Research Note 84-2

MAINTENANCE PERFORMANCE SYSTEM (ORGANIZATIONAL) INFORMATION AND EVAULATION SYSTEM DESIGN CONSIDERATIONS

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This report covers design considerations relating to the Information and Evaluation System (I&ES) of the Maintenance Performance System-Organizational (MPS-O). The I&ES will be a system for obtaining, analyzing, tabulating, and disseminating maintenance performance information. This report describes the analyses that underlie the design and makes preliminary design recommendations. MPS-O will be an integrated system for measuring maintenance performance, diagnosing performance problems, taking corrective actions, and providing training.

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INTRODUCTION

This report covers design considerations relating to the Information and Evaluation System (I&ES). The I&ES will be a system for obtaining, analyzing, tabulating, and disseminating maintenance performance information. I&ES design is not complete. This report describes the various analyses that underlie that design and makes preliminary design recommendations. Actual design will be described in a future report, which will also serve as a system design specification.

I&ES USES

The primary use of the I&ES during initial stages of the project will be as a **research tool**. In this application, the I&ES will consist of procedures for obtaining data; methods for storing, analyzing, and tabulating various feedback measures; and procedures for providing the information to research personnel responsible for developing such project products as on-the-job training methods. The I&ES will provide the experimental and concomitant measures necessary for product development and evaluation.

The IE&S will also be a **product development tool**. Various project products will be prepared, introduced into the field, and undergo development before they are completed. The I&ES will serve as a development tool by providing continuous feedback information that will enable product developers to modify and fine-tune their products to maximize effectiveness.

The I&ES will be an **evaluation tool**. Feedback information provided by an information system such as the I&ES is not inherently evaluative in nature. Measures imply no judgement, positive or negative. The system becomes evaluative when its results can be associated with standards. Standards may be developed within the system itself (based, for example, on long-term averages), or applied from the outside (standards provided, for example, in system user documentation). Additionally, the system can become evaluative when related measures are logically combined, via algorithms, to yield Figure of Merit (FOM) indices. The I&ES will be designed with some or all of these evaluative features--historical data base, documentation, and necessary algorithms.

Finally, the I&ES will be a **management information feedback system.** As in its research application, the I&ES must encompass procedures for data collection and dissemination and methods for storing and processing data to generate feedback reports. However, the audience and application are quite different. Feedback information will be provided to Army commanders, maintenance managers, and trainers to permit them to review maintenance/training performance for the purpose of improving unit maintenance/training effectiveness. The system measures provided may be quite broad in scope, as opposed to those required in the I&ES research application.

To summarize, the I&ES will be at least four things—research tool, product development tool, evaluation tool, and management information system. To serve in these capacities, the I&ES must encompass a number of techniques and procedures. One of these techniques is data processing. Various others will also be needed. Procedures must be developed for data collection, report generation, dissemination, and other aspects of system operation. Some procedures will be manual, others automated. Level of automation will vary from functional area to functional area. Some parts of the I&ES will be manual. Others will use a minicomputer. Still others may use a large mainframe computer. And the amount and level of automation may change during the project.

PROJECTED EVOLUTION OF THE I&ES

The I&ES will be developed during the first year of the project primarily as a research tool, and to support product development and evaluation. Secondary emphasis will be placed on the management information system application. The system will be applied to a limited number of MOS's (6) and equipment types (2). The system will be developed as a prototype, operated by Anacapa personnel, and evaluated. Based on results of this evaluation, it will be modified and the measures it provides will be refined and revised.

Subsequent to Year One, the I&ES will be expanded to encompass additional MOS's and equipment types. Management information capabilities will be enhanced. Eventually, the most successful portions of the management information system will be selected for inclusion in the final I&ES. This "final"

I&ES will be a management information system designed to provide Army personnel with maintenance effectiveness reports. The I&ES will include changes to make it acceptable to and usable by its eventual audience: it will be streamlined, operator and user procedures will be structured, and complete user documentation will be prepared. At that point, Army operators and users will be trained and the system will be packaged for turnover to the Army.

A NOTE ON TERMINOLOGY

In this report, a few terms are used in a fairly specific sense, and operational definitions are in order.

The term **information** is used in reference to the highest hierarchical level of knowledge about events or processes. Information is a general category of knowledge, usually quite abstract and unconnected with any specific event. The term skill, as in "skill information," is an example.

