one or two elements present in a <u>fully</u> developed form.

When we look at the results of Task 3, we find that almost all of the research results have been collected from a relatively small number of new concepts that have some elements fully developed. Other concepts represent only "good intentions" or partial developments. For instance, FORECAST and SIMMS concepts utilize very fully developed block diagrams for understanding. Their block diagrams have been developed for dozens of systems; the rules for their construction have been defined, and they have been tested with thousands of maintenance personnel and refined through successive iterations. They are fully developed aids to understanding and performing troubleshooting. ATOMS and other new concepts also utilize block diagrams, but the ATOMS concept is represented only in a few pages of a company brochure; the block diagrams are examples only of intent. The ATOMS concept, then does not add anything to SIMMS and FORECAST. ATOMS is actually subsumed under them as a less developed form of each fundamental element. Other new concepts that utilize the same elements are also subsumed under the prime concepts. They are not in competition with the prime; they merely represent supporting evidence for the fully developed form of each fundamental element. Any new concepts that are developed or have been missed in this survey can be subsumed under the fully developed fundamental elements of the major concepts.

Task 2 was extremely useful for revealing the notion of "fully developed". It had not been recognized previously as an organizing principle. This principle, coupled with the redefined fundamental elements, organizes the entire field into a meaningful picture. The issues opened up in Task 2 are resolved in Task 3, where evaluations are accomplished in conjunction with results.

B. Specific Analyses and Results

The various objectives of new concepts are summarized in the following list:

- To Improve Technician Performance
- To Improve/Reduce Technician Training

o To Reduce Technician Skill Level Requirements

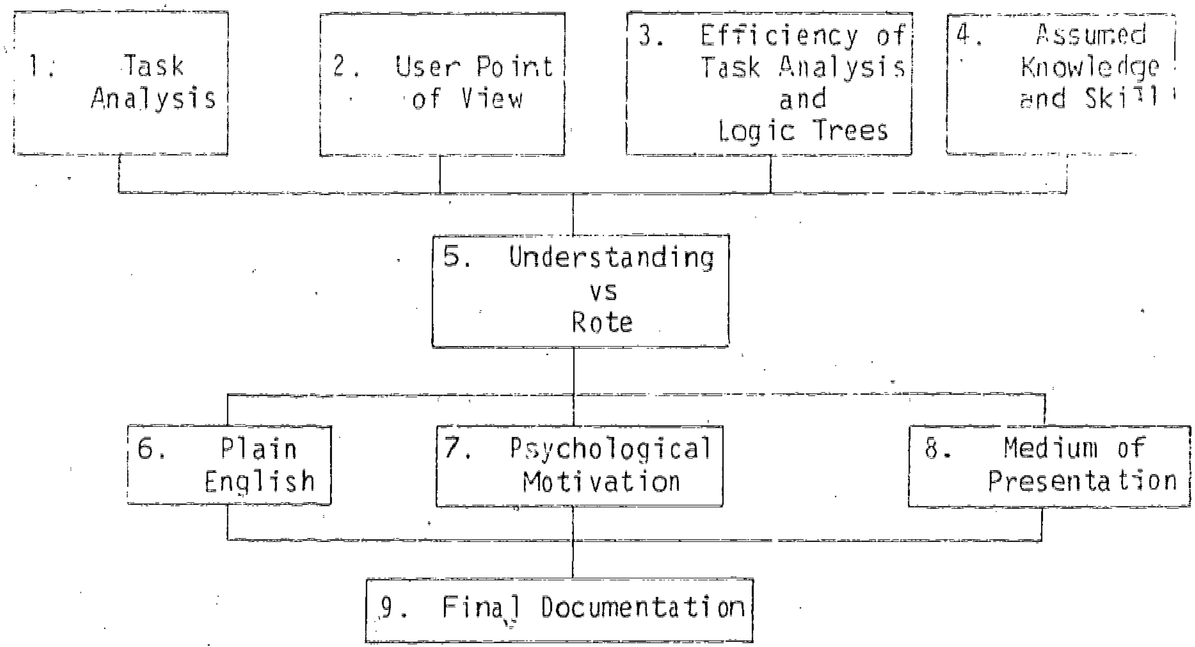
o To Reduce Equipment Downtime

These objectives are concerned with the personnel and training subsystems. Through these systems they have the potential of affecting cost of ownership. The results of the research studies are in terms of the objectives listed above, and costs of ownership are projected from them. These projections are made in Tasks 3 and 4.

The original list of fundamental elements, hypothesized to account for all of the results obtained with the concepts, is as follows:

1. Task Analysis
2. User Point of View
3. Efficiency of Task Analysis/Logic Trees
4. Assumed Knowledge and Skill
5. Understanding Versus Rote
6. Plain English
7. Psychological Motivation
8. Medium of Presentation

The initial organizing framework for these fundamental elements was:



This framework means that Task Analysis (1) is performed on the subject equipment. The User Point of View (2) is used in making this analysis. The efficiency of the Task Analysis and the resultant Logic Trees (3) is a function of the procedures used. Since the trees represent a very inefficient set of steps for doing the job, a set of efficient procedures is to be selected for use here. The Assumed Knowledge and Skill element (4) is the basis on which the details of the prescribed step are determined. For instance, if it is assumed that a user knows how to remove a carburetor, the step need only say "remove carburetor", but if not, the step must be broken down to "remove air filter, disconnect gas line, etc." Likewise, the steps can be broken down for "disconnect gas line" to "place 1/4 inch open end wrench on nut 1, turn counterclockwise, etc." The assumptions made on skill and knowledge of the user determine the level of task step detail which the Task Analysis goes into.

The framework has Understanding versus Rote (5) as a decision and also an optional method of treatment <u>after</u> the basic data is analyzed. It means that the data can be organized for understanding (at a functional Block Diagram level) or for a series of procedures for rote performance with no understanding.

After the analyzed data is prepared for Understanding or Rote, there are additional processes to perform before it is placed in a technical manual.

All written material should be put in Plain English (6). This means preparing it so that it is comprehensible to the user population. If it is prepared properly in Plain English, it will pass readability standards.

Psychological Motivation (7) is any technique for making the content interesting to the reader. This is typically done by incorporating graphic devices and color. This has been called the comic book technique by detractors, but it has good user acceptance. This can be done in addition to putting the content in Plain English. The third technique option listed at this level of the framework is the medium of presentation (8); e.g., paper, film, magnetic tape, etc.

Using the matrix for successive iterations resulted in the following redefinition of the original eight fundamental elements into fifteen elements.

The first three original elements were redefined as four types of analysis that had been used effectively in various concepts. They are described as four types of content analysis:

1. Equipment Analysis

2. Functional Analysis

3. Task Analysis

4. Behavioral Task Analysis

These analyses are all processes that have been used to generate job aids and training in some new concepts. They have been well developed in one concept or another, but have never all been used in one concept.

The fourth and fifth original elements were changed into:

1. Procedures

   a. Serial

   b. Branching

2. Functional Understanding

   a. Training

   b. Narrative

   c. Graphics

These represented means by which certain new concepts had achieved either Understanding or Rote, and this in turn required assumptions about how much skill and knowledge the user had in order to use the documentation provided. Those new concepts which used procedures for rote performance generally assumed no special training for the user. Those that used training with the documentation assumed the user would learn certain equipment functions in that training - but this was quite different from the training content of traditional formal schools.

The original element of Plain English was changed to Intelligibility, and included:

1. Simplified Text

2. Text/Graphic Combinations

3. Organized Formats to Support Multi-User Performance

These were seen to be ways which certain new concepts used to achieve simplified content. The use of graphics and English words required that the term "Plain English" be changed to a term such as "Intelligibility".

The seventh original element was expanded from Psychological Motivation to Motivational Graphics, and included:

1. Motivation Graphics

2. Personal Involvement

3. Color Graphics

The first and third new elements are graphic techniques. The second involves the use of personal pronouns in the accompanying text.

This, then, is the list of elements for evaluation in Task 3:

1. Content Analysis

   a. Equipment Analysis

   b. Functional Analysis

   c. Task Analysis

   d. Behavioral Task Analysis

2. Procedures

a. Serial Procedures

b. Branching Procedures

3. Functional Understanding

a. Training

b. Narrative

c. Graphics

4. Intelligibility

a. Simplified Text

b. Text/Graphic Combinations

c. Organized Formats to Support Multi-User Performance

5. Motivational Graphics

a. Motivation Graphics

b. Personal Involvement

c. Color Graphics

It is not the final list, since as a result of that analysis, the fundamental elements were again redefined (Task 3).

C. Definition of Elements

1. Content Analysis

a. Equipment Analysis

The Equipment Analysis is the point of contact with system design. Its output is the identification of all equipment items authorized for various kinds of maintenance in each maintenance category. The inputs to Equipment Analysis include schematics, parts lists, the identification of required tools and test equipment, and all Logistics Support Analysis Records (LSAR) (formerly known as MEADS) information.

Equipment Analysis identifies the major job tasks. It insures coverage of all equipment items, and it is a manager's tool for assigning tasks to analysts, and checking off their completion; however, it does not provide an identification of all tasks that need to be performed on the job. There are several ancillary tasks associated with most major tasks. For instance, the major job task of adjusting a carburetor requires that the ancillary

tasks of operating the hood and removing the air filter be completed before the major task is performed. Likewise, tasks such as going to get lubricants, parts, etc., are ancillary to major tasks. These ancillary tasks are identified by the analyst in a Task Analysis after he receives the assignment of analyzing a job task. The term "job task" is used to refer to the tasks identified in the Equipment Analysis. The ancillary tasks are called "subtasks", and are identified as behavioral objectives in the Task Analysis process.

The Maintenance Allocation Chart (MAC) is an example of the summary output of this Equipment Analysis process. For troubleshooting maintenance, the MAC is used to verify that the functional analysis (described below) is complete. For non-troubleshooting maintenance, the MAC is used to generate a comprehensive list of tasks by reading off the intersection of maintenance functions with component assemblies, including associated Group Number, Tools and Equipment, and Remarks. The ultimate source document for this analysis is the engineering drawing. Questions about specifications and tolerances must be resolved by referring to this document, and products not consistent with this document are in error.

Note: The Army is the only service to produce a product like a MAC. In the other services this product must be produced by the personnel preparing the TM. This product of this analytic process is called the Task Identification Matrix (TIM) in the Air Force.

Modification of the MAC, per se, is not a technical manual development responsibility. Inconsistencies in part-stocking and distribution, etc., which may be revealed by the other analytic process, are treated by calling them to the attention of the system design shop. It should be noted that these inconsistencies must be cleared up before the manual can be finalized. Any information from LSAR (formerly known as MEADS) is source information for the TM developers.

b. Functional Analysis - Troubleshooting Tasks Only. A Functional Analysis is performed for troubleshooting tasks:

(1) To develop an understanding of system functions and subfunctions and how they are related in the equipment through functional block diagrams and functional descriptions.

(2) To identify all the inputs and outputs of the blocks, and show how to measure them.

(3) To identify symptoms of abnormal equipment function that are associated with each block.

(4) To allocate parts to blocks so that the failure of any part assigned to a block will not affect the measured input to the block, but only the measured output.

The functional descriptions say in words what the functions of each of the blocks on the block diagrams are. This is not a recapitulation of the theory required to design the system; it describes how the equipment functions and indirectly indicates where the user should look when it malfunctions. It is man-oriented, not system-design oriented. It employs simple, understandable concepts couched in Plain English. It is more concerned with what is understandable than with what is true in terms of competing theoretical or engineering positions. It is coordinated with the functional block diagrams generated for troubleshooting purposes. The boundaries of troubleshooting functions are not physical boundaries or design engineering boundaries[1], but are the boundaries that make troubleshooting and maintenance most effective and efficient for the human beings doing the maintenance.

The troubleshooting block diagrams take into account the block diagrams generated for design purposes, but their final boundaries are established in the Functional Analysis, including examination of the subject equipment. The analysis must be a "hands on" analysis.

These paragraphs are not sufficiently detailed to convey the rigor that this analysis must entail.[2] This analysis takes into account accessibility, probability of failure and discriminability.

c. <u>Task Analysis - Non-troubleshooting Tasks and Procedural Aspects of Troubleshooting Tasks.</u> The Task Analysis converts the job tasks identified in the Equipment Analysis to the series of tasks and steps required to get that job task accomplished. The MAC lists the parts of the equipment and what type of maintenance is needed on each. Task Analysis is concerned with the conversion and organization of maintenance tasks into performance sequences of steps. The job task of replacing a carburetor is defined as a series of tasks including raising the hood, removing the air filter, removing the gas line, etc. These data are developed by the analyst from the experience and information available to him, rather than by the soldier on the job. It is new data, not a recapitulation of information developed by design engineers in describing the equipment. Later, in Behavioral Analysis, these tasks are confirmed and developed into more detailed graphic and written instruction by a "hands on" performance on the equipment. Notes, cautions and warnings are identified, specified, and inserted at the appropriate places in the task structure during the Task Analysis and Behavioral Analysis.

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[1] TB 750-93-1, Functional Grouping Codes, represents engineering functions, not the troubleshooting functions described here.

[2] Shriver, E. L., et al. <u>A Procedural Guide for Technical Implementation of the FORECAST Methods of Task and Skill Analysis.</u> Training Methods Division, Human Resources Research Office, George Washington University, Alexandria, Virginia, July 1961.

The user population for whom these procedures are intended includes the novice with no experience or training on the subject equipment. The task step procedures for every task are prepared.

d. Behavioral Task Analysis. Behavioral Task Analysis is concerned with human sensory perception - with what can be seen, heard and touched. Maintenance personnel are the users of maintenance documentation, and as human beings, they come equipped with certain sensory capacities. Those sensory capacities are immediately available for use in sensing deficiencies in the equipment, and are often easier and faster to utilize than test equipment.

Behavioral Task Analysis elicits from the hardware the cues (from various side effects or from intended displays) which the user will use to find sources of trouble or to perform a sequence of steps. What the user will actually see, hear, etc., is an important part of the analysis. In mechanical situations (serial) the sensory capacities are used in making inspections and checkouts. The Behavioral Task Analysis should ensure that the distinctions between acceptable and unacceptable situations are adequately described in behavioral/sensory terms so that the maintenance personnel can make the correct discrimination in any given case.

In troubleshooting situations the Behavioral Task Analysis must "look ahead" to what lies along a given branch. If the collection of sensory information on all alternatives is not equally easy, sensory discriminations should be programmed in the order that they are the easiest and fastest to obtain. Equally, where branching is involved, sensory discriminations that are too fine should be avoided; that is, the boundary for functional entities should be selected as a function of the ease of making an effective measurement at the output of that function. This fundamental element involves "trade offs" that are functions of human characteristics. Along with these "trade offs" is another factor which involves the probability of a failure being in any particular place. For instance, if there is a very high likelihood of a failure at an inaccessible location, then maintenance personnel should be directed to that location sooner than if it had parts that failed only infrequently. So, although probability data has no similarity to human behavioral considerations, the probabilities of machine "misbehaviors" must be traded off against human characteristics at this point.

In practice, the Behavioral Task Analysis always looks for the simpler, more efficient way. This means simpler in terms of cues, discriminations and the behavioral responses of personnel. This is not an engineering analysis, and only starts with the hardware features of the system.

The Behavioral Task Analysis product includes what some of the concepts have called a malfunctional analysis. If, for example, the plates of a B+ rectifier will glow red shortly after warmup if there is a remote short

on the B+ line, whereas they will arc and spit immediately if there is a short in the output filter, then these cues and discriminations should be elicited by the Behavioral Task Analysis. There will be no record of such information in the engineering design sheets, but this information is what a human being uses to perform an effective job.

Since relationships such as this are clearly not derivable from an analysis of function only, the Behavioral Task Analysis should not be conducted sequentially, but in parallel with the Functional Analysis. Thus, it is the information from a Behavioral Task Analysis (BTA) conducted side by side with the Functional Analysis, that provides the basis for building task sequences around discriminability during the task organizational phase. Cues which cannot readily be described in the BTA may have to be rejected for use in the Functional Analysis. For instance, an "igniter" in a jet engine makes a snapping sound like two screwdrivers being struck together while being held by the blades. This is a very useful troubleshooting cue. The description given above represents an effort to describe the cue. Once recognized it is highly discriminable. But some cues are so difficult to discriminate that a "hands on" analysis of the equipment is essential for the Behavioral Task Analysis. It is desirable to do some of this in tandem with the Functional Analysis. It may require more experience on the part of the analysts to do this than they will possess initially, and it may take time to develop this level of sophistication.