An **information requirement** is an expressed need or desire for certain types of information, for example, information about skill. Since skill is a broad category, the precise events or processes that would have to be measured to yield the required information are great in number and variety.

The term **measure** is used in more specific reference to the types of events or processes that would have to be measured to provide specific types of information. One measure of skill information, for example, would be the accuracy with which a particular task was performed by a subject.

The term **data** is used in reference to the specific parameters observed in computing a measure--for example, the number of errors made in completing a task performance such as that mentioned above.

TECHNICAL APPROACH

The work reported here consists of four tasks: Conduct of an Information Analysis, Definition of Information Requirements, Development of an Evaluation Model, and Selection of I&ES Measures. Each of these tasks includes one or more subtasks, as shown in Figure 1.

The Information Analysis was completed along three separate paths. The main path, shown at left, consists of analyzing the organizational maintenance process and developing an information taxonomy. This taxonomy is the basis for defining candidate I&ES measures.

The central and right paths relate to factors that influence the selection of I&ES measures. Constraints on I&ES design are defined; these, in turn, influence definition of measure selection criteria. A preliminary analysis of SAMS (Standard Army Maintenance System) is performed. SAMS influences the selection criteria because it is necessary to avoid redundancy between I&ES and SAMS.

Development of Information Requirements proceeds along two paths, one for determining research information requirements, the other for determining management information requirements. Research information requirements are based primarily upon the research information needs of the developers of each of the project products. Management information requirements are based upon combat unit user preferences, review of measures used in the direct support level Maintenance Performance System (MPS(DS)),[1] analysis of various subjective maintenance performance indicators, and original invention.

The Evaluation Model is based mainly on analysis of the information taxonomy. The taxonomy identifies the categories of information necessary to assess maintenance effectiveness, and the model logically combines system measures to arrive at higher-order effectiveness measures.

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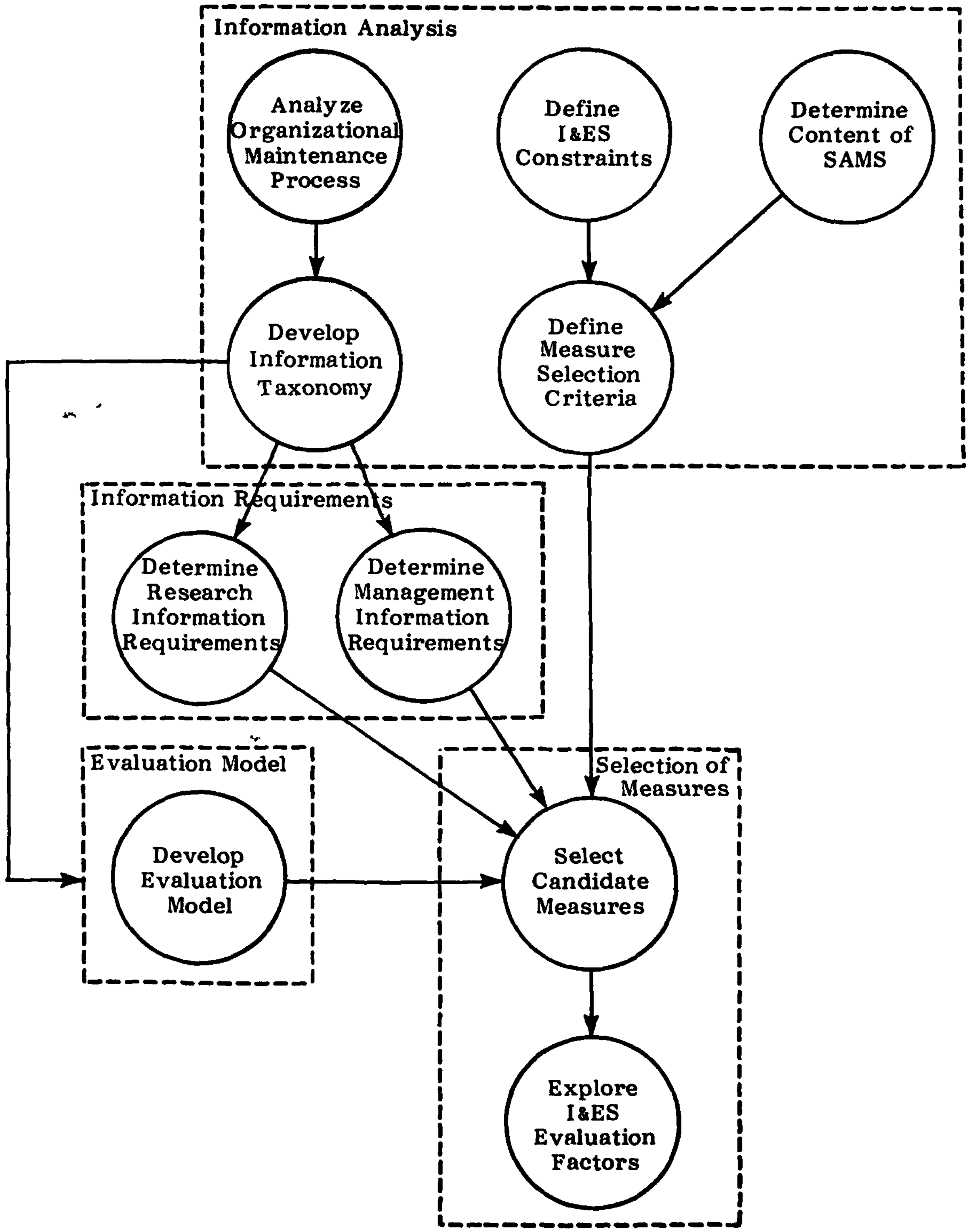
[1] For further information on MPS(DS), refer to Harper, W. R., Simpson, H. K., Fuller, R. G., & Harris D. H. **Develop and evaluate new training and performance systems for maintenance jobs.** Santa Barbara, California: Anacapa Sciences, Inc., Final Report, April 1981.



Fig· e 1. Steps in Technical Approach.

Selection criteria are applied to the candidate measures during Measure Selection. Evaluation model characteristics also influence measure selection, as sufficient and appropriate measures must be provided to satisfy the needs of the model. Measures are selected. Finally, I&ES evaluation factors are explored as a prelude to I&ES evaluation.

The reader should recognize that Figure 1 does not show all of the complex interactions that occurred among tasks and subtasks, although it does accurately illustrate general workflow. Tasks and subtasks are described in detail in the body of this report. Report organization generally follows the sequence shown in Figure 1.

INFORMATION ANALYSIS

ORGANIZATIONAL MAINTENANCE PROCESS

High-Level Model

Anacapa Working Paper WP 465-1 identified 65 problems and assigned them to five categories—command emphasis, management information, management proficiency, application of resources, and technical proficiency. These categories are considered to be the five primary elements needed to support maintenance effectiveness, and they provide the framework through which maintenance effectiveness can be enhanced.

The relationships among the five elements are presented in Figure 2. The primary function of the I&ES is to provide the information feedback loops shown in the figure. As can be seen, command and management actions work in an upward direction. The underpinning of all is command emphasis. Given this, and given adequate management information and management proficiency, resources will be properly applied. If there also is adequate technical proficiency, the result will be maintenance effectiveness. However, there may be a break at any point in this cause and effect chain. The I&ES will provide feedback information in the downward direction that will enable evaluation of this process at each step. Feedback information is required from the three highest blocks: **maintenance effectiveness, technical proficiency,** and **application of resources.** These three are the basic categories of management information and taken together are the logical highest categories of an Information Taxonomy.

Definition of "Maintenance Effectiveness"

The desired end result of maintenance is maintenance **effectiveness.** Maintenance effectiveness can be defined in many different ways, depending upon the dimensions of effectiveness one is concerned with. The Army often assesses its maintenance effectiveness with such overall system-level measures as materiel readiness and average available days per period. Such measures are important, but not very revealing of the internal workings of the maintenance operation. We have found it useful to define effectiveness in terms of three variables: efficiency, quality, and productivity.