2. Procedures. Deleted (Task 3, paragraph C1).

3. Functional Understanding. Deleted (Task 3, paragraph C1).

4. Intelligibility. Redefined (Task 3, paragraph C1).

5. Motivational Graphics. Deleted (Task 3, paragraph C1).

D. Summary

The major finding of Task 2 was that the fundamental elements exist in varying degrees in each concept: rudimentary, highly developed, or any point in between. This was found during the process of entering the elements from each new concept in a matrix, and iteratively redefining and re-entering them in a new matrix. This finding is further developed and resolved in Task 3.

A second important finding was that the number of elements in a concept was not an important determiner of results. It was initially believed that the concept which had the greatest number of elements would be the most effective, but in this task it was recognized that the degree of development of an element was more important than the number of elements. This finding is further developed and resolved in Task 3 which evaluates the results obtained with the new concepts.

Task 2, then, resulted in a definition of fundamental elements, which was the prime objective. However, the important findings of the task concerned breaking with the preconceived notion that the quantity of the fundamental elements represented in a new concept would determine its effectiveness. In resolving this reassessment, the elements in Task 2 were reduced in number, as indicated in Section C of the Task 2 description.

TASK 3

A. Objectives

There were four main objectives of this task:

- o To examine individual Army situations and determine the appropriate elements for each.
- o To make a comparative evaluation of the fundamental elements identified in Task 2.
- o To evaluate those concepts listed in Task 1 which had no appreciable effect on the cost of ownership.
- o To project, broadly, changes in cost of ownership.

1. Matching Fundamental Elements to Situations.

Before this study started, there was a strong belief that each of the new concepts was tailored to a particular environment or situation in the various services. It, therefore, seemed necessary to identify and match specific situations with appropriate fundamental elements from the new concepts. During the process of performing this task, it became clear that the original belief was in error. Only two basic situations were found for which different fundamental elements were required: the troubleshooting situation, and all other maintenance situations (non-troubleshooting). This had to be checked against specific Army environments in the next task, Task 4, but these were the only two situations (across services) which appeared to require different technological processes for developing information in manuals.

2. Evaluating Fundamental Elements.

Before the task started, there was a common belief that evaluating the fundamental elements (technological processes) would be like comparing apples and oranges. The basic problem was that there had been no experiments made on the individual technological processes used in each new concept. The new concepts had always been tested as packages. Consequently, it was difficult to see how any of the separate parts could be evaluated, let alone compared across different concepts and the situation for which they had been developed and tested. The answers to that problem which were developed in this task now seem simple and obvious, but they were not obvious when the task was begun: the questions had been plaguing

the field for years. The deceptively simple answer came only through a long process of trial and error analyses in the present study. A summary is provided below which leads from the initial problem to the final conclusion in logical steps, rather than in terms of the trial and error steps. The logical steps were designed to answer the following questions:

a. What is a fundamental element and what are its boundary conditions?

When this study was initiated, anything that was found in any of the new concepts that improved user performance or lowered training time was called a fundamental element. This was still true at the conclusion of Task 2. At the end of Task 3, however, a fundamental element was no longer a "thing". A fundamental element was now recognized as a technological process for producing a new type of TM, each process converting one kind of information into another kind.

b. What kind of fundamental elements are needed in order to prepare an integrated specification?

Four of the fundamental elements are analytic processes. The fifth fundamental element utilizes stored information and techniques as part of the process for converting the results of the other four analytic processes into intelligible information for the grade school reader. All of the processes are used for troubleshooting tasks, while functional analysis is omitted for non-troubleshooting tasks.

c. How are the best fundamental elements selected on the basis of the results of the individual studies?

In this step, the fundamental elements were defined and evaluated in the following terms:

- o Did use of the concept result in improved performance and/or lowering training time? If so, how much?
- o Were one or more of the fundamental elements more fully developed than others in the concept producing the best results?
- o Were there any fundamental elements which were well developed but did not produce good results or were not tested at all?

The important thing that was recognized was that the technological processes called fundamental elements are not in conflict with each other, that every concept uses some form of each, and that the best results are obtained when one or more is fully developed. With one exception, the

fully developed form of a fundamental element always had good results associated with it.[1] In retrospect, this can be seen to be a "self-selective" process. That is, there are few reports on technological processes that didn't work. The key to the evaluation was the results obtained. Every concept with good results was found to have one or more fundamental elements in a thoroughly developed form. It was therefore deduced that the fundamental elements which were well developed must be the factors producing the good results from a given concept. For instance, concept A produced good results. It had a well developed form of Task Analysis (one of the fundamental elements). It had a rudimentary form of making text readable (another fundamental element). Concept B also produced good results, but it had a rudimentary form of Task Analysis and a fully developed technique for making text readable. It is a logical deduction that it is the fully developed form that is responsible for the good results in each case, and that an improvement in only one fundamental element can produce good results. Each fundamental element selected for inclusion in the final specification has proven itself to be the effective ingredient in one new concept study or another.

The second part of this step was to answer the question of which fundamental elements in a fully developed form are more effective than the others? It seemed initially that an answer to this question was needed in order to choose between them. For example, Task Analysis produced greater improvements in performance than did Intelligibility, but on reflection it became apparent that both are desirable, and that neither is in conflict with the other. This important point was not apparent when the study started; there had always been a conflict in peoples' minds over which single concept should be adopted, which seemed to be solvable only on the basis of which concept produced the best results. But when the concepts are broken down to their fundamental elements, it becomes evident a single integrated concept should be designed in which all the fully developed elements are incorporated to the extent they are not in conflict. Each one that has been shown to be effective in one concept or another is a desirable component of an integrated concept. There is no need to say which is best. We just use all which have demonstrated a value.

At one point in this task, problems such as the following required resolution. One concept had resulted in a 40% reduction in training time and another had shown a 60% reduction based on development of the <u>same</u> fundamental element. Which presentation of the element should be used in the integrated specification? This turned out to be no problem; it was the same fundamental element, the same process in different stages of development, and we, therefore, use the most fully developed form -- the one that has the most precise specification and/or description of the process.

3. Evaluating Ineffective Concepts.

The third objective of this task was to evaluate the concepts

[1] The Maintenance Dependency Chart (MDC) is the exception and it is discussed later in this section.

(listed in Task 1) for which no experimental results exist. It was found that concepts which do not affect ownership costs do not have well developed fundamental elements. They are generally at the level of development of a company brochure. They advocate Task Analysis or Block Diagrams or improved readability, and they may show some examples, but they do not provide the details on the technological processes for developing the fundamental elements they advocate. Their advocacy points to the importance of these elements, but it contributes nothing to their development. Consequently, these new concepts can be subsumed under those which did develop one or more of the fundamental elements. Their presence should not be allowed to confuse the evaluation picture. They are not contending for implementation, but merely point in directions that have been developed in other concepts. These concepts are described in Appendix B

4. Developing Cost of Ownership Projections.

The fourth objective was to translate the results obtained in various studies into common measures which could be used with cost data to project changes in cost of ownership. For this purpose the results were reduced to the following.

a. Reduction in training time.

b. Reduction in size of work force.

c. Reduction in false removals.

This was accomplished in this task and the results carried forward to be combined with costing elements in Task 4.

B. Approach - General

Task 3 marked a major milestone. It was the first point at which a complete outline of the final specification became available. The outline was subject to further confirmation (in Task 4), expansion (Task 5), application (Task 6), and Test (Task 7). Nonetheless, it represents the first "rough cut" at a final product.

Tasks 1 and 2 were deliberately expansive in nature. That is, every effort was made to identify all possible concepts, elements, categorizations, etc., that might conceivably bear on maintenance documentation. Task 3 marked a turning point in orientation. It began the process of closing off options and consolidating them. The fundamental elements became better understood, and their number was reduced to five. The results were consolidated into three categories for projecting costs of ownership, and ownership costs were analyzed and combined with results to project the costs of ownership that could be changed by the use of the combined integrated specifications.

1. Terms of Results

The results obtained with each new concept were generalized across all Army situations. Specifically, the results were reduced to those concerned with:

a. Reduction in training time

b. Reduction in work force

c. Reduction in false removals

2. Boundary Conditions of Fundamental Elements

Based on these analyses a better understanding of what was effective in producing results was developed, and the fundamental elements were accordingly redefined. Some elements brought forward from Task 2 were deleted, and the boundary conditions (or definitions) of others were changed. It was finally recognized that the fundamental elements are processes for producing the documentation in the new concepts. Five distinct processes are defined, but it should be recognized that in practice, the point at which one process stops and another starts is somewhat arbitrary. The boundaries between the processes as given here are aids in understanding the processes (fundamental elements) and represent a useful way of organizing them for application.

3. Sample Formats

Format differences were found to be preferred ways of displaying the results of the processes. The formats given as samples in the specification (Task 5) are adaptations of those used to present the results of the analytic processes in the effective studies. Others may be found to be useful at some future time, but an integrated set of formats, based on those that have been found effective, are prescribed here and in Task 5 (Specification).

C. Approach - Specific

1. Analysis of Existing Data in Terms of Fundamental Elements

The following is a list of the fundamental elements generated in Task 2, which was the starting point for Task 3:

(a) Content Analysis

(1) Equipment Analysis

(2) Functional Analysis

(3) Task Analysis

(4) Behavioral Analysis

(b) Procedures

(1) Serial Procedures

(2) Branching Procedures

(c) Functional Understanding

(1) Training

(2) Narrative

(3) Graphics

(d) Intelligibility

(1) Simplified Text

(2) Text Graphic Combinations

(3) Organized Formats to Support Multi-User Performance

(e) Motivational Graphics

(1) Motivation Graphics

(2) Personal Involvement

(3) Color Graphics

Each new concept was described in terms of the fundamental elements which were fully developed in the concept, and those which achieved moderate development. However, the process of doing this led to the drawing up of a simplified set of fundamental elements, and to the recognition that every concept included something of each element. When independent judges attempted to describe each concept in terms of the elements listed, each found it difficult to decide whether a concept used a given element or not. After they had done their job, they discussed their difficulties together and came to the realization that it was not a case of have or have not, but a question of degrees of having each element.

The Task 2 list also has Functional Understanding as an element, with Training, Narrative, and Graphics as means for achieving it. However, Functional Understanding is an objective of Functional Analysis, and not a process in itself, and was dropped from the list. Procedures are a product of a process like Behavioral Task Analysis and not a process in themselves. So they also were dropped from the list. The original element Training was deleted as well: training is a medium for delivering information, not a process for generating the information needed for understanding. Similarly, Narrative and Graphics are means or media for the delivery of information, and not processes for generating it. All of these were rejected as fundamental elements.

Intelligibility, next on the list, was retained as a fundamental element, but without its sub-elements. Intelligibility is a characteristic of information. It depends on the characteristics of the user. In the present study, the user on whom most of the costs of ownership hinges is the novice. Certain of the new concepts used processes for making information intelligible to novices. These processes are fundamental elements, and have been given the name Intelligibility Standards. This, then, is the fifth fundamental element. It is used in conjunction with the four types of analytic processes. It consists of two parts, text and graphics. Text is used to convey information about action (verbs). Graphics are used primarily to convey information about things (nouns). Organized formats for supporting multi-user formats are not included as a fundamental element, but the format prescribed is organized for multi-users.

One last element, Motivational Graphics, appears on the Task 2 list. Motivational Graphics is recognized to represent processes for improving performance, and the Army Materiel Command has been the leader in all the services in using these processes. However, there has been no research follow-up. Without results there is no way to project costs. For this reason, Motivational Graphics is not included as a fundamental element. However, there has been good acceptability from the field on manuals for organizational personnel which have similarities to motivational graphics manuals. These manuals use color, simplified graphics, graphics and instructions on the same page and somewhat simplified words and have been produced without specifications by the Armament Command. The processes for producing them sound very much like the processes for the other new concept manuals, but without data and without specifications it is impossible to go beyond what is said here about this type of manual.

Even though Motivational Graphics and its sub-groups are not considered fundamental elements, the use of color should certainly be considered for organizational manuals. No requirement for color has been positively identified, but it is not precluded by the specification produced under the present contract.

The final list of fundamental elements accepted for purposes of conducting evaluations is as follows:

- Equipment Analysis
- Functional Analysis
- Task Analysis
- Behavioral Task Analysis
- Intelligibility

It was in terms of this list that the new concepts were investigated.

2. Terms in Which Results Have Been Reported

In evaluating the data it was found that the dimensions along which investigators have collected data in this field include:

- o The number of items completed per unit time
- o The time to complete unit items
- o The time to train
- o The skill level of the personnel pool being tapped
- o The number of parts erroneously replaced
- o Accuracy
- o User endorsement
- o Differences in school attrition rates
- o "Within tolerance" performance rates

These results are not directly translatable into costs of ownership. Therefore, it was necessary to select those that would directly translate in factors that are known to be the major contributors to cost of ownership. To do this the results were reduced to:

a. Reductions in Training Time

The data on time to train translates directly into reductions in training time. Some results are reported in terms of school attrition rates. While such reductions certainly affect time to train, the translation factor is difficult to project, and, therefore, results reported in terms of reductions in attrition can only be considered supportive of results reported in terms of time to train. If they could be figured in, it would increase whatever values are reported in terms of reduced training time. In certain studies personnel perform with a new concept TM, or general tasks like using torque wrenches and safety wiring. Such study results are recorded as "approaching 100%" reduction in training time. They are characteristic of non-troubleshooting tasks, not troubleshooting.

b. Reductions in Work Force

The number of items completed per unit time translates easily into work force. If one man can produce twice as many items per unit time using a new concept TM, then a work force reduction of 50% can produce an equal

number of items in the unit time. It is recognized that work force reductions can involve other factors than speed of production. For instance, if fewer men are placed in the work force, one may have to have multiple skills that were previously inherent in the complete work force. There is evidence that the new concepts result in good transfer from one job specialty (MOS) to another, but it would be exceedingly difficult to translate this into specifics across all Army situations. It is much easier to make a conservative estimate on what reduction in work force would be possible, for instance, to project a reduction of 15% instead of 50% for the results used in the example above.

Reductions in False Removals.

The number of parts erroneously replaced translates directly to "false removals". In contrast, other measures such as "accuracy" and "errors" do not translate directly. The definition of an error is not that the individual makes an error in what is removed; it refers rather to what the experimenter defines as an error. The term error might refer to a false step that the individual user corrected himself; it might mean an inefficiency -- that an alternative series of steps would have completed the same job more rapidly -- or it might mean a false removal. In the first two cases, more time than necessary would have been taken to complete the job. Some experimenters record only "errors" and not the time required to complete the job. This does not translate into data useful for cost projections. Recording in terms of "accuracy" has the same deficiencies as recording in terms of "errors". It is dependent on the experimenter's judgement of what is accurate, and it does not translate into time or any other data form that is useful for cost projections. Without knowing how long the work took or how many items were completed per unit time, "accuracy" means nothing. It might take twice as long to be accurate. The data on errors is supportive of data on parts erroneously replaced, but it is not used directly in the estimate of false removals.

The results obtained with various concepts and the fundamental elements to which the results were attributable are contained in Table 1.

3. Discussion of Results of Data Reduction

Data on troubleshooting performance have been collected and reported for seventeen instances of implementation. The fundamental element of Functional Analysis has been fully developed for troubleshooting tasks, primarily electronic, but also mechanical and hydraulic. Concepts which developed Functional Understanding through training and block diagrams have been demonstrated to be effective for troubleshooting. Procedure-oriented concepts have not been demonstrated to be effective for troubleshooting, except for some "error" reductions, which are largely a matter of the experimenter's definitions.