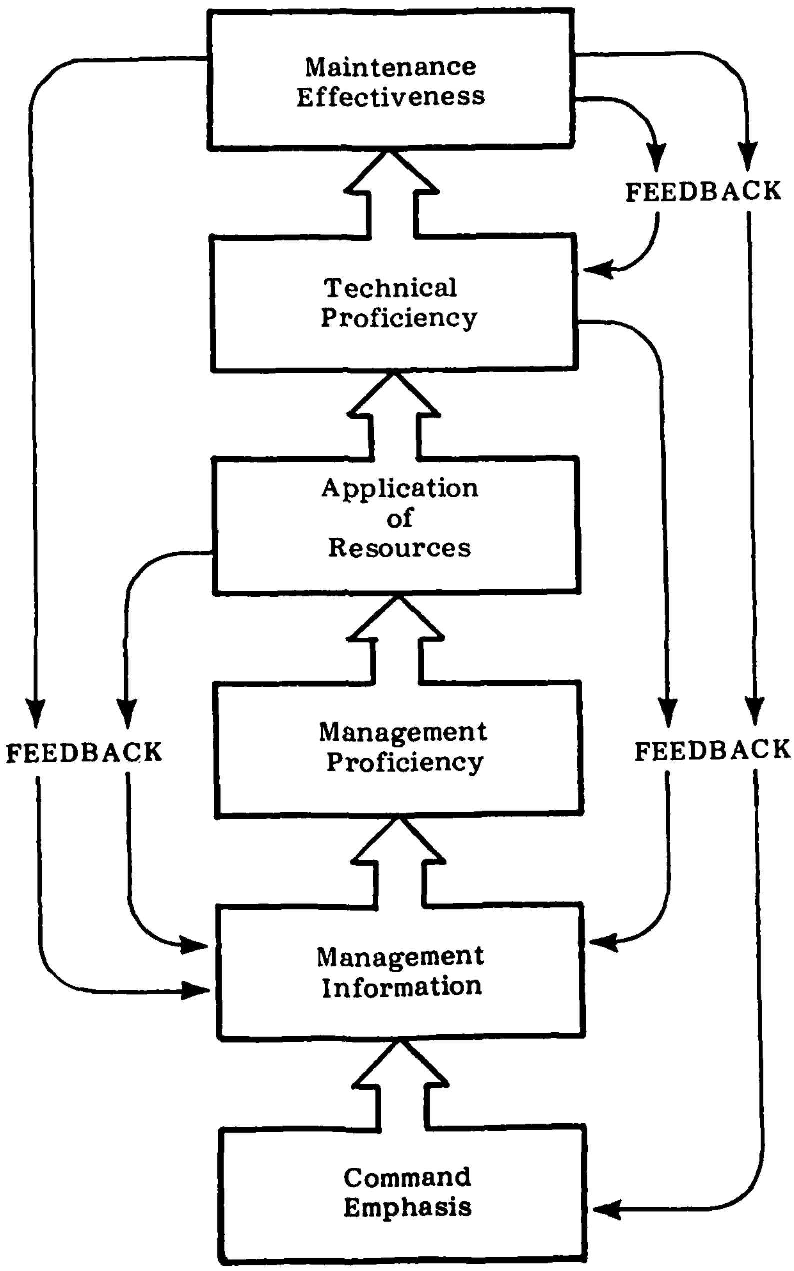


Figure 2. Elements that support maintenance effectiveness.

Efficiency is reflected in the amount of output for a given input. The higher the output for this input, the more efficient the system. The maintenance system input consists of the resources used. In the specific case of Army maintenance, these resources include the personnel, repair parts, tools, publications, TMDE (test, measurement, diagnostic equipment), facilities, and time. Output is the number of completed repair jobs.

Quality of a repair job is degree of correctness, both during job performance and at completion. Quality is reflected in performance of job according to correct procedures, using proper resources, and achieving desired end result.

Productivity is how much work is done—maintenance tasks completed, jobs performed, equipment deficiencies and shortcomings corrected, and the like. Productivity, as its name implies, is a product variable. It is, in a sense, the bottom line on maintenance.

High productivity combined with low quality is generally unacceptable. The same is true of high productivity and low efficiency. The ideal is for the maintenance system to be highly productive, efficient, and to turn out quality work. If it falls short significantly in any area, then maintenance effectiveness, as we are defining it, is reduced.

INFORMATION TAXONOMY

A two-level **Information Taxonomy** was developed based on analysis of the organizational maintenance process according to the considerations discussed above. The taxonomy is presented below.