Table 1

Results of Concepts

Concept	Fully Developed Fundamental Elements	Elements Moderately Developed	Task	OBJECTIVES Reduced Training	More Work	Fewer Errors
FORECAST 1958 - Army Radar	Functional Analysis	Equipment Analysis Intelligibility Task Analysis	NTS/ TS*	60%	0	
FORECAST 1959 - Army Radar	Functional Analysis	Equipment Analysis Intelligibility Task Analysis	TS	50%	40%	
FORECAST 1963-1964 Navy Loran	Functional Analysis	Equipment Analysis Intelligibility Task Analysis	TS	0	200%	
JOBTRAIN 1962 - Army Communication Equipment		Equipment Analysis Functional Analysis Task Analysis	TS	50%	0	
MAINTRAIN 1963 - NIKE		Functional Analysis	TS	0	80%	
MAINTRAIN 1964 - HAWK		Functional Analysis	TS	0	40%	41%

* NTS = Non-troubleshooting
TS = Troubleshooting

Table 1

Results of Concepts

Concept	Fully Developed Fundamental Elements	Elements Moderately Developed	Task	OBJECTIVES Reduced Training	More Work	Fewer Errors
SIMS 1964	Functional Analysis	MDC* lowered intelligibility for novices *Maintenance Dependency Chart	TS	0	24%	
MDS AVIS 1964 - Radar		Functional Analysis Intelligibility	TS	0	23%	
BFIC 1966		Functional Analysis Equipment Analysis Task Analysis	TS		200%	80%[1]
Fully Proceduralized Aids JPA 1968		Functional Analysis Task Analysis	TS	Almost 100%		
PIMO 1968 - C141A	Task Analysis	Intelligibility	NTS	0	11%	80%
BRITISH[2] ALGORITHM 1969		Functional Analysis		0	200%	0

1 No valid comparison to performance of another group. No measure of effectiveness.

2 Reported in other secondary sources but not confirmed in primary sources (only 5 subjects).

Table 1

Results of Concepts

Concept	Fully Developed Fundamental Elements	Elements Moderately Developed	Task	OBJECTIVES Reduced Training	More Work	Fewer Errors
FEFI/TAFI 1969		Functional Analysis Intelligibility	TS	0	314%	0
JPA - Non-TS 1970 - F-4J	Task Analysis Intelligibility		NTS	100%	30%	0
SIMMS 1971 - SRC-20 Radio	Functional Analysis		TS	0	Positive	
JPA [1] 1971 & MDC [2] UHIH	Equipment Analysis Task Analysis Behavioral Task Analysis Intelligibility	Functional Analysis	NTS/ TS	Almost 100%	60%	0
SMD			TS		Negative	0
MDS 1972 - Radar Generator			NTS/ TS	0	0	0

[1] JPA was revised by Behavioral Task Analysis and Functional Analysis before results reported were obtained. Without revisions there was no difference in performance.

[2] Personnel could not use MDC and could not be trained to use them in reasonable time.

Table 1

Results of Concepts

Concept	Fully Developed Fundamental Elements	Elements Moderately Developed	Task	OBJECTIVES Reduced Training	More Work	Fewer Errors
JPA[1] 1972 - Power Plant		Functional Analysis	NTS	Large	Less	0
MDC 1973		Lowered Intelligi-bility for Novice use	TS	0	-20%	0
AAT 1973			TS	More Training	130%	0

[1] Manual had to be revised for test to be conducted.

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The effectiveness of proceduralized troubleshooting has not been demonstrated in the new concepts analyzed in this study.[1,2] It has been demonstrated that troubleshooting can be proceduralized. And it has been demonstrated that some people can follow troubleshooting procedures. But the efficiency of personnel using fully proceduralized troubleshooting procedures has not been demonstrated except for very short sequences. A procedure is inherently inefficient for troubleshooting because it prevents the user from skipping time consuming steps while remembering that they must be returned to if necessary. An equally serious source of inefficiency is that a user who misinterprets a reading and takes the wrong path in a procedure has no way of returning to that point after he finds he is on the wrong path. He must return to the beginning of the procedure and repeat many steps that were originally performed correctly.

On the other hand the increased effectiveness of block diagram approaches to troubleshooting have been demonstrated several times. When this approach has been used in new concepts the results have been increases in troubleshooting effectiveness up to 200% (FORECAST, 1963-1964, see Table 1). The functional analysis for the block diagram approach is therefore selected as the fundamental element in this study.

It should be noted that within the block diagram approach some procedures are used. These are procedures for making measurements. They are produced by the Behavioral Task Analysis and incorporated in the block diagram troubleshooting produced by functional analysis.

In the case of "understanding" implementations, only those using the MDC failed to meet with success in all cases when used by novice personnel. This is somewhat surprising, in that the MDC presents exactly the same information as the block diagram used to support understanding, and the block diagram implementations were uniformly successful. But the MDC is a cryptic, abbreviated presentation, whereas block diagrams are common use in our culture. The MDC must be learned as a new language. This characteristic forces the treatment of MDCs as a special case. If the MDC implementations are omitted, increase in productivity associated with understanding ranges up to approximately 200%. Training reductions for troubleshooting tasks range up to 60%.

Procedural implementations have been used extensively on non-troubleshooting tasks. They have produced good results. Task Analysis has been used to identify detailed task steps. The results have been good in tests of the PIMO concept.[3] When the same processes were followed for generating the JPA manuals, there was no improvement in performance until a Behavioral Task Analysis was performed, and the JPA was revised according to this analysis.

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[1] Elliot, T. K. Development of Fully Proceduralized Troubleshooting Routine, AMRL-TR-67-152, November 1967.

[2] Whitmore, P. G. Some Problems in the Analysis of Troubleshooting Behavior, Human Resources Research Office, George Washington University, Research Report No. 2, October 1959.

[3] Project PIMO Final Report, Serendipity, Inc., Chatsworth, California, May 1969.

The median increase in performance associated with procedure-oriented concepts in non-troubleshooting tasks ranges up to 60%, and training reductions approach 100% in studies using these procedures.

4. Evaluation of Concepts Lacking Experimental Data

The concepts with data were compared with the concepts without data. The fundamental elements were not well developed in the published material on the concepts without data, but it was relatively easy to identify similarities between the fundamental elements of the concepts that were well developed, and those that were not. It is believed that any new concepts which might appear in the future can be compared in a similar fashion. Appendix B contains descriptions of each of the concepts that had no data. Their similarities to other concepts, and certain unique features, are also discussed here.

5. Results in Terms of Projection of Costs

a. Training Time Reduction

(1) Non-Troubleshooting Tasks. Training time for non-troubleshooting tasks has been reduced to a near zero level in some research studies. Personnel with virtually no training have performed as well as personnel with sixteen weeks of training. Manuals produced with the fundamental elements of Equipment Analysis, Task Analysis, Behavioral Task Analysis and Intelligibility Standards have made that difference. A figure of 95% reduction in training is used for the cost projection.

(2) Troubleshooting Tasks. Training time has been reduced as much as 60% for troubleshooting tasks with performance remaining equal. The content of the reduced training was entirely different from that in the longer training. The content was functional information presented in special manuals, and rehearsed during the training. The fundamental elements used to produce these results were Equipment Analysis, Functional Analysis and moderately developed forms of Task Analysis, Behavioral Task Analysis and Intelligibility Standards.

(3) A figure of 75% reduction in training is used as an average for troubleshooting and non-troubleshooting tasks. This is carried forward to the cost projection made in Task 4.

b. Reduction in Work Force

Increases in performance levels reported in these studies have ranged to as high as 200%. This means that personnel with new concept manuals and training have correctly performed as much as three times as many tasks per unit time as personnel using conventional TMs and training. This would indicate that as much work can be done by one-third as many people, a 66% reduction in work force. There are many factors which affect work force size other than this one. Some are discussed in Appendix C. For the purposes of the cost projection, a conservative figure of a 15% reduction in work force is used.

c. False Removals

The number of false removals is difficult to estimate from results reported in terms of "errors". Only a fraction of errors made are actually false removals. However, from the results given, a figure of 15% reduction in false removals is a conservative estimate.

D. Summary

The following estimates from results obtained with the new concepts are carried forward to the cost projections made in Task 4. These are the estimates of reductions which would prevail if the fully developed form of each of the fundamental elements were to be used in one integrated concept. The specification developed in Task 5 includes the fully developed form of all the processes for production of a Job Performance Manual (see Task 5, paragraph A1).

- o Reduction in Training - 75%
- o Reduction in Work Force - 15%
- o Reduction in False Removals - 15%

TASK 4

A Introduction

This section describes activities completed under Task 4: Evaluation of Approaches by Commodity Systems and Cost of Ownership Projections. The activities performed during this task were:

- o To collect information on the Commodity Systems.
- o To review the fundamental elements from Task 3 against this information in order to confirm that they apply to all Commodity Systems and to detect situations in which the fundamental elements would not be appropriate.
- o To examine the TM specifications for Commodity Systems in order to identify conflicts with the fundamental elements.
- o To identify the cost elements of each of the three changes in the personnel subsystem identified in Task 3 and to project the change in cost of ownership which could accrue through use of the fundamental elements to produce all Army TMs.

Information on Commodity Systems was collected through field trips and a review of available literature.

The fundamental elements identified in Task 3 were reviewed for their appropriateness in the various Commodity Systems. The basically different situations were identified in Task 3, Troubleshooting and Non-troubleshooting Tasks. The fundamental elements for the items are the same except that Functional Analysis is performed only for troubleshooting tasks. The question addressed in Task 4 was whether the five fundamental elements were sufficient for treating situations and environments in all Commodity Systems, or whether some systems required new elements or variations to treat some unique situation.

The TM specifications of each Commodity System were examined to see if any of the fundamental elements would be in conflict with them.

The costing objective of this task was to collect data on costs of ownership that are affected by the results brought forward from Task 3, and to project reductions in cost of ownership across all Army systems.

The primary source of data on cost was the Comptroller of the Army and the Military Occupational Specialty Training Cost Handbook[1] (MOSB) in particular.

The primary source of data on numbers of personnel in maintenance categories in the Army was the Department of Commerce Statistics.

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[1]Published by the Directorate of Cost Analysis, Office of the Comptroller of the Army, Washington, D. C., 20310, May 1974.

B. Results

1. Commodity Systems Characteristics

In order to evaluate the responsiveness of the hypotheses developed in Task 3 to the various Commodity Systems, it was necessary to examine the operational and maintenance environments of each Commodity System. This was accomplished through visits to several operational facilities, interviews with Army personnel in the responsible commands, reviews of current reports, and a review of the current technical manual specifications covering the various Commodity Systems. The Commodity Systems covered are as follows:

COMMODITY SYSTEM	COMMAND
a. Aircraft	Aviation Systems
b. Communications	Electronics
c. Missiles	Missile
d. Munitions	Armament
e. Weapons	Armament
f. Vehicles	Tank-Automotive
g. Support Commodity System	Troop Support

Each Commodity System was reviewed to identify personnel skill levels, equipment types and complexity, and maintenance facility requirements.

Technical Manual specifications reviewed for the various Commodity Systems are listed in Appendix D. Each specification was reviewed for organization requirements, theory requirements, troubleshooting task requirements, non-troubleshooting task requirements, text and diagram format requirements, and quality assurance requirements. This examination was performed to identify the extent to which requirements were established in each of these areas, and differences in these requirements across commodity types.

a. Aircraft Commodity System

The Aircraft Commodity System is administered by the U. S. Army Aviation Systems Command (AVSCOM).

With respect to maintenance manuals, AVSCOM is responsible for maintenance engineering, stock and supply control, and technical assistance to users of all Army aviation and aerial delivery equipment.

Equipments include end item aircraft, airframe structural components, ground support equipment, wheel and brake systems, gas turbine engines, jet engines, internal combustion, radial and horizontally opposed air-

craft engines, parachutes and parachute accessories, hydraulic pumps, starters, etc.

Enlisted personnel maintaining aircraft commodity equipment fall generally under the following MOS series:

67 Series - Aircraft Maintenance

68 Series - Aircraft Components Repair

Army aircraft are large, complex, diverse systems. A complete aircraft normally consists of several independent systems, such as the airfame, navigation equipment, communications equipment, armament, power plant, etc. Within some of these systems there are very diverse equipment types and complexities. Without precise documentation, it takes a wide range of specialties to maintain an aircraft. At present there are 27 MOS positions for aircraft maintenance. In addition, multiple levels of maintenance are used to ensure short down-times. For example, a defective assembly or even entire equipments will be removed and replaced so that the aircraft will be quickly returned to operation. The assembly or equipment is then repaired off-line. Aircraft are designed with this process in mind, probably more than any other type of equipment. Once the assembly or equipment is removed from the aircraft, however, its maintenance characteristics are basically the same as those for other Commodity Systems. Thus, the critical difference between aircraft systems and other systems is at the first level of maintenance, which is designed to return the aircraft to service quickly. This also includes preventive maintenance, checkout, and scheduled maintenance.

Finally, aircraft require very diverse spares provisioning and tools.

b. <u>Communications Commodity System</u>

The Communications Commodity System is administered by the U. S. Army Electronics Command (ECOM).

ECOM is responsible for maintenance support and supply of communication and electronic equipment and systems.

Enlisted personnel maintaining communications commodity equipment tend to fall under the following MOS series:

26 Series - Radar and Microwave Maintenance

31 Series - Field Communications Equipment Maintenance

32 Series - Fixed Plant Communications Equipment Maintenance

33 Series - Intercept Equipment Maintenance

34 Series - Data Processing Equipment Maintenance

Communications systems are electronic/electro-mechanical in nature. Electronic equipment design has had a marked effect on electronic maintenance philosophy. With the advent of semiconductors and micro-miniaturization, equipment packaging became more modularized and sometimes more functional. This created the potential for simplification of troubleshooting and repair of these equipments, but in practice it has not consistently led to simplification. The modules are seldom designed functionally from the troubleshooting point of view. Usually, many different signal paths trace through one module so that although modularization reduces the number of items of spares required for a given equipment, the overall effect is to increase the cost of each spare item. Furthermore, modules tend to be unique for given equipments. For instance, when an entire high cost "deck" of integrated circuits is the replaceable unit, the low cost 1/4 watt 1000 ohm resistor, which may be common to many systems, is no longer an item of replacement.

Tools and test equipment requirements are not especially diverse nor extensive in electronic equipment. Test equipment is typically common to all equipment, with special test equipment required only for equipment operating at very high and ultra-high frequencies. However, there are often different models of the same basic test equipment, e.g., different oscilloscope and multimeter models. The need for the extensive varieties of the same basic instruments is questionable.

The maintenance environment at the organizational level ranges from primitive field situations to shop environments. Upper level maintenance occurs in environmentally protected shop-type work areas.

All levels of maintenance use technical manuals to approximately the same degree.

c. Missile Commodity System.

The Missile Commodity System is administered by the U. S. Army Missile Command (MICOM).

MICOM is responsible for the maintenance, with technical manuals, of rocket, missile, and related programs.

Equipments include free rockets, guided missiles, ballistic missiles, target missiles, air defense fire coordination equipment, special purpose and multi-system test equipment, missile launching and ground support equipment, and missile-fire control equipment.

Enlisted personnel maintaining missile commodity equipment and systems tend to fall under the following MOS series:

21 Series - Ballistic Missile Electronic Maintenance

22 Series - Guided Missile Electronic Maintenance

23 Series - Missile Fire Control Electronic Maintenance

24 Series - Air Defense Missile Electronics Maintenance

26 Series - Missile Mechanical Maintenance

Missiles are similar to communications systems in that both are highly electronic/electro-mechanical, with modular packaging of newer equipment. Maintenance tasks include a lot of inspection and checkout. Troubleshooting occurs in the event of an inspection or checkout failure, or report from operators. Test and checkout equipment tends to be unique for each missile, except for the common test equipment, e.g., oscilloscopes and multimeters that come in various models. Some 42 MOS positions are used in this system.

Troubleshooting and repair tasks are performed at the higher echelons of maintenance, usually in shops and laboratories for test instrument calibration. Spares provisioning tends to be unique for each missile type. All levels of maintenance use technical manuals to approximately the same degree.

d. Munitions Commodity System

The Munitions Commodity System is administered by the U. S. Army Armament Command (ARMCOM).

ARMCOM is responsible for technical manuals for nuclear and non-nuclear munitions, including rocket and missile warhead sections, demolition munitions, and offensive and defensive chemical material.

Typical items include grenades, mines, warheads, explosives, smoke generators, chemical irritants, and incendiary units.

Munitions are maintained by the following MOS series:

54 Series - Chemical

55 Series - Ammunition

Munitions maintenance is unique in that virtually no maintenance is performed at the organizational level except specific storage and inspection tasks. Direct support maintenance adds only the cleaning, repackaging, and replacement of external components. General support extends to internal repair. Thus, there is a very fixed division of activities. The variety of skills is minimal. Only 5 MOS positions are required. Because of the extreme dangers involved, manuals are used extensively even by experienced personnel. The maintenance environment at the organizational level is the storage facility. At direct support/ general support level the maintenance environment tends to be an elaborate shop/laboratory facility.

e. Weapons Commodity System

Like the Munitions System, the Weapons Commodity System is also administered by ARMCOM. (ARMCOM was formed in 1973 by merging two major subordinate commands - Munitions and Weapons.)

ARMCOM is responsible for technical manuals for all nuclear and non-nuclear weapons, including artillery, infantry, gun-type air defense, and surface vehicle mounted and aircraft mounted weapons.

Equipments include artillery and infantry weapons and weapons systems, tanks and tank-like vehicles, small arms, armament for Army aircraft, and fire control equipment for these weapons systems.