MAINTENANCE EFFECTIVENESS

- System-Level Measures
- Maintenance Efficiency
- Maintenance Productivity
- Maintenance Quality

TECHNICAL PROFICIENCY

- Skill
- Training

APPLICATION OF RESOURCES

- Personnel
- Repair Parts Supply
- Tools
- Test, Measurement, Diagnostic Equipment (TMDE)
- Publications
- Facilities

CONCOMITANT VARIABLES

- Maintenance Effectiveness Concomitants
- Technical Proficiency Concomitants
- Application of Resources Concomitants

This taxonomy forms the framework for the development of specific I&ES measures. These were developed, in subsequent steps, and added to the taxonomy to arrive at an **Information/Measure Taxonomy** (shown in Appendix C and discussed later in this report). Though the information taxonomy preceded determination of information requirements and definition of specific measures, there was a period of time during which these steps overlapped and information requirements influenced the taxonomy, as well as vice-versa.

This taxonomy contains four major categories: Maintenance Effectiveness, Technical Proficiency, Application of Resources, and concomitant variables. Each category has several subcategories. Measures contained in the first three categories reflect the maintenance process. The Concomitant Variables category contains variables used for interpreting measures in the remaining "mainline" categories. An example of an important concomitant variable is workload, which significantly influences many of the measures in the other three categories. Although all concomitants are lumped together in a single category, generally they will not be used collectively; rather, individual concomitants will be referred to in the course of interpreting "mainline" measures. The following discussion of individual taxonomy categories covers mainline measures and related concomitants together.

Maintenance Effectiveness

Maintenance effectiveness is divided into four subcategories--system-level measures, efficiency, productivity, and quality. System-level measures are measures commonly employed by the Army to assess overall maintenance effectiveness. Examples are equipment materiel readiness and available days per period. Efficiency is reflected by such measures as job completion speed and number of jobs completed per man-hour expended. Productivity is reflected by a measure such as as number of jobs performed. Quality is reflected by a measure such as false replacement rate. Numerous concomitant variables may influence the interpretation of these measures, including unit operations, fleet characteristics, and workload.

Technical Proficiency

Technical proficiency is divided into skill and training subcategories. Skill is reflected by a general indicator such as exposure index (an index that reflects mechanic experience on technical tasks) and a specific indicator such as maintenance task procedural accuracy. Skill may exist without training, and vice versa, but skill will not be developed or maintained without training. Training measures should reflect type and amount of unit technical training. Concomitant variables influence the interpretation of technical proficiency measures in a manner similar to that for maintenance effectiveness measures, as discussed above.

Application of Resources

Application of resources is divided into a separate subcategory for each resource--personnel, repair parts supply, tools, TMDE (Test, Measurement, and Diagnostic Equipment), publications, and facilities. Note that the time resource is not included, although time is often treated as a maintenance resource. The reason is that time is one of the dimensions used in defining maintenance efficiency, which is contained elsewhere in the taxonomy (maintenance effectiveness). In general, measures contained in each resource category reflect how well the resouce is applied in the overall maintenance process. The key concomitant variable is resource availablility.

Concomitant Variables

The concomitant variables are broken into three subcategories, one for each mainline variable category. Examples of concomitant variables are unit operations, fleet characteristics, workload, mos characteristics, resource availability, demographic characteristics, and attitudes. Knowledge of these variables is important for correct interpretation of measures in the remaining three categories of the taxonomy.

I&ES DESIGN CONSTRAINTS

I&ES design is constrained by four factors: physical location, intended audience, the requirement for nonredundancy with other Army systems, and data availability. These factors are discussed below.

Physical Location

I&ES processing equipment will initially be located at Anacapa headquarters in Santa Barbara, California. Primary processing vehicle will be an IBM 5120 minicomputer. Other processing equipment may also be employed and this will also be remote from site. These factors have implications for I&ES design. Location remote from site means that system users such as maintenance managers will not themselves have direct access to the computer. Rather, they must rely on periodic hard copy reports which are prepared according to predetermined specifications. Very likely, data will be collected on site, mailed to Santa Barbara, entered into computer, and batch processed. Reports will be generated and mailed back to site. A time delay of up to two weeks is anticipated.

Audience

The I&ES is being designed for a primary audience (Anacapa researchers) and a secondary audience (Army commanders, maintenance managers, and trainers). The needs of these two audiences differ somewhat. Both audiences require measures of maintenance effectiveness, technical proficiency, and application of resources. Anacapa researchers require several specific and highly focused research measures that may be of little interest to Army users. Design priorities give research needs precedence.

Non-Redundancy With Other Army Systems

The I&ES will be designed so as not to perform functions anticipated or already being performed by other Army systems. Such redundancy cannot be justified. It is particularly important to avoid redundancy with such automated systems as SAMS (Standard Army Maintenance System), which will eventually be fielded.

However, there is also another, more subtle requirement that the I&ES avoid redundancy with any existing Army system--even if that system is not doing its job well. For example, the Army has systems for keeping equipment historical records. For various reasons, these records are not well maintained and do not provide very useful historical perspectives. But since these are in place and required by doctrine, it would be inappropriate for the I&ES to reproduce them in some new form.

Data Sources

One of the guiding principles in I&ES design is that the I&ES should make minimum demands upon Army personnel. To the extent possible, the system should use existing sources of information such as records, DA Forms, equipment log books, and the like. This said, it must also be recognized that such data sources are not necessarily well maintained or reliable and that some data collection efforts, involving Army personnel, will be necessary. We will look closely at existing data sources before imposing any new data collection requirements that affect Army personnel.

Special short-term, dedicated data collection efforts will be required for many of the very specialized and narrowly focused research measures. Much of this data will be collected by Anacapa staff members, however, and will not place any burdens on Army personnel.

DETERMINE CONTENT OF SAMS

Background

Work is currently underway concerning I&ES compatibility with SAMS. Content of SAMS is important to this study, however, because SAMS should be considered in defining measure selection criteria. The general "compatibility" requirement is that the I&ES avoid redundancy with SAMS. More specifically, this means determining what types of SAMS reports will be generated relating to organizational level maintenance and what measures they will contain. When these are known, we can assure that we do not duplicate any SAMS measures in the I&ES. A preliminary analysis of SAMS reports was therefore performed to satisfy the needs of this study. A more comprehensive analysis is in progress and will be reported at a later date.

SAMS is being developed by the U.S. Army Logistics Center for implementation in 1983-1985. Since SAMS is not now operational, analysis of SAMS reports was limited to information provided in systems documentation.[2] Documentation used for analysis pertains to SAMS-2, which will be implemented at the MPOM (Maintenance Programs Operations Management) level. MPOM includes DISCOM (Division Support Command), COSCOM (Corps Support Command), TAACOM (Theater Army Area Command), and DIO (Directorate of Industrial Operations). SAMS-1 will be implemented at the Maintenance Operations Management (MOM) level for direct support and general support maintenance activities. Work order data will be put into the SAMS-1 database at direct support or higher level, using a keyboard and CRT display, and edited as changes in job order status occur. Data from SAMS-1 will be transmitted via telephone line to SAMS-2 for compilation and

[2]Systems documentation reviewed is the following:

Headquarters, Department of the Army. **Executive Summary: Standard Army Maintenance System (SAMS). Maintenance Program Operations Management (MPOM).** Fort Lee, Virginia: Management Information Systems Directorate, U.S. Army Logistics Center, May 1980 (TM38-L26-2)

Headquarters, Department of the Army. **Maintenance Program Operations Management (MPOM) (SAMS-2). Annex F - Telecommunications Requirements.** Fort Lee, Virginia: Management Information Systems Directorate, U.S. Army Logistics Center, May 1980 (Draft - TM-38-26-2F) generation of reports. These reports will be distributed to multiple audiences, including lower-level audiences such as battalion commanders, direct and general support maintenance managers, and organizational level customers.

Description of Reports

The major input and output functions of SAMS-2 are organized according to **processes.** Of the seventeen processes handled by SAMS, eight contain reports concerning organizational maintenance. Some of the these reports are distributed to organizational level, others only to higher command levels, as noted below.

Inoperative equipment process — The inoperative equipment process provides the current status of reportable and maintenance-significant inoperative equipment that is in the hands of organizational level users or support maintenance activities. ("Maintenance-significant" equipment is equipment selected for tracking by MPOM managers.) Repair parts needed to repair the item, current status of work order (such as awaiting parts, awaiting NORS parts, back-ordered), and maintenance actions are provided. SAMS will interface with the supply system to obtain current *status of supply actions pertaining to inoperative equipment.* At least three reports generated by the inoperative equipment process are pertinent to organizational maintenance. These are described below.