Enlisted personnel maintaining Weapons Commodity equipment tend to fall under the 45 MOS Series: Armament Maintenance.

Weapons are largely mechanical and electromechanical in nature. Failures normally occur as a result of improper care or routine wearout. Maintenance is largely preventive: replacement of worn parts, and overhaul. Preventive maintenance is performed at the operator level. Organizational maintenance is largely limited to replacement of parts that can be accomplished in a field environment. Direct support and general support maintenance is performed in both field and shop environments, often using powered tools and holding fixtures. Overhaul, of course, occurs at the depot level. The variety of skill level requirements is minimal, as only 5 MOS positions are required in weapons maintenance. All echelons use technical manuals to about the same degree; use tends to decrease with increased experience on a particular weapon.

f. Vehicle Commodity System

The Vehicle Commodity System is administered by the U. S. Army Tank-Automotive Command (TACOM).

TACOM is responsible for technical manuals for tank-automotive material throughout the entire U. S. Armed Forces.

Equipments include combat and tactical vehicles, motorcycles, motor scooters, trucks, trailers, their accessories and components.

Enlisted personnel are primarily in the 63 MOS Series: Mechanical Maintenance.

Vehicles systems maintenance is like aircraft maintenance. Many components are replaced on-line, in order to return the vehicle rapidly to service, and then repaired off-line. This is particularly true for combat vehicles that include sophisticated armament systems. It is these armament systems which make the combat vehicles much like the aircraft in maintenance characteristics. The variety of different sub-systems on combat vehicles is less, however, as there are only 8 MOS positions. Four of these are associated with tank turret maintenance (45 MOS Series). The rest relate to wheeled and tracked vehicle maintenance. Thus, when compared with aircraft maintenance, the variety of skill requirements is small.

In terms of spares provisioning and maintenance support also, vehicle maintenance is similar to aircraft, but without the extreme variety.

g. Support Commodity System

The support commodity systems are administered by the U. S. Army Troop Support Command (TROSCOM).

TROSCOM is responsible for such items as barriers and bridges; water purification equipment; rail, marine, and amphibious equipment; power generators; materials and food handling equipment; industrial engines and turbines; and environmental control equipment. Materials handling equipment which are presently under TROSCOM will be transferred to TACOM 1 July 1975.

Enlisted personnel tend to fall under the following MOS series:

52 Series - Power Production and Distribution

61 Series - Marine Operations

62 Series - Engineer Heavy Equipment Operation and Maintenance

65 Series - Railway Maintenance and Operations

Support systems are a conglomeration of the equipment necessary to support troop activities. Maintenance requirements of this diverse group equipments are similar to those of one or more of the other commodity systems. Skill level requirements are also diverse. Approximately 10 MOSs are associated with support maintenance, with less than 5 positions in any one category. Tools, test equipment, and facility requirements run the gamut. The equipment is often commercial, for which commercial manuals are used or adapted. Non-troubleshooting maintenance tends to predominate in this system and inspection plays an important role as it does in munitions systems. This importance of inspection implies an emphasis on graphic support, because graphics are the primary basis for distinguishing visual cues. Words are more useful for stating the action that should be taken after the visual discrimination is made.

h. Depot Level Operations

A visit to the Corpus Christi Depot made it clear that the fundamental elements of the new concepts would not apply easily to depot operation, because so much fabrication is done there that is not amenable to standard procedures described in a manual. The assembly processes are amenable, but they are generally performed by personnel with years of experience. This is described and discussed in Appendix E. But for the purposes of this study, depot level maintenance is excluded.

2. Concept Fundamental Elements Reviewed Against Commodity Systems

In Task 3, five fundamental elements were identified as the processes for producing a manual. Slightly different combinations were identified for troubleshooting and non-troubleshooting situations:

Processes Required

Troubleshooting	Non-Troubleshooting
Equipment Analysis	Equipment Analysis
Functional Analysis	
Task Analysis	Task Analysis
Behavioral Task Analysis	Behavioral Task Analysis
Intelligibility	Intelligibility

Once the maintenance characteristics of the commodity systems (Aircraft, Communications, Missiles, Weapons, Vehicles, Munitions, Support) had been defined, the effects of those characteristics on the processes for generating a manual were examined. The examination was made in terms of which environments or situations in a commodity system would not be amenable to any one of the five processes (fundamental elements).

3. Analysis of the Maintenance Situations

a. Maintenance Mission

The maintenance missions are constant throughout the commodity types. Preventive maintenance is performed only at the operator/organizational level with the remaining activities being performed across all of the echelons. As defined in Task 3, the maintenance missions are still categorized under either troubleshooting tasks or non-troubleshooting tasks.

Troubleshooting Tasks	Non-Troubleshooting Tasks
Malfunction Diagnosis and Isolation	Preventive Maintenance
	Replacement
	Repair
	Overhaul

Although replacement and/or repair tasks are required to complete a troubleshooting task, they may also be performed as a result of an inspection. Thus, they are considered non-troubleshooting tasks. Troubleshooting, as used here, describes those actions necessary to locate a faulty component once a malfunction symptom has been detected. All commodity systems have both kinds of tasks.

b. Commodity Characteristics

A detailed discussion of the commodity characteristics is provided in paragraph B of this Task description. In terms of the commodity breakdown (electrical/electronic, mechanical, fluid/air flow; and simple versus complex), each commodity type can still be characterized as being made up of one or more of these equipment types. This has little effect on the process for preparing documentation. The content specifics differ, but the processes for preparing the specifics are the same. It was noted that as a system becomes more complex, the maintenance mission tasks are spread across the echelons of maintenance and MOSs. This requires that the information be packaged and indexed accordingly. It does not affect the process of preparing information for each echelon or each MOS specialty.

c. Skill Level

The skill level for a job is usually defined in terms of the amount of training required. Skill levels are sometimes defined in terms of fineness of discriminations, dexterity, etc. There are also subtle distinctions made in terminology, e.g., repairman, technician, maintenance personnel, etc. There are also some distinctions made in terms of aptitude. The higher the echelon, the more highly skilled the incumbents consider themselves to be.

The process for producing a manual should describe each task so that personnel of grade school reading ability can follow the instructions and perform the task. There are no assumptions about the skill level required to do this. For the higher echelon personnel there will be more tasks to be performed within an MOS, and this variety may be considered a matter of skill, but to follow the instructions for any individual given task, no special skill is assumed.

Experienced personnel may be regarded as more highly skilled in the sense that they have memorized many of the steps which constitute a task. They often can perform a task faster. Experienced personnel know "short cuts" and this may be regarded as higher skill, but none of this affects the processes for producing manuals for the novice. The analyst who prepares the task step details identifies the shortest set of steps for getting the task done properly. The process results in detailed instructions (graphic and written) for the novice user on how to perform each task within a job. Skill increases as personnel continue to use the manual, but there are no differential skill requirements for using it. "Complex" tasks will result in more pages of description than a "simple" task. But page for page the complexity will be the same. Experienced personnel who have learned many of the procedures in the manual can skip over those details of how to accomplish the instruction, but the details will be generated by the fundamental processes and will be included in the manual.

d. Maintenance Environment

The extent to which tools, test equipment and facilities are available in the maintenance environment is a function of the level of maintenance. The length and support requirements of various tasks and the allocation of spares at the various levels of maintenance are factors which determine the maintenance environment. The higher the echelon, the greater the support provided in terms of tools, test equipment, facilities, processes, etc. Since tools and test equipment are used in task performmance, instructions on how to use them are given in the manual. The specifics of the instructions will be different for each tool, but the process for generating the instructions remains the same for all. With more tools, more instructions are needed. Increases in special tools and equipment indicate that more of the instructions for their use should be taken out of the main body of the manual and placed in off-line training (see Task 5). This is done to avoid repetition in the manual, but it does not affect the processes for preparing the step-by-step instructions. The processes for generating content going in the manual and in training are the same.

4. Review of Existing Specifications

In an additional attempt to discover any differences required in the process for producing documentation for the various Commodity Systems, sixteen technical manuals specifications were reviewed. The specifications covered all of the commodity types required under this contract. Each specification covered at least the organizational, direct support, and general support levels of maintenance.

The technical manual specifications reviewed across the commodity systems revealed the following differences and similarities:

a. The most detailed requirements were contained in the specifications for electronic equipment and for aircraft and aircraft equipment.

b. Content organization requirements were basically the same for each commodity type with aircraft requirements being the most specific. Here specific subsystem headings were called out and coverage for each subsystem detailed.

c. All specifications called for "theory". Only four specifications, those for telecommunication equipment, teletypewriter equipment, electronic configurations for aircraft, and photographic equipment, required theory in detail. Of these four, only the specifications covering electronic equipment maintenance were explicit by calling for theory "to the point of explaining each circuit". So, though these specifications are different, none of them is sufficiently explicit to make much of a difference in what the TM producers do. In fact, what the producers do is determined more by what is "traditionally done" (i.e., by examples from previous TMs that were acceptable), than by the specifications themselves.

It is very important to recognize that the Functional Analysis process element specifies a particular level of functional description. This analysis requires functional descriptions to a level consistent with the troubleshooting process presented. This is consistent with all current specifications, but it involves a change in practice. It "forces" a particular level more than any specification does today.

d. Except for electronic, aircraft, and aircraft equipment, troubleshooting requirements in existing specifications only call for symptom cause tables and require that the fault isolation must be consistent with requirements. They do not specify how functional information should be developed to guide the user.

Functional Analysis also calls for symptoms, but each symptom must be identified with the block which contains the parts that can produce that symptom (bad output). This means that each symptom is identified as a bad output from a specific block. The troubleshooting strategy calls for measuring the prescribed inputs to blocks with bad outputs until a block is found with good inputs and a bad output. Then the block diagram of that block is treated in the same way, and this is repeated until a replaceable unit is reached.

e. In the specifications examined, the requirements for non-troubleshooting tasks are not detailed. Generally, they merely require consistency with the MAC.

f. The text format requirements for all of the specifications examined are those required by MIL-M-38784, General Requirements. The content analyses are not in conflict with this, but do specify additional data.

g. Diagram format requirements were very detailed in the specifications for electronic (excluding missiles), aircraft, and photographic commodities. Diagram format requirements in the other commodity systems were virtually non-existent.

h. Finally, for quality assurance requirements, validation and verification were referenced to MIL-M-63000 and MIL-M-38784, Technical Manual Requirements for Manuscripts. But more stringent requirements are required. They include performance of all job tasks by new users (novice soldiers, not highly experienced personnel). That is, to pass validation and verification inspections, new users, not just experienced personnel, must demonstrate that they can use the manual products to perform all job tasks to technical standards of adequacy with no other information or training.

i. Existing specifications provide no substantive basis for establishing different specifications for the different commodity types. A note needs to be made of the fact that different maintenance levels and different commodity areas are recognized to be different in regard to test equipment, specific tools, and sophistication of equipment. It is also recognized that this is a traditional basis for producing multiple specifications. However, the same analyses should be performed for all levels of maintenance (not including depot).

The TM producer will be required to produce products from certain specified processes to meet new specifications. It is not sufficient just to have the required formats. The products of Equipment Analysis, Task Analysis, Behavioral Task Analysis, Functional Analysis, and Intelligibility processing must be specified, as well as the processes. It should be recognized that the details of a format for a battery charging meter will be different from those of a format for a dual trace scope (there are more knobs to set, for one thing), but a new specification must prescribe a process that says "all settings on the test instrument will be shown in such and such a way" and examples show how this same process applies to different types of equipment. The format specifications for each type of meter are not different, though the examples do not have the same appearance. For instance, examples associated with mechanical test equipment, engines, etc., would be different from those associated with complex electronic systems. But the point is that the specified products of the required analytic processes will be the same regardless of what the meter or special equipment looks like. The producers of TMs will have to meet the same criteria regarding an output regardless of the type of test instrument used to measure the output.

5. <u>Summary of Applicability of Fundamental Elements to Commodity Systems.</u>

The processes represented by the fundamental elements, Equipment Analysis, Functional Analysis, Task Analysis, Behavioral Task Analysis, and Intelligibility, apply equally well to all Commodity Systems. These are processes for accurately stating how the maintenance job should be accomplished in intelligible graphic and written form.

Any of the tasks in the Commodity Systems are amenable to such analyses. Analyses of different systems, e.g., hydraulic, electronic, mechanical, will produce products that look different, but the processes for preparing the content are the same. A complex task can be analyzed in the same way as a simple one. The products of the analyses will differ in length, but page for page the difficulty will be the same. A commodity system with a lot of MOSs requires the analysis of more tasks, but the processes for each are the same.

The only situation which requires a different kind of analysis is the troubleshooting situation. It requires Functional Analysis to provide the user with functional understanding of the system. All other fundamental elements are also required for troubleshooting tasks. Non-troubleshooting tasks do not require Functional Analysis.

None of the existing specifications are in conflict with those of another commodity system. They differ only in the amount of detail they call for in TMs. A new specification must call for more detail than any existing specification in regard to what processes are required. The fundamental elements are processes for generating manuals.

The one maintenance situation which had a major effect on the fundamental elements was depot. There is no way to adapt the fundamental elements to the local fabrication processes prevalent at depot. Therefore, depot level maintenance was excluded as beyond the scope of this study.

5. Changes in Cost of Ownership Through Fundamental Elements of New Concepts.

The Military Occupational Specialty Training Cost Handbook (MOSB), Volume I, Enlisted MOSs, is the primary source document for costs.[1] All major commands and many schools are on the distribution list for this document. The following is an excerpt from the Introduction of the MOSB:

> ". . . training costs account for approximately 10% of the FY budget. Too often the cost of a soldier is quoted solely in terms of pay and allowances and possibly the supplementary benefits such as free retirement, health and dental care. While this framework might appropriately be used to describe the functioning soldier, it does not take into account the soldier in a training status. When a soldier is training, he is not producing benefits to the Army, but is incurring a number of training-associated costs that are not reflected in the conventional costing described above."

[1]Military Occupational Specialty Training Cost Handbook (MOSB), Directorate of Cost Analysis, Office of the Comptroller of the Army, Washington, D. C., May 1974.

There were 167 courses leading to electronic and mechanical maintenance MOS that the first enlistment soldier could be trained in. No course which ... operator MOS was included in this analysis. The average length of ... was computed, as was the average cost (per soldier) of the ...

... average length of a school and/or ATC courses for maintenance ... difficult to determine precisely across all schools, MOS, types ..., etc. Course lengths change frequently, but the MOSB provides ... of 20.6 weeks, which was correct in 1974. The average total ... of these courses was $20,348 per soldier. This represents a cost per ... per week of about $1000. This cost is remarkably constant across ... seldom varying more than 20%. The time spent in travel and awaiting ... of the course and assignment after graduation must be added to this. ... three weeks on each end of a course is common. Travel can add a few ... A figure of five weeks is used as an average amount of time in ... activities. The cost of this waiting and travel time is ... at $300/week, or just slightly more than the MOSB figures for a ... BCT. Five weeks at $300/week is $1500 for the waiting time. Added ... $20,348, the average amount spent on training a soldier for mainten... is $21,848. The MOSB does not provide any figures for the cost ... of a soldier on the job. But the cost per week of a soldier in ... about $300. The cost per week of a soldier in formal training is ... The cost on the job has to be more than $300 and less than $1000. ... use a figure of $600/week, this represents a cost of about $30,000 ... year. With the estimate of 169,000 full time maintenance personnel in ..., the yearly cost of this work force would be almost $5 billion per ... including the costs of training.

... number of full time maintenance personnel varies each year as the ... services strength varies. The estimated enlisted personnel ... the Army at the end of FY 1974 was 676,000 according to Department ... Statistics.[1]

... source[2] indicates that approximately one-third of all personnel ... Armed Forces were occupied in full time maintenance duties in 1967, ... year this particular statistic is available. It is assumed that ... Army had a somewhat smaller percentage of its personnel in full time ... maintenance duties in 1974. There are no specific statistics for the Army ... this year, but a conservative estimate is that one-fourth of the Army ... personnel were in full time maintenance jobs. This would mean (1/4 of ...,000) about 169,000 personnel were in full time maintenance jobs in ...

... Abstract of the United States, United States Department of ..., 95th Edition, 1974.

...tical Abstract of the United States, United States Department of ...ce, 91st Edition, 1970.

The reenlistment rate varies over different years but 10-20% would be a reasonable estimate for maintenance personnel. To replace the losses of experienced personnel each year, about one-third of the work force must be replaced with new personnel. These are the personnel who must be trained each year. One-third of the work force of 169,000 is approximately 56,000.

a. Training Costs

The cost of training 56,000 new personnel in maintenance duties at almost $22,000 per soldier is $1,232,000,000 per year.

b. Labor Force Costs

The cost of 169,000 personnel in the full time maintenance labor force at $30,000 per soldier is $5,070,000,000 per year.

c. Training Cost Reductions

If maintenance training time is reduced by 75%, this represents a lowering of cost of ownership by $924,000,000 or approximately $.9 billion (.75 x $1.232 billion).

d. Labor Force Cost Reductions

If the maintenance labor force can be reduced by 15% the annual cost reduction is $755,000,000 or approximately $.7 billion dollars.

The total of these reductions in personnel costs is $1.6 billion (.9 + .7) annually.

e. Cost of False Removals

The other cost to be added to the 1.6 billion dollar figure comes from the reduction in false removals. The figure of a 15% reduction in false removals was brought forward from Task 3. The assumptions involved in estimating this cost are extensive. A false removal is often "corrected" at a higher echelon, and returned to service. Some false removals are thrown away. Statistics on these factors are not readily available. Nor are the costs to the system of transporting these parts from one echelon to another and keeping the paper work on them. If we estimate that these costs are on the order of $500,000,000 per year, a 15% reduction would represent a cost of ownership reduction of $75,000,000. This is only .075 billion dollars, little more than a rounding error in the personnel figures. The figure of 1.6 billion could be rounded up to 1.7 billion with addition of the estimated cost of false removal reductions. In view of the magnitude of the false removal factor, it may be seen that increased precision in this estimate is not justified.

C. Summary

The projected changes in cost of ownership that can be effected with a new manual specification is on the order of 1.7 billion dollars annually. The exact figure is not important. Even if the actual figure is half that amount or twice that amount, the appropriate action is the same. The changes represented by the new concepts should be implemented. The implementation cannot be made overnight, but the direction of movement is clear. It may be possible to make the reduction in cost of ownership more, or it may be less, but either way it represents a goal worth achieving.

The specification [illegible] prepared in this task represents an integration of [illegible] the fundamental elements which have resulted from various [illegible] in maintenance over the past twenty years. These fundamental elements apply to all situations in the Army commodity systems. An integrated specification based on the fully-developed forms of the fundamental elements in new concepts should produce manuals that have the advantages found in tests of the original manuals. This includes a 75% reduction in training time, 15% reduction in the maintenance labor force, and a 15% reduction in false removals. The cumulative effect of this combination of factors on cost of ownership is on the order of $1.7 billion annually.

Before presenting the integrated specification it is appropriate to describe the elements and give acknowledgement to their sources.

1. Title. The term "Job Performance Manual" is an acknowledgement of the contribution of the Air Force Human Resources Laboratory. Dr. John P. Foley, Jr. coined the term Job Performance Aid (JPA). The term "aid" is a term that is probably no longer appropriate. The product of the specification is a manual. The term Job Performance Manual or JPM is sufficiently similar to JPA to acknowledge the origin of the acronym, while using the more appropriate nomenclature. The term "integrated" is used to acknowledge the contribution made by all the originators of new concepts. The contributors will find words and phrases that they should find compatible with their views and with the statements they have made in describing their concepts. It is not feasible to attribute every phrase, but those who have worked in this field during the past twenty years will recognize their contributions.

2. Equipment Analysis. The specification for this analysis is adopted from the JPA specification.[1] The process is one of identifying all the job tasks that need to be performed on an item of equipment. The Army Maintenance Allocation Chart (MAC) does almost the same thing. Task Identification or Maintenance Allocation is based on the equipment items, and states what maintenance (task) is to be performed on each. The basic information for this chart is engineering information. It represents the interface between engineering and the process of developing instructions for the maintenance user. It is a management tool for producing technical manuals. It insures that every major job task is identified for analysis and preparation of instructions for performing the task. It does not indicate how to perform the tasks it identifies. That is done in the following processes.

[1] MIL-J-83302. Job Performance Aids Advanced Type, for VNAF Organizational Maintenance. 15 March 1971.

3. Task Analysis. The Task Analysis identifies the conditions for performing each job task and the subtasks associated with each job task. The conditions include such things as number of personnel required, lubricants required, tools required, etc., by task. Task Analysis does not provide the exact cues and responses involved in performing a given task, nor how each job task should be described with graphics and short verbs. (This behavioral detail is specified in the Behavioral Task Analysis.) The Task Analysis is used for non-troubleshooting tasks and the procedural aspects of troubleshooting tasks, e.g., test equipment setup. This is a form of analysis common to many new concepts, but its most fully developed statement is in the JPA Specification.

4. Functional Analysis. The term "functional" means troubleshooting functions, not functions as the design engineer would think of them. The sources of this part of the JPM specification are FORECAST and SIMMS. The products of the analysis are block diagrams, inputs, outputs, symptoms, functional-physical overlays, and functional descriptions that tie these things together and provide understanding of each functional block. More studies have been conducted on the products of this analysis than on all the other new concepts combined. The integrated JPM specification identifies the products of this analysis and the criteria they must meet. Each functional area (block) of the equipment must be precisely defined in terms of both the parts within the area, and those outside the functional area. The symptoms associated with a malfunction in each block must be defined, as well as the correct block inputs and outputs. No part can be included in a block if it affects the measured input to the block. The analysis is accomplished in several levels. The top-level breaks the equipment down into about seven functional areas. The second level breaks each of the top level functions down to about seven smaller functional areas and this continues in levels until the smallest replaceable part (at a given echelon) is broken out.

[illegible] troubleshooting concept used in this specification is designed to counter [illegible] two inherent disadvantages of the fully proceduralized approach and to take advantage of certain characteristics of a block diagram approach.

[illegible] proceduralized approach, call it tree, or cause/effect table or [illegible] has inherent disadvantages. One is that the efficiency of troubleshooting [illegible] is a function of test point indications produced by a given malfunction [illegible] means that each item of information collected can change the strategy for what item of information should be collected in the next step. A [illegible] procedure cannot shift strategy or order of steps. Another is [illegible] may misinterpret a test point reading which sends them into a [illegible] shouldn't be in. They only find that it is a dead end when [illegible] end. Then the user does not know where he took a wrong turn [illegible] back to the beginning. He thus repeats steps done correctly [illegible]. This is inherently inefficient and psychologically taxing and unrewarding.

The block diagram approach avoids both of these serious disadvantages. The particular block diagram approach selected here is the one that "holds" the user at one level until the trouble is localized to a particular area, then releases him to the details of that particular area to repeat the process there. The user never deals with more than about seven blocks at a time. He always has a level to go back to if he misinterprets a reading. He does not repeat from the beginning. Also the block diagram approach allows for a change in strategy as the user becomes more experienced. The user is instructed to always test the inputs to the block with a bad output. This single general instruction makes a strict procedure out of the block diagram data. But when the user is experienced he can deviate from the instruction of this fixed strategy. He is told he can skip blocks so long as he remembers (or makes notes) of what he skipped. This allows him to skip to the test points that are easier to measure or have a higher failure rate or are more likely in view of the test point data already collected. Thus this particular block diagram approach provides for a mixed strategy. The one used by a novice amounts to a procedure. But the user can use other more efficient strategies when he is experienced. The data grows with the user.

Therefore, the processes for producing a fixed procedure with its inherent inflexibility and inefficiency is not selected in this study. The advantages are all with the block diagram approach. It has proven its efficiency in many tests of large scale equipment while the fully proceduralized approach has not proven efficient except in very limited tests of small equipments and the inherent disadvantages of proceduralization for troubleshooting make it unsuitable.

A functional description is prepared for each level. It describes the equipment functioning at each level in terms of cues and conditions for obtaining the cues. This is the level of understanding the design engineer has for designing the equipment. The analyst uses more basic, theoretical information to make the analysis that reduces this to functional information. All studies indicate that this functional information is a better level for troubleshooting the equipment than design theory information.

There are detailed techniques for making these analyses on different kinds of electronic circuits (FORECAST) but these technical details are not considered appropriate for inclusion in a specification. Both FORECAST and the SIMMS specifications[1,2] call for these functional analyses.

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[1] Shriver, E. L. FORECAST and Other New Developments in Manuals, Matrix Corporation, Alexandria, Virginia, May 1964.

[2] MIL-M-24100B. Symbolic Integrated Maintenance Manuals (SIMM) for Systems and Equipment, May 1972.

No attempt is made here to sort out the contributions of each of these new concepts to the integrated specification. But these functional analyses are the only way that has been [illegible] for improving trouble-shooting performance. They do not [illegible] the user's strategy to an inflexible series of steps [illegible] and [illegible] to only those. He has guidance for determining the order in which [illegible] take the steps. But the format allows him to skip steps as he [illegible] in doing so, without confusion. Thus he can increase his [illegible] the job without negatively affecting his effectiveness.

5. Behavioral Task Analysis (BTA). Many of the new concepts [illegible] form of this type of analysis, but have not developed it fully. Its fullest development was in a particular study on JPAs for the Air Force.[1] The JPAs as originally prepared showed no improved performance over standard TMs with the group of individuals who used the first version. Behavioral Task Analysis was used to produce two other versions of the JPAs for test purposes. The final version resulted in substantial increases in performance levels over standard technical manuals. This is clear evidence for the effectiveness and importance of BTA. BTA involves an analysis of cues and responses used primarily to prepare graphics, but also to make the written material match the graphics. It was fully developed as a defined method of analysis in a supplement report by Edgar L. Shriver on that Air Force test.[2] It has not been included in the AF JPA specification.

The Behavioral Task Analysis requires the analysts to perform on the equipment. The performance is the subject of analysis, not the equipment. The final manuals contain graphic and written instructions for performing the tasks analyzed by the BTA. The materials must be intelligible to novice performers. If not intelligible, they must be changed and tested again. It is not acceptable for a JPM producer to say that the fact that information is not final on a task is sufficient reason for not performing a test of drafts (graphic and written), because this test is for intelligibility and not just accuracy. Even if the equipment changes before the final TM is produced, these validations must be performed for intelligibility during development.

The Behavioral Task Analysis is called for in the integrated JPM specification. It is not specifically attributable to any one of the new concepts. Some form of this analysis is used in many of the new concepts. But it was not well developed until the test cited above. This was the first time that it was shown that lack of this procedure could negate the others.

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[1] A Report on the Evaluation of Job Performance Aids for UH-1H Organization Maintenance, AFCS, Wright Patterson AFB, Ohio, September 1971.

[2] Shriver, E. L., Behavioral Task Analysis, AFHRL, Wright Patterson AFB, Ohio, 1971.

[illegible] graphic and written. Each has certain rules and examples "stored" in it. These materials [illegible] Behavioral Task Analysis listed above. Strictly speaking, this element is not another form of analysis. It is a standard [illegible] analyses. The written and graphic aspects of this element are integrated.

a. Written Aspects: This fundamental element has a prescribed list of [illegible] verbs. It also prescribes a certain sentence and model [illegible] for written instructions. When applied with graphics it results in material which is intelligible to users with a grade school reading ability. This element was first developed in PIMO and a form of it was later placed in the JPA specification. The initial list of verbs was modified for the present JPM specification by replacing the multiple syllable verbs in the original list with single syllable verbs. There has been no new concept study that verifies the advantage of single syllable verbs over multiple syllable verbs. But there have been many studies on readability, which have shown that the smaller the number of syllables, the lower the level of reading ability required to understand the passage. In fact, most definitions of reading level use the number of syllables along with sentence length as part of the definition. The original PIMO word list and sentence length prescription resulted in text readable at about the ninth grade level. The new concepts of PIMO-JPA, and the many people who have studied readability, are acknowledged as the source for this part of the JPM specification.

b. Graphic Aspects. The first new concept to fully develop graphics as a major technique for imparting information was PIMO. Traditional TMs contain some graphic material. But TM specifications traditionally allowed the use of graphics only if necessary. Many of the new concepts used graphics extensively. But PIMO made a full break. PIMO prescribed a graphic on every page, facing the words instructing the user in what to do to the pictured equipment. The graphic became of central importance for every instruction - not just in support of a manual that primarily consists of words. PIMO, and later JPA, prescribed line drawings for graphics rather than photographs. In practice the line drawings became less like mechanical drawings and more oriented to the viewpoint of the user. It is virtually impossible to write a specification on the appearance of a graphic. The integrated JPM specifies that a context and focus view of each graphic be included on each page, and that only the detail necessary for the user to make a match between the graphic and the equipment it represents be included. There are also certain requirements about numerical indexes between the graphic and the step-by-step instructions associated with the graphics. The intelligibility standards and the Behavioral Task Analysis are developed together. The graphic is specified as the source of the visual cue information, with the associated instructions containing the response action information. Intelligibility is checked during the Behavioral Task Analysis. The sources of the specifications on intelligibility of graphics for the integrated JPM are Behavioral Task Analysis, PIMO and JPA.

7. <u>Validation-Verification Tests.</u> Validation and verification tests are common to most specifications. The important aspect of the JPM verification is that it requires a novice user using nothing but the Draft Equipment Publication prepared under this specification to perform all job tasks. The specification does not require that the validation be done with novice subjects. But clearly the validation should be done as if the subjects were novices. The government may use the validation as its verification process if it chooses.

B. <u>Job Performance Guide (JPG)</u>

The Integrated Job Performance Manual is complimented by a Job Performance Guide. The subtasks such as using wrenches, tools, opening hatches, etc. that are common to many job tasks, are analyzed and placed in the Job Performance Guide (JPG). The JPM and the JPG constitute a complete guide to performance of all job tasks. But the JPG includes material which soldiers should learn, rather than constantly refer to the JPG. The content of the JPG is recorded in the context of selected job tasks. Content is not extensive. It is not theoretical. It is just content which would appear over and over again in the JPM, and increase its volume if not placed "off line" in the JPG.

All content for the JPG is produced by the same fundamental elements as are used for producing the content of the JPM. It is validated and verified along with the JPM. It can be used as OJT, or with tape audio cassette, or with audio visual cassettes. It is validated and verified by tests with novice soldiers. There is no precedent in the various new concepts for this breakout. It is included as a practical measure to prevent the JPM from becoming excessively large in volume, and in recognition of the fact that users do learn procedures that are repeated often. As such it constitutes a training program in basic procedures which are required frequently on the job. The content of the JPG is produced in the identical way that it is produced in the JPM.

The JPM and JPG specification produced under these tasks are titled MIL-M-632XX(TM), Draft Military Specification for Preparation of Improved Technical Documentation and Training, Part I, Job Performance Manuals, and Job Performance Guides, <u>Part II, Training Materials</u> (Supporting Job Performance Manuals and Guides). Part II of the specification defines requirements for the development content and product performance of extension training material (ETM) to be used in conjunction with JPM/JPG documents, in support of the maintenance of Army materiel. See section on training specification following the Task 7 description.

TASK 6

Task 6 involved the preparation of a sample in accordance with the specification developed in Task 5. The equipment selected for the sample was the M60A2 tank turret with specific coverage of selected portions of the armament subsystem to include the Laser Range Finder. The sample provides general information, scheduled maintenance, troubleshooting, and remove-replace procedures at the organizational, direct support and general support levels. The sample is provided as a separate document to this report.

Field Test Plan

The Field Test Plan prepared and submitted under this contract is contained in Appendix F. It combines field test and research test characteristics. The plan is designed to evaluate the sample prepared in Task 6 in terms of cost, user effectiveness, and user acceptability. The plan is also designed to test any competing manual concepts or techniques.

The JPM/JPGs which are the product of the processes prescribed in the Draft MIL-M-632XX(TM) describe how to perform the maintenance and operator job tasks. This is what the user should be trained to do. The current objectives of the U. S. Army Training and Doctrine Command, TRADOC, are to prepare training material which tells soldiers what to do to accomplish job products. This is exactly what the JPM/JPGs do. Therefore, TRADOC became interested in this product from the training point of view and added funds to this contract to produce Part II of Draft MIL-M-632XX(TM).

Parts I and II use the same fundamental elements, or processes, and essentially the same products of the analyses. However, Part II prescribes the preparation of certain administrative instructions for the new soldier to use as he is exposed to various tasks during his early time on the job. It also provides for a handbook that the job supervisor uses to select jobs that are appropriate for the new user at various stages of work on the job.

The JPG contains instructions for using common tools and performing common tasks. These are the types of things that should be programmed early in the new user's job experience. They are the things a user will learn to do without the JPG after some experience with them. They tend to be the things that are remembered because they are frequently used, whereas job tasks described in the JPM are not as frequently performed. They will not be memorized until much later in the user's experience. Some may never be memorized.

To the extent that it is consistent with the unit's work schedule the new user should be assigned certain tasks sooner than others. This does not imply a strict sequence. It merely means that, on the average, the new user should be assigned to some kinds of jobs earlier rather than later. There is a Training Managers Handbook prescribed in Part II. This tells the job supervisor/training manager what tasks should come sooner rather than later, but it does not prevent him from assigning any job at any time. The JPM and JPG used together describe how to do any job task. The soldier can do any job task from descriptions in these sources. He learns from doing that job task. He will learn certain common procedures and common tools from doing almost any job tasks. However, there are certain sequences of job tasks that will require all commmon procedures and tasks. If such a sequence of these job tasks is completed the soldier and the supervisor know he has performed everything in the JPG. The confidence of both are increased when this sequence is completed. Therefore, such a sequence is given in the Training Manager's Handbook. It is one that also minimizes the chances of damage to the equipment or the soldier. For each lesson prescribed in the Training Manager's Handbook there is a Lesson Administrative Instruction (LAI). This tells the soldier where to look in the JPG and what his objective and criterion of performance is on each task in the lesson. The LAI is no more than a single piece of paper which provides a

beginning and an end point for each hour of the soldiers early time on the job. Part II also provides for the use of other media than the JPM/JPG. It provides for audio only and audio/visual information. Audio visual would be used to show the "big picture" for a given equipment. For a radar this might be an overview of one or more batteries of radar equipment operating together to acquire, track and destroy targets. If the equipment is a tank, a tank or platoon of tanks might be shown in action. The audio visual includes motion and would be used to show anything that it would be inconvenient to demonstrate for a single new soldier on the job. The audio/visual mode can also be used to introduce the soldier to the JPM/JPG, the Lesson Administrative Instructions, and how he is going to learn by doing. The processes for preparing audio visual material are prescribed in Part II. But it should be noted that the processes prescribed in Part I are the only processes to be used for preparing specific maintenance/operating instructions for maintaining/operating the equipment. Part II is not an alternative to Part I. Part II provides for some additional materials that the job supervisor and new soldier use to bring the soldier through his early job experience with minimum concern to the soldier and supervisor and maximum building of confidence on the part of each.

The other medium allowed by Part II is audio only. This medium might be used to pace a soldier, or more likely a crew through a procedure that must be performed within relatively rigid time constraints. An example is operation of the equipment. Maintenance personnel have to know how to operate the equipment, but they can do this at their own speed. They do not have to be skilled operators. But a tank crew or a radar crew must be pushed to higher skill levels. The JPM/JPG can only describe a procedure, they cannot pace personnel to bring them to higher skill levels. The audio only mode can pace personnel. The audio/visual mode can also pace personnel, but the visual medium generally is not a desirable one on which to build up skill. Generally skill must be built on the actual equipment or a mock up of it rather than through a picture on a screen. The audio medium matched with the real equipment or a mock up of the equipment is expected to be used extensively for operator and crew training. Again the content of training would not be different than that produced by the processes prescribed in Part I. But the application of this content to the user(s) would be by a different medium than paper.

Also, in a crew training situation a soldier at one position may perform part of a procedure and then wait for another to perform part of another procedure, etc. The situation that the crew is in may require different combinations of basic procedures. The crew must gain skill in recognizing situations and performing the proper portions of their procedures as well as performing them rapidly.

Summary

Part II of the specification provides the option of the audio only and audio visual media. It does not prescribe the situations in which they will be used. It does not prescribe any analytic processes separate from those specified in Part I. The content of the JPM/JPG is expected to be the basic content for training. But the examples and discussion in this section are intended to show how Part II can be used to round out the basic training content of the JPM/JPG and provide for a smooth progression for the soldier and his supervisor.

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APP[illegible] A

LIST OF CONCEPTS

LIST OF CONCEPTS

AT?	Administrative Te... System
ADMIRE/MIRA...	Automatic Diagno... ...intenance Information Retr...
ADPEP	Automated Data Preparation Evaluation Program
ATOMS	Automated Technical Order Maintenance Sequences
AVIS	Audio Visual Information System
BFIC/BIFAC	Binary Fault Isolation Chart
Block Form	
British Algorithm	
C-A Logical Processes	
CATA	Computer-Aided Trouble Analysis
CMG	Condensed Maintenance Guides
Comp...ter-Aided Loop Di...gram Representations	
Computer Graphics and Visual Module System	
CONSD	Condensed Servicing Data
CONTEXT (Vitro Laboratories)	
DATOM	Data Aids to Trai...ing, Opera...ion and Maintenance
... Dynamic Display	
...OCULAR	Electronic Ocular
	Fast Access to Systems Technical Information
...AFI	Flight Engineers Fault isolation/ ...n Around Fault Isolation
Filesearch System	
FIST	Fault Isolation by Se... ...utomatic Techniques
FLAPS	Functional Layout and Presentation System
FOMM/SIMMS/IM/IMP/IMC/BAMAGAT	Functionally Oriented Maintenance Manuals/Symbolic Integrated Maintenance Manuals/Integrated Maintenance Package/ Integrated Maintenance Concept/Block-a-Matic, a-Gram, a-Test
...RECAST	
...JPA/PI...O/JPA	Fully Proceduralized Job Performance Aids/Presentation of Information for Maintenance and Operations/Job Performance Aids
GPAM	Graphically Proceduralized Aids for Maintenance
HAWK Radar Mechanic/System Collection Manual	

LIST OF CONCEPTS

[illegible]	
[illegible]	
[illegible]	
JOBTRAIN	Job Training Aids for Maintenance
LCI	Learner-Centered Instruction
[illegible]	Lexical-Graphical Composer-Printer
LTS-1/LTS-2	Lincoln Training System
M3DD	Microfilmed Maintenance Manual Data Dissemination
MADAR/GPS	Malfunction Detection, Analysis and Recording Systems and its Ground Processing System
Maintenance on Microfilm	
MAINTRAIN	Maintenance and Training in Complex Systems
MDS	Safeguard Maintenance Data System
MEMRI	Maintenance Engineering Management and Repair Information
Microcard	
Minicard System	
Miracode System	
MMS	Maintenance Management System
Model 205F, Micro Twin Recorder-Reader	
Model 530D and 530H Reader-Printer	
Neostylized Manuals	
Optimum Picture/Word Format	
Procedures Flow Chart	
Profile Cards	
PS Magazine	
Pulsed Light Projection	
PYRAGRAM	Pyramid Diagram
RAPIDS	Rapid Automated Problem Identification Data Systems
REPOM/MIRM	Reliability Prediction Oriented Maintenance/Maintenance Instruction Recorded Magnetically
RESTORE	Rapid Evaluation System to Repair Equipment
SPARES Test Capability Report	

LIST OF CONCEPTS

Teaching Manuals	
Team Training	
TRACE	Transistor Radio Automatic Circuit Evaluator
Trouble Locators	
TRUMP/MIARS	Technical Review and Update of Manuals and Publications/Maintenance Information Automated Retrieval System
VATE	Versatile Automatic Test Equipment
Videofile System	
Videosonic System	
Work Package Concept	
WSMAC	Weapon System Maintenance Action Center
XFL	Experimental Fault Locator

APPENDIX B

DESCRIPTIONS OF THE LEVEL OF DEVELOPMENT OF FUNDAMENTAL ELEMENTS OF TECHNICAL DOCUMENTATION CONCEPTS WITHOUT EXPERIMENTAL DATA

ATOMS

[illegible] few pages of a company brochure. It is not fully developed. It has not been put into practice. And it is not known if people can perform effectively with it or not. It is based on a functional analysis and its diagrams are functional loops. This concept is similar to FORECAST and SIMMS in its fundamental elements. The process for making the Functional Task Analysis is not described in the brochure. But the ATOMS product (functional loops) is evidently based on some form of functional task analysis. For all practical purposes, except one, it can be said that the fundamental elements in this concept, if developed, would be very similar to those developed in FORECAST and SIMMS. The one exception is that the "functional loops" used in this concept imply documentation of subfunctions within functions. FORECAST training included this "indented" function within functions but the FORECAST documentation did not show this in the rather clear way that ATOMS does. However, since ATOMS was never worked out for a large system it is not known if the functional diagrams that look clear on one page would look clear when spread over many pages. This problem of scale has been a problem for more than one concept as it moved from an idea to implementation. The MDC's of SIMMS are a good example of this. The oversized pages were used in an attempt to keep all of a big system on page as had been done for a little system when the MDC was at the idea stage.

BLOCK FORM

This concept has not gone beyond the idea stage. It has not received implementation or test. It uses a block format, wherein the blocks contain step-by-step instructions similar to PIMO and JPA. The block diagrams do not provide descriptions of the equipment functions as in FORECAST and SIMMS despite the [illegible] "block". If developed it would be similar to FPJPA: it provides no development of a fundamental element that has not been more fully developed by other concepts which have been implemented and tested.

CATA

This concept uses computers. The nature of the analyses, (the fundamental elements) in this concept, are not well defined. Whatever effectiveness has been claimed for the concept must be achieved through the analyses that are performed before the computer is programmed. But there is insufficient information to tell what kind of analysis was made. There are no test results. Nothing is contributed to our knowledge of fundamental elements by the information that has been obtained on this concept. The fact that the results of an analysis can be programmed and displayed on a computer is not a contribution. Other concepts have shown that the results of content analyses can be presented effectively by lower cost means.

CMG

This concept has not been implemented or tested. It is designed solely for the experienced technician who already knows all the procedures but can't remember certain specifics on test point readings, tolerances or control sequences. It is apparently based on analyses but they are not specific. The Condensed Maintenance Guide (CMG) is designated as the experienced man's "little black book" of condensed information. The relevance of such summary information is a function of how the man has developed his techniques in his own experience. That is, some types of summary information are idiosyncratic to people. Some aspects of this concept might be considered for use as a checklist to summarize material in documentation used by the experienced man. But CMG has not been implemented or tested. Except for its relative uniqueness (with CONSD) in being designed for the experienced man only, it does not hold much promise for use in the present study. This doesn't mean the experienced man should be ignored. But costs of ownership will not be changed significantly by making things easier for highly experienced men.

CONSD - Condensed Servicing Data

The Condensed Servicing Data (CONSD), like the Condensed Maintenance Guide (CMG), is designed for the highly experienced technician operating without the standard technical manual, or it can be used with the standard Tech Order. It apparently utilizes content analysis more so than does CMG. It includes a list of fault cues, suggesting some kind of behavioral analysis. Like CMG this might have potential as a check[illegible] summary, but it is untested and has not been implemented. Also, c[illegible] ownership is not going to be affected significantly by some help fo[illegible] experienced man.

DATOM

DATOM manuals can be used for training and also on the job. They are based on analysis and provide understanding for the user. This concept has not been tested. But the fundamental elements in this concept are like those in FORECAST and MAINTRAIN. If the fundamental elements were fully developed and documented they would look very much like those in concepts which have been implemented and tested. The fact that this concept uses techniques which promote understanding for troubleshooting is an endorsement of that approach, but it does not represent any advance in the state of development of fundamental elements over that found in implemented and tested concepts.

FLAPS

The key feature of FLAPS is the organization of its format for multi-use through the use of FLAPS attached to the edges of pages. Unfolding a flap overlay reveals more detailed information. FLAPS also utilizes at

least two kinds of analysis, task and [illegible]. The tech[illegible] analysis as they are defined in the [illegible] report do not advance the state of the art. The use of [illegible] is the [illegible] of this concept. There is an [illegible] Training Devices Center but it has not been [illegible] problem of [illegible] on flaps attached to [illegible] evidence [illegible]. This technique, though [illegible] before [illegible] considered for general use.

GRAM

This concept utilizes analysis and "Plain English" [illegible] to gain its main effects. The development of this fundamental [illegible] is not as broad and complete as that of PIMO and JPA. If it were [illegible] fully, it would be very similar to PIMO and JPA. But it does [illegible] an increased development in one respect. It tries to reduce the [illegible] for language by using graphic representations of verbs as well as [illegible] GPAM has not been implemented and tested. It is difficult to make [illegible] judgement on its unique use of graphics to communicate verbs. This [illegible] be a useful research area, but it cannot be utilized in a specific [illegible] before more development and testing is accomplished.

HYBRID MAINTENANCE AIDS

The HYBRID AID [illegible] one aid for the experienced man and [illegible] the inexperienced man. The idea of having different documentation [illegible] different experience levels is very consciously identified in this concept. Using different documentation for each level is not exact[illegible] unique, and neither are two levels in one. During tests and [illegible] experienced personnel showed a marked disdain for PIMO documentation (mechanical systems) that describes each step in detail. This reaction may be psychological, but it was a reason to cause those who worked on [illegible] to add another summary level of documentation for experienced personnel. [illegible] and CMG are examples of a concept produced for the experienced personnel only. FORECAST, SIMMS, MAINTRAIN and other [illegible] designed for electronic troubleshooting all include two-in-one or [illegible] four-in-one levels of organization.

This concept has not been tested but it may be worthy of considera[illegible] tion for more research in mechanical situations. This concept might [illegible] a question. It may or may not provide an answer. The question may or may not be a problem.

The multiple levels of organization are used in virtually all [illegible] the concepts developed for electronics troubleshooting and this [illegible] has not been detected. Often the contrary has been found. The reason for this self-conscious use of the term "hybrid" and two levels [illegible] document may stem from the fact that psychologists like to find differ[illegible] ences in individual reactions and often cater to this rather than work out "across the board" solutions.

OPTIMUM PICTURE/WORD FORMAT

This concept [illegible] fundamental element [illegible] for one variation. It uses graphics to depict actions [illegible] and places action words on the graphics [illegible] visibility of the intended message. Data was collected [illegible] but it was done in a simulated environment which was [illegible] different from an operational situation. The data [illegible] over PIMO, all type, and all graphic formats.

Even though the academic research on this content [illegible] practical tests are needed before it can be considered [illegible] of field tested PIMO (JPA) techniques.

PYRAGRAM

Information on this concept has been hard to obtain. The concept has not been implemented or tested. So far as can be determined from information collected on it, PYRAGRAM does not advance the state of the art on any fundamental element. Its effects are based primarily on functional analysis and organized formats for multiple users. It was developed for large scale digital equipment. It specifies four levels of breakdown (same levels used in FORECAST, SIMMS and other concepts originally developed for large scale systems) achieved through a top-down analysis (also common to FORECAST and SIMMS). It segments information to what is needed at each level (as with FORECAST and SIMMS). But it proceduralizes information at each level. This is different from FORECAST and SIMMS and similar to PIMO in intent, but there is not information on what the procedures looked like or how they were derived from analysis. It is interesting to note that the integration of elements in the specification developed under this contract produces a product that has a feature of PYRAGRAM. The procedural information and information for understanding used for troubleshooting tasks is similar in concept to PYRAGRAM's proceduralization of information at each level of troubleshooting.

TRACE

The primary feature of TRACE is its use of plasticized cards with holes aligned over test points on printed circuit boards. TRACE uses some form of task analysis to identify the proper test points and organize them into sequences for testing, and it also uses some narrative with graphics in addition to the plasticized cards. It assumes the technician has a background in design theory, knowledge of the system under test and proficiency in the use of test equipment. The card does limit the user's actions to probing at prescribed test points and thus protects other parts of the equipment from damage. It uses the unique plastic card to achieve its effects. It does not offer any state of the art improvement over more fully developed concepts on the elements it uses - except for the plastic card. The plastic card with holes is a unique implementation of an element that needs to be researched for possible future use. But it has not undergone any tests and should be considered only for research rather than implementation at the present time.

VATE (Versatile Automatic Test Equipment)

VATE is a computer [illegible] [illegible] faults to the plug-in module level. It is [illegible] reported on in this project to identify [illegible] mentation approaches to improving human technician perf[illegible] represents a whole class of automated test equipment.

It provides an opportunity to make a major point [illegible] between machine testing and human testing [illegible] and people do not have the same sensory ca[illegible] sense patterns (e.g., oscilliscope patterns) as eas[illegible] humans do not make measurements as [illegible] machines. [illegible] analyzed to utilize cues that human[illegible] sense easily [illegible] different analysis than that used [illegible] [illegible]ine what machines [illegible] programmed to test. However, the [illegible] [illegible] is that [illegible] used to work out solutions that make [illegible]an technicians more effective [illegible] for programming machines. There are many approaches that can be taken with machines. VATE and the other automated testing [illegible] in this project are just a sample. These samples are provided to identify them as a class of approaches which are different from but similar to the approaches which are the subject of this project. The concepts of relevance to this project use analyses to accomplish the same purposes as do the analyses for programming automated testing equipment, but the content of the analyses are different because the sensory and other characteristics of humans and machines are different. Analysis is not just the province of the machine; the use of analysis is common to both machine approaches and people approaches. The effectiveness of analysis has been demonstrated in both cases. The present project is aimed at using people to do the sensing as well as accomplishing the replacement to effect repairs. It is the premise of the present project that this approach will have a greater impact on cost of ownership than will the machine approach, at least during the next five to ten years.

WORK PACKAGE CONCEPT

The Work Package Concept uses all the fundamental elements of PIMO, JPA, etc., but it does not carry any of them to full development. When those fundamental elements are used in their full state-of-the-art form, they enable novice personnel to do effective work without training as witnessed in field tests of PIMO and JPA. The Work Package Concept uses the fundamental elements in a relatively rudimentary form, so the users must bring ex[illegible]ive training in design theory and equipment usage, etc., to the work s[illegible]ion. Thus the concept fails to achieve the effect[illegible] PIMO and JPA hav[illegible] already demonstrated. It is true that the Work Package Concept does utilize a relatively well developed organization of formats brought together in work packages. It uses a functional analysis to some degree to prepare subordinate work packages and reference them to higher order packages. Sets of work packages are prepared which separate

troubleshooting from non-troubleshooting information, and each of those from principles of operation. Other breakouts are made for wiring diagrams, functional diagrams, and illustrated parts breakdowns. This organization of the documentation probably makes it easier for the trained/experienced maintenance man than standard documentation (but there are not data to demonstrate this).

The Work Package Concept is unique and a very important example of a special type of situation. It uses all the eight fundamental elements but does not use them to their full extent. It is as if technical writers, gaining a rudimentary understanding of the various fundamental elements, began putting them into practice without benefit of specifications, guidance or quality control. The result can be lauded as a move in the right direction, or it can be condemned as a poorly executed implementation of techniques which could be and have been implemented much better. The Work Package Concept is clearly not well enough implemented to guide novice personnel, and though it may be an improvement over traditional documentation, it will not support their performance as well as concepts employing well developed and implemented fundamental elements. With respect to costs of ownership this means the Work Package Concept will only provide marginal decreases in the cost of ownership while leaving the major cost reductions untouched.

If further research and development on this concept is contemplated it should either (1) be adapted to what has been fully developed in other concepts, or (2) it should be tested against such other concepts rather than against standard documentation. This field is now too well developed for a demonstration of marginal improvements over standard documentation. The goal now has to be improvement of fundamental elements that have already shown very substantial improvements over standard documentation.

APPENDIX C

DISCUSSION OF ANCILLARY RESULTS

C. Ancillary Points for Discussion

In addition to the data in Table 1, there are other points to be drawn from the studies. The discussion does not directly impinge on costs of ownership as do the data from Table 1. However, in studying the relevant documents in primary and secondary sources, the following points were selected as ancillary points, deserving of discussion.

1. Non-Troubleshooting Tasks

a. Work Force Loading

(1) Span of Control. As part of the F-4J study as discussed by Rowan[1], a hypothetical work center was modeled mathematically and manpower utilization implications explored. It was projected that, using the traditional manuals, 71 percent of inexperienced labor time is spent observing and assisting experienced technicians. Using new proceduralized manuals, 83 percent of inexperienced work time would be spent performing maintenance and the remaining time in assisting.

Another study reviewed by Rowan of the NC-8A mobile electronic power plant indicated that an experienced technician could keep at least four inexperienced men occupied using JPAs. The work situation did not permit testing the capability of experienced men to keep even more apprentices busy. Thus, the potential for increasing the supervisor's span of control (the number of tasks that can be supervised at one time) seems great.

(2) Inventory Maintenance. Rowan reports another finding from the F-4J study concerning error rates for technicians with and without proceduralized manuals. For experienced personnel, procedural errors decreased from 14 to 4 percent. As discussed in this report, procedural errors are a matter of definition, but at least some of these errors are likely to affect the spare part inventory and distribution system, because they lead to unnecessary replacement (false removals). These data suggest that the "float" requirements for prime equipments and assemblies can be reduced by perhaps 15 percent.

b. Equipment Utilization

(1) Mean Time Between Failures (MTBF). The second consequence of reduced errors is a reduction in technician-induced component failures. Data on this effect require long-term monitoring [illegible] up-time", and

[1] Rowan, Thomas C. Improving DOD Maintenance Through Performance Aids. ARPA Order No. 2244, Project Code 3D20, Advanced REsearch Products Agency, Washington, D. C., 1973.

has not been developed. PIMO (Serendipity, 1969)[1], however, projected such effects using a mathematical model, and it seems reasonable that a reduction in non-troubleshooting errors in removal, refitting, and replacement will reduce system down-time due to such errors. The cost of this effect is difficult to project. It requires amortizing each type of prime equipment in the Army inventory and calculating the value of an increased "up-time" for each. It is not included [illegible] in this study. But it should be recognized as [illegible], if included, would increase the amounts actually computed.

2. Troubleshooting Tasks

a. False Removals

(1) Inventory Maintenance. An "Optimum Troubleshooting Aids Study" (Naval Weapons Engineering Support Act [illegible]) suggests that "float" requirements may be reduced by conserving [illegible]. Apprentices used only 9 percent more spares than absolutely necessary [illegible] new type manuals. Journeymen used 20 percent more spares with the [illegible] manuals, and 48 percent more without them.

These data resulted from a simulation and may not reflect [illegible] conservation in the field. However, similar findings were obtained as part of the PIMO study. Specifically, under [illegible] conditions, a five-fold reduction in the replacement of unneeded parts was observed using a simplified Maintenance Dependency Chart (MDC).

The projection of these costs is not included in the final analysis, but they would represent an additional savings.

b. Productivity on the Job.

(1) Mean Time to Repair (MTTR). A [illegible] shows that two separate FORECAST studies reported increases in [illegible] over standard TMs of 47 percent (1960)[2] and [illegible] percent (1964).[3] [illegible]

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[1] Project PIMO Final Report, Contract AF04-(694)9[illegible], Serendipity, Inc., Chatsworth, California, May 1969.

[2] Shriver, E. L. Determining Training Requirements for Electronic System Maintenance: Development and Test of a New Method of Skill and Knowledge Analysis. HumRRO Technical Report 63, June 1960.

[3] Shriver, E. L., et al. FORECAST Systems Analysis and Training Methods for Electronics Maintenance Training, HumRRO Report No. 13, May 1964.

reported 140 percent (1965)[1], and AVIS 40 percent. Productivity increase from HAWK (1964)[2] ranged from zero to 106 percent. PIMO using MDCs found a 12 percent increase in productivity. FEFI/TAFI increases (1969)[3] were 314 percent under unique circumstances. Rowan reports the F-4J work center model projected improved departure reliability of 50-65 percent, with a 30-40 percent improvement in operational readiness (1973).[4] These data all support the projection that MTTR can be substantially reduced with improved technical manuals.

[illegible] Training Time Reductions

(1) Training Reductions. FORECAST reported reductions in training time of 60 percent and 56 percent, JOBTRAIN 50 percent, and [illegible] (1967)[5] 100 percent and (1971)[6] of 5% and 20%. Rowan reports that PIMO studies (1973)[7] project from models that training time can be reduced 25 percent by using OJT time for productive work.

(2) On-the-Job Training (OJT). Post and Price (1972)[8] suggest that modified JPAs can be an effective OJT vehicle. Such use is not limited by the experience of supervisors and trainers.

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[1] Rogers, J. P., and Walter, T. H. The Development and Evolution of an Improved Electrician's Troubleshooting Manual, HumRRO Technical Report 65-1, March 1965.

[2] Rogers, J. and Thorne, J. H. Development of a Procedure-Oriented Training Program for HAWK Radar Mechanics. HumRRO Technical Report 69-25, December 1969.

[3] DC-10 Fault Isolation. McDonnell Douglas Corporation, Report DAC 68447A, October 1969.

[4] Op. Cit.

[5] Chalrysky, A., et al. Job Performance Aids and Their Impact on Manpower Utilization. EDL-TR3270, Philco Corp., Palo Alto, California, May 1967.

[6] Folley, J. D., Jr., et al. Fully Proceduralized Job Performance Aids. Technical Report AFHRL-TR-71-53, WPAFB, Ohio, December 1971.

[7] Rowan, Op. Cit.

[8] Post, T. J. and Price, H. E. Development of Innovative Job Aid Concepts: Volume I - Description of Concepts. NAVAIRSYSCOM, Arlington, Virginia, May 1972.

(3) Cross Specialization. JOBTRAIN withheld training on one of the equipments. After just one day's familiarization, trainees using the new manuals performed satisfactorily. FORECAST demonstrated satisfactory transfer from a simulator representing only a portion of the system to the entire system. Foley (1972)[1] points out that, using standard training and technical manual support, training for one specialty requires 37 weeks plus 24 weeks OJT, after which the enlistee is still only effective on the system for which he is trained. Reassignment requires additional OJT, and perhaps some additional formal training.

(4) Tour Effectiveness. Inexperienced personnel using the new job guides were able to troubleshoot the F-4J as well or better than experienced personnel. Substantially the same findings were reported by the Naval Weapons Engineering Support Activity.

The cost savings projected from a reduced labor force with improved performance are included in the cost projection, but the estimate of 15 percent must be considered conservative.

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[1] Foley, J. P., Jr. Task Analysis for Job Performance Aids and Related Training. Training Research Division, WPAFB, Ohio, October 1972.

APPENDIX D

TECHNICAL MANUAL SPECIFICATIONS REVIEWED

LIST OF SPECIFICATIONS

MIL-M-63011 (TM) 30 December 1972
Military Specification
Manuals, Technical: For Maintenance Test Flight of Army Aircraft

MIL-M-63019 (TM) 15 October 1969
Military Specification
Manuals, Technical: Telecommunications Equipment (Except Teletypewriter)

MIL-M-63021 (TM) 15 December 1969
Military Specification
Manuals, Technical: Teletypewriter Equipment

MIL-M-63022 (TM) 22 December 1970
Military Specification
Manuals, Technical: For Electronic Configurations (Aircraft)

MIL-M-63024 (TM) 9 February 1970
Military Specification
Manuals, Techical: Photographic, Motion Picture, Sound, and Recording Equipment

MIL-M-63026 (TM) 15 March 1969
Military Specification
Manuals, Technical: For Army Aircraft

MIL-M-63027 (TM) 13 March 1969
Military Specification
Manuals, Technical: Maintenance and Overhaul Instructions (Aeronautical Accessories and Support Equipment)

MIL-M-63028 (TM) 31 January 1969
Military Specification
Manuals, Technical: Manuscript Requirements for Maintenance of Aircraft Engines and Engine Accessories

MIL-M-63030B (TM) 1 May 1973
Military Specification
Manuals, Technical: Preventive Maintenance Services

MIL-M-63032 (TM) 25 September 1968
Military Specification
Manuals, Technical: Manuscripts Requirements for Weapons, Combat Vehicles, and Fire Control Materiel

LIST OF SPECIFICATIONS

MIL-M-63041 (TM) 3 September 1970
Military Specification
Manuals, Technical: Content Requirements for Depot Maintenance Work Requirements

MIL-M-63043 (TM) 27 May 1970
Military Specification
Manuals, Technical: Missile System Equipment Check Procedures

MIL-M-63044 (TM) 2 September 1970
Military Specification
Manuals, Technical: Missile System Equipment Unit-Under-Test (UUT) Procedures

MIL-M-63046 (TM) 2 September 1970
Military Specification
Manuals, Technical: Missile System Equipment

MIL-M-38784 (TM) 1 May 1974
Military Specification
Manuals, Technical: General Requirements

AR 310-3 December 1968
Military Publications
Preparation, Coordination, and Approval of Department of the Army Publications

APPENDIX E

DEPOT MAINTENANCE

DEPOT MAINTENANCE

The maintenance environment as characterized in Task 3 was borne out in the commodity systems investigations. The extent to which tools, test equipment and facilities are provided tends to be a function of the echelon of maintenance. The higher the echelon the greater the support provided in terms of tools, test equipment and facilities, processes, etc. This is to a great extent determined by the complexity and support requirement of various tasks and the allocation of spares at the various levels of maintenance.

However, based on our visit to Corpus Christi, Texas, Army Maintenance Depot, we determined that this factor of the Maintenance Environment has characteristics that differentiate it from other echelons. We no longer believe that Depot level maintenance falls under the purview of this project. Our reasons for this change are detailed below:

Helicopters are usually brought in (some flown in) to depot. There is some general diagnosis performed in which logged hours on engine, transmission and main rotor assembly is an important aspect. It is the exception when a few things are corrected and the aircraft is returned to regular duty. The common action is a virtually complete strip down to the airframe. After the strip down, only the engine, transmission and a few other items that were originally on an airframe are matched up with that airframe again. All other parts are sent to a pool. The depot also receives parts from lower echelons, as well as complete aircraft. These are treated as a pool. The depot "owes" various "customers" a certain number of parts of a given type but they are not controlled by serial number.

The remaining discussion refers to mechanical aspects down to the point where electronic parts are identified as a separate topic.

The airframe is cleaned and so are all the mechanical parts. The parts are inspected. There are criteria for the inspection established by engineering control. The criteria are a function of manufacturing specs and the local situation. The criteria are based on <u>make or buy</u> decisions. For instance, a floor panel may:

1) be bought as a replacement part;
2) be fabricated at the depot from scratch;
3) be repaired if damage is 80% or less.

The extent of repair is a function of how easy (or costly) it is to get a new item. An item like a floor panel may be completely out of production at the subcontractor's plant that originally set up an assembly line to produce 5000 of these items. If the item cannot be readily obtained from the subcontractor it is produced at the depot. The decision on whether to make this part from scratch at the depot or make a repair of it is based on local cost factors and cost factors regarding entire purchase - make or buy decisions based on local processes. The same decision is made on making an 80% or 30% repair.

Other parts may have been eroded to 3 thousandths or 8 thousandths of an inch. The chrome plating department may be able to deposit an amount of chrome on this part to "make up" the amount eroded. This is a variable amount. And some parts may be too large to fit in existing chrome plating vats. The decision again is a local one based on local manufacturing capability. There are thousands of such local decisions. The manufacturer's specification on what the parts should measure will not determine what processes are used to get the parts to those dimensions.

Therefore, it is not practical to prescribe performances for accomplishing particular processes in depots as there is a standard way of accomplishing the job. The processes at echelons below depot are standard and can be documented in "how to do it" books because there are no decisions on what process to use. The process is always replacement. Documentation which describes the process for replacement of parts is standard when replacement is the process that will be used. But at depot there are many alternatives to buying replacements from the original manufacturer. The depot has a manufacturing function. How much manufacturing, and the most cost effective process is a function of many factors. There is no way to solve all these answers before the fact so it is impractical to document specific solutions.

These decisions regarding the process for repair of parts are not the only thing going on at the depot. There is also the assembly process. This is a standard process. Parts arrive at the assembly line and they are assembled in a standard way. It makes no difference to the assemblers whether the parts delivered to them are new, built up with 7 thousandths or 2 thousandths of chrome or whatever. The parts delivered to them are standardized parts regardless of how they got that way.

The assembly process can be described completely. But there is a question of the extent to which the detail should be described. If we assume new employees, then the process should be described in great detail. But if there are many old experienced personnel the detail is not needed. Clearly a depot does not have the turnover in personnel that the lower echelons have, and some people coming to the depot have had training before. If depot operations were to expand quickly (as in war time) there would be an influx of new personnel. So there is a question of whether assembly procedures should be described in detail for depots. It is clear that they can be for assembly process, but there is a question of what the "pay off" for doing it is. The number of depot people is not great with respect to the number in lower echelons. Doing it or not doing it at depot level is not going to have a large effect on cost of ownership under current situations. If rapid expansion is necessary the "pay off" of having assembly processes documented would be great. But it is probably a lower priority item under current conditions.

There is one additional idea that should be introduced at this point. It is that manufacturers have been increasing the use of job aids on their assembly lines. Videosonics is a job aid Hughes developed to show its people how to wire certain circuit boards. So continued thought should go on this point even though we say it is a low priority for the immediate situation. It should not be forgotten. But when it is considered it should

be done in a larger context of job aids than we are doing in the present study. We are focused on pictorial-language job aids that go on paper or film or videoscreen. There are other types of job aids - especially for production processes. There are jigs, for instance. The wiring harnesses that were assembled at depots had jigs to guide their construction. Plywood jigs had clamps on them to hold wire. Lines on the plywood showed how long the wires should be, where they should go and how many to each point. Other information was also on the job regarding connecting the wires to pins on connector plugs. There are a great variety of job aids in a production/manufacturing plant that go beyond those documented on paper. It would be inappropriate to go into a depot environment with only the type of job aids that are needed at lower echelons.

This is another reason for not making definitive statements about depot maintenance in the present study. The big changes in cost of ownership can be made with paper aids at field maintenance echelons. We should limit our conclusions and documentation specifications to those echelons of high payoff and high applicability for the present. But we should also initiate broader studies at the depot level. The "crunch" is not on us at the moment as it is not wartime or expansion time. But all the advantages of job aids in expansion are clearly critical.

Now let us discuss electronic equipment. The process is entirely different for repair of electronic equipment. The depot does not take all the parts off of electronic equipment and replace them. But for circuit board avionics equipment the process in depot is much like it is for tube type, non-modularized equipment at field echelons. The depot people troubleshoot electronic equipment and replace only the bad parts. But at depot the equipment is likely to contain many unrelated bad parts (field echelon personnel, knowing an item is going to depot, will pack it with every manufacturing card they have). The personnel at depot see the same modules over and over, every day. They say they learn the idiosyncracies of those modules so well that a subtle cue like an indicator wiggle or a slightly irregular pattern will suggest the failure of a particular part they have experienced as especially weak in this module. In short, through intense repetitive experience they are able to go from a subtle cue to a highly likely bad part. This is a very useful technique when the equipment is packed with a multitude of unrelated bad parts. This situation is quite different than that in field maintenance echelons. Documenting the process for depot would provide a different product then documenting the process in field repair shops. A logical troubleshooting process may be inefficient at depot but highly efficient in field echelons. These observations lead to the conclusion that documentation of different processes may be appropriate for depot and field. This is not so astonishing because field and depot are likely to require different documentation anyway, just because they are focused on different parts of the same equipment; e.g., depot on parts within a module, and field on modules within a larger system. This aspect of the situation has always been different and requires different documentation. But our observations have led us to hypothesize that the efficient troubleshooting processes (as well as content) may be

different at depot and other echelons. It would appear that cost of ownership is not going to be affected greatly by this distinction. So, if we limit our prescriptions to echelons below depot we will have basically the same impact on cost of ownership as if we included depot. And the advantage of not addressing depot operations at this time, is that the situation there is likely to require a different tailoring of prescriptions (like including other job aids than 2 dimensional), than field echelons. We, therefore, avoid giving a prescription that fits a somewhat different situation.

The reasons for eliminating depots from further technical documentation study are:

1. The nature of the work is qualitatively different from work performed at other maintenance levels. Depot maintenance consists largely in fabrication, not easily proceduralized. (Note that this fabrication is not a characteristic of any one Commodity System, but rather of the depot echelon in general.)

2. Large variations in specific work procedures exist across depots, dictated by available equipment and local SOP's.

3. Depot personnel are primarily civilians with long experience. They perform the same assembly and disassembly procedures and need TMs only when switching to a new job situation.

4. Depot operations account for only a small fraction of total ownership costs. To address specific depot problems would not be cost effective.

It should also be noted again that the specification that will be produced in Task 5 could be applied to certain depot activities (e.g., assembly processes).

APPENDIX F

FIELD TEST PLAN

APPENDIX F

FIELD TEST PLAN

I. SCOPE

This report covers the development of a field test plan for evaluating cost effectiveness of the prototype information presentation/transmissions package developed in Task 6.

II. OBJECTIVES

The objectives of this task were to develop a field test plan which would evaluate the prototype information package in terms of cost, user effectiveness, and user acceptability.

III. APPROACH

A. General

Many tests have been conducted on the new concepts over the past twenty years. It is instructive to look at their strengths and weaknesses as a background for the proposed Test Plan.

1. Validity of Results

Two communities with the same goals have different criteria for believability or validity. They are the research and the military communities. The military community believes in tests that are close to the everyday military environment and involve the judgement of military observers who are intimately familiar with that environment. The research community believes in tests that are highly controlled, repeatable, and are independent of the (presumably biased) opinions of any observer, military or scientific, experienced or inexperienced. The grounds for common expectations from these communities is that the test environment should look something like the operational environment. But the research person will sacrifice similarity for the sake of control and repeatability and the military person will sacrifice those criteria for similarity to field conditions. The research person will agree to observer evaluations only if the criteria for what category to place an observation in is so well defined that virtually anyone can make the same "correct" judgement. The military person will eschew "reliability and objectivity" for an observer who can evaluate a given performance in terms of other performances he has seen in similar circumstances. In effect, one is looking for an evaluation while the other is looking for an observation.

To provide a believable and valid test for those in both communities, the Test Plan integrates a tightly controlled three week test with a nine month field condition test.

2. Job Incumbents

When personnel receive an experimental treatment, it is generally on a "one shot" or exception basis. That is, after the test, the "guinea pigs" are not given the job for which the experimental treatment was designed to prepare them. This kind of future has generally been no secret to the "guinea pigs". It is easy to see that people working under such conditions cannot have the same motivation as those who can expect to achieve the job goal. On the other hand, the conclusion that an experimental program will produce personnel as job qualified as the traditional program (treatment) is difficult to accept before the test. When the differences in treatments are quite different, e.g., procedures versus understanding, it is very difficult to give the job duty to an experimental person prepared the "other way".

The proposed Test Plan includes a provision for most test subjects to be incorporated into the regular unit operation after the testing is complete.

3. Range of Types of Maintenance

In a controlled research study, malfunctions are artificially inserted into the equipment. Troubleshooting and non-troubleshooting tasks are selected on the basis of some criteria that are intended to identify a range of tasks that are representative of the real world. Advantages to this approach are that lots of different tasks can be run in a short period under rather close experimental control. But maintenance personnel do not normally function on a compressed time scale. Nor do they normally encounter maintenance tasks in the frequencies used in a controlled test. (Some experiments only fail once or twice a year.) Maintenance personnel may perform one type of task almost daily and another hardly ever, or not at all.

The proposed Test Plan allows both a compressed and controlled test, to collect a wide range of information quickly and efficiently, followed by an operational follow-up that monitors maintenance activities as they occur during the longer term course of "normal" operations.

B. Test Objectives

1. Purpose

The general purpose of the Test Plan is to evaluate a new documentation package, its strengths and weaknesses, its costs and effectiveness, and its acceptability to the target user population. The specification from which it was developed will be partially validated because it was the source of the implemented documentation package.

To this end, it is important to identify and collect information on all aspects of the documentation's operational use. Results will be used to justify decisions regarding the implementation of the documentation package. Recommendations must be based upon good research design data as well as salient military considerations.

2. Goals

The purpose of the test may be stated in terms of three general goals, relating to costs, effectiveness, and acceptability.

a. Costs: Cost is the most important test dimension. There is a potential reduction of 1.7 billion dollars annually in the cost of Army equipment ownership that can be effected by new types of technical documentation. Maintenance costs is the key to reducing life cycle ownership costs. The Test Plan must generate accurate data that can be used to project cost savings achievable from adoption of the documentation package.

b. Effectiveness: Although costs are of primary concern, the documentation package must also be tested for its effectiveness in the hands of the intended users. Consequently, data will be collected on the levels of skill demonstrated by personnel maintaining the equipment under the guidance of the documentation package, with respect both to individual effectiveness and overall manpower utilization (group effectiveness).

Effectiveness data will be reported separately. Where possible, however, these data will be translated into cost estimates as well. (For instance, when effectiveness or job production is increased by 50%, this can be translated into reduced personnel or into increased readiness of capital equipment.)

c. Acceptability: Whenever a new innovation is introduced, there is danger that it will be dismissed out of hand, just because it is new, independent of its value in reducing costs or improving effectiveness. Consequently, a third goal of the Test Plan is to collect information on the acceptability of the new concept to its intended users and to the Army Commanders responsible for training and staffing. Is the documentation package accepted on its face or is an indoctrination or "weaning" phase required? Is it immediately preferred over the existing package or does it depend heavily on prior experience with traditional forms of documentation? Is it immediately acceptable to new users (new personnel to the Army)?

3. Objectives

Objectives bearing on these goals include but are not limited to the following:

a. Costs

(1) Development

Determine absolute costs of package development, estimated separately for:

- content analysis
- materials preparation
- materials production
- materials reproduction, distribution and display

Compare these costs with costs associated with current documentation.

(2) Training

Estimate savings in training costs, per user (trainee), relative to standard training costs.

(3) Maintenance

Estimate savings in maintenance costs attributable to lowered incidence of replacing good parts, especially non-expendable parts; and savings from increased manpower utilization.

b. Effectiveness

(1) Productivity

Estimate increases in user productivity, as measured by time to successful completion of maintenance tasks, or user idle time, under alternate manpower configurations.

(2) Readiness

Estimate increases in prime equipment downtime attributable to slow or ineffective maintenance.

c. Acceptability

Estimate preferences for the documentation package over existing guidance, by novices, trainees, users, their supervisors, and commanders.

IV. RESULTS

The proposed Test Plan will evaluate the prototype information package covering the Armament Subsystem of the M60A2 tank. The testing will cover a representative sample of tasks in the prototype package and corresponding tasks in the following Technical Manuals.

- o TM 9-2350-232-20/2 - M60A2 Turret Organizational Maintenance
- o TM 9-2350-232-34/2 - M60A2 Turret Direct and General Support Maintenance
- o TM 9-1240-366-34 - Laser Range Finder General and Direct Support Maintenance

A. Design

The Test Plan is divided into three phases:

Preparation
Experimental Phase
Operational Phase

The Experimental Phase consists of a controlled research study lasting approximately three weeks.

The Operational Phase is a long term (approximately nine months) follow-up to collect data under normal operational conditions.

This general approach is intended to satisfy both research requirements (Experimental Phase) and military requirements (Operational Phase). It treats subjects (users) more as professionals than as guinea pigs, because all subjects will be allowed to perform in jobs for which they were trained (at least over the nine month period).

Since preparation activities are dictated by the designs for the Experimental and Operational Phases, the discussion below is presented in the following order:

Experimental Phase
Operational Phase
Preparation

1. Experimental Phase

Test objectives require an evaluation in both absolute and relative terms. For example, absolute data includes raw dollar costs of analyzing the equipments, clock hours required to return equipment to operational status, and so on. Relative data, on the other hand, requires a comparison standard. For example, how much training time is saved relative to current practices? How high is productivity relative to existing standards?

Comparison standards are available in the literature, but only in rough form (e.g., 85% of non-expendable parts returned to the depot as bad are tested and found to be good), and none are available for the specific equipments to be tested.

Consequently, the design calls for a comparison of users maintaining equipment with and without the new package.

a. Subjects

Data collected during the experimental phase will be used to establish two groups, an Experimental Group and a Control Group. Each group will be subdivided into novices, apprentices and journeymen as defined below:

Novice: No experience maintaining the target equipment or comparable equipment, i.e., BCT graduates.

Apprentice: Less than 6 months experience or Technical School graduate - no experience

Journeyman: More than one year's experience

Novices, apprentices and journeymen in the two groups will be matched for important characteristics, e.g., months experience. The Experimental Group will include at least 15 novices, 15 apprentices, and 15 journeymen. The Control Group will contain equal numbers of subjects in each category. All subjects will be working under their primary MOS, and will be picked for their availability during the Operational Phase. Some personnel from the Experimental Phase will be available for the Operational Phase, others will not. Those that are should be utilized; additional personnel should then be added to bring the numbers in each group to the specified levels.

b. Treatments

All subjects will be administered training as required and defined by the prototype package, but only as necessary and appropriate to the documentation to be used. It should be noted here that the prototype package is designed for the novice and should severely reduce the training requirement. Thus, the training will be limited to access tasks, use of special tools and test equipment, etc.

Following training, subjects will be asked to perform maintenance tasks as directed by test personnel. These tasks will be pre-selected from the prototype package for such criteria as:

Non-Troubleshooting

(1) All maintenance missions will be covered (preventive, remove and replace, assemble/disassemble, align and adjust, etc.).

(2) A wide range tool/test equipment usage will be required.

Troubleshooting:

(1) Malfunctions inserted will require a range of isolations to each of the possible levels (module replacement to piece part).

(2) Malfunctions inserted will require a wide range of test equipment.

c. Measures

Data will be collected during test administration as required to accomplish cost and effectiveness objectives. Acceptance data will be collected via interview and questionnaire methods at the termination of the Experimental Phase.

2. Operational Phase

The critical feature of the Operational Phase is that it be representative of the "real world". For example:

The equipment should be in service under conditions for which it was intended. Thus, malfunctions should be those normally expected under typical usage. No malfunctions will be artificially inserted.

Similarly, the maintenance environment should be the regular operational environment except for the special documentation and possible special tests and record keeping.

Finally, the personnel themselves should be typical of the type of personnel expected to routinely maintain the equipment.

To the extent that these assumptions are unmet, the final results are "impure" projections of what to expect beyond the test envi ronmemt.

Consequently, it is important that measures taken on the two groups during the Operational Phase be as unobtrusive as possible. To this end, documents routinely generated in performance of maintenance tasks will be reviewed to identify data bearing on differences between the two groups and subgroups. These documents will be analyzed during the experimental phase. Simple procedures will be implemented during the Operational Phase to capture data elements identified as relevant.

Test administrators will visit the test site bimonthly to confirm that data collection procedures are being implemented properly, to collect accumulated data, and to refine measures as necessary.

Since equipment breakdowns will be taken as they normally occur, the Operational Phase may have to continue for several months before sufficient data are available to justify conclusions and recommendations. This Phase will be terminated as soon as sufficient data are collected. In no event will it run longer than nine months.

3. Preparation

a. Experimental Phase

To prepare for the Experimental Phase, test administrators will select and justify maintenance tasks in terms of criteria stated earlier. Detailed measures of these tasks will be identified or developed, including data collection, data reduction, and data analysis techniques. All planning will be carefully coordinated with local supervisors and commanders.

Data necessary to establish the Experimental and Control Groups and subgroups will be furnished by the test administrators. At minimum, subgroups in the Experimental and Control Groups will be matched for subgroup mean months relevant experience (on the target equipment or comparable equipment).

Site preparation for the Experimental Phase will begin on arrival at the test site at least one week in advance of formal testing. Important tasks include:

(1) secure the cooperation of local personnel
(2) become thoroughly familiar with local maintenance environments and conditions
(3) dry run and debug specific measures to be employed.

b. Operational Phase

Test administrators will review TM 38-750 (TAMMS) to identify opportunities for monitoring maintenance activities in terms of routine forms. Plans for unobtrusively collecting information in this manner will be confirmed during the Experimental Phase. Additional measures will be developed only as necessary.

Plans for data collection during the Operational Phase will be coordinated with cognizant personnel.

B. Data Reporting and Analysis

1. Experimental Phase

Data collected during Experimental Phase testing will be analyzed to determine the effectiveness of the prototype package as compared to the conventional Technical Manual. This analysis will be in terms of successful completion of tasks, time required to perform tasks, and mistakes and problems encountered. These data can be used to determine cost effectiveness in terms of personnel utilization, impact on training and on maintenance costs and productivity. The anticipated savings accrued here can then be compared against the cost of the development of full scale manuals under the new concept.

2. Operational Phase

The data collected during this phase can be used to update the projections developed during the Experimental Phase. These data represent the "real world" and as such should form the basis for broader implementation of the new concept.

There are three forms of data which can be collected during the Operational Phase. The first type of data is that of operational readiness of the major equipments to which maintenance of the subcomponents contributes. If the group using the new manuals is of sufficient size to conduct maintenance of all subcomponents of an identifiable group of equipments, then the material readiness of that group of equipments can be used as a measure of the effectiveness of the personnel doing the maintenance.

However, if the group is not large enough or other operational constraints make this form of data collection impossible, a second form may be used. Records would be kept on the individual items maintained, rather than on the major items which the maintenance contributes to. These individual items would be the normal "work units" assigned by the job supervisor. The jobs are identified in the MAC Chart (which is called a Task Identification Matrix in Air Force terminology). The records kept would include the man hours expended in accomplishing the maintenance tasks assigned by the job supervisor. The effort expended by those using the new documentation and those using traditional documentation would be the basis of comparison. (This measure is available even if both groups of personnel work on the same major equipment items.)

A third form of data would be statements from job supervisors. These would not be general opinion statements, but would be specific to events which occurred. The supervisor will be asked to cite specifics in his statements on how well personnel performed their jobs. He will be asked to state why he failed to assign certain jobs to members of either group and why. This data form is intended to be more objective than the usual opinion gathering survey. It is intended to use his judgement about job effectiveness applied to specific situations which he observed. It is not a global impression measure of pure opinion.