- **Inoperative Equipment Report-Unit** is distributed to customer units each day. The report identifies inoperative item, status of work order, total days item has been inoperative, and repair parts required to return item to operative condition. The customer unit or support maintenance activity updates the report for changes in maintenance or supply status.
- **Inoperative Equipment Parts Summary** lists only those requisitions which MPOM managers desire to review for organizational and support-level maintenance. There are no plans to distribute this report to the customer units.
- **Equipment Inoperative over NNN Day by Unit** provides status, by unit, of all reportable items of equipment which have exceeded the number of inoperative days set by MPOM management. The report identifies the item of equipment, repair parts required, and status of parts requisition. There are no plans to distribute this report to customer units.

Monthly support maintenance evaluation process — This process provides information concerning maintenance responsiveness (such as job turnaround time and staff hours expended per repair) that is intended for use at support level. The one report directly pertinent to organizational maintenance is described below.

- **Customer Support List** identifies the support units from which the unit will receive maintenance support. Location of support activity and parent battalion are also identified.

Calibration and recall process — The calibration and recall process provides a listing of all items of equipment that require calibration or recall for scheduled maintenance. SAMS automates these processes, which are presently performed manually, by searching the equipment historical file. At least three reports generated by this process are pertinent to organizational maintenance. These reports are described below.

- **Recall Requirement by Customer Quarterly** is distributed to the customer unit to identify equipment that requires maintenance or calibration, maintenance level at which maintenance should be performed, type of maintenance, and scheduled service date.

- **Recall Requirement by Item** is distributed to MOM, which generates and distributes recall schedules for each item of equipment to customer units. The report is also distributed to support units to assist resource planning for the next quarter.

- **Monthly Recall Master Inventory** lists recall items for each customer. The customer unit will be expected to review the list and make note of any changes. Changes to the list are submitted to direct support level for entry into the SAMS-1 database.

Equipment historical process — The equipment historical file in SAMS is expected to replace most of the associated manual record keeping presently performed by unit equipment owners. Information currently contained in DA Forms 2408-5 (Equipment Modification Record) and 2408-9 (Equipment Control Record) will be submitted on worksheets by equipment owners for entry into the SAMS data base at the direct support level. The equipment historical file will include manufacturer, unapplied MWO's (Modification Work Order), usage, and recall data for each item of equipment owned by the unit. The one report supplied to customer units is described below.

- **Unit Equipment Historical Data Report.** A single page report for each item of equipment is distributed to the customer unit. The report provides a complete record of information maintained by the Equipment Historical File.

Component change process — The component change process maintains records of component usage at the battalion level. This process automates records of installed components currently maintained on DA Form 2408-10. The one report generated by this process is described below.

- **Component Usage Report** is provided on a monthly basis to maintenance managers. The report is intended to identify questionable component usage. The information contained in the report is from work sheets submitted by unit equipment owners and job order data in SAMS-1.

ALT/SRO process — The ALT/SRO (Administrative Lead Time/Standing Route Order) process receives MWO's and safety recall broadcasts from wholesale SAMS and equipment manufacturers. Upon receipt of a broadcast, MPOM updates the SAMS-2 equipment historical file and distributes a broadcast to the support maintenance unit. The support unit in turn prepares a schedule and coordinates with the customer to make MWO.

Financial management process — The financial management process portion of SAMS is interfaced with STANFINS (standard financial system). Reports generated by SAMS/STANFINS are intended to assist financial and maintenance managers in monitoring fund expenditure relative to the approved operating budget (AOB) and preparing the proposed command operating budget for the following year and the AOB midyear budget extension. Most of the reports are distributed to support levels; the one report distributed to customer units is described below.

- **Maintenance Cost by Customer Unit Identification Code** provides cost of each work order completed by support maintenance during the month. Copies of the report are sent by MPOM to the support unit responsible for supporting the customer unit. In turn, reports are distributed by the support unit to customer units.

Army oil analysis process — The Army oil analysis process provides a summary of actions taken to meet requirements of the oil analysis program. The Army Oil Analysis Program (AOAP) laboratories provide data for entry into the SAMS database. Two reports are generated by SAMS: Command Oil Analysis

Summary, and Unit Oil Analysis Status. The latter report is pertinent to organizational maintenance and is described below.

- **Unit Oil Analysis Status** report provides three types of information: 1) a summary, by battalion, of number of oil samples required, received, and delinquent; 2) identification of unit, item, and model and serial number for each delinquent oil sample; and 3) a summary of number of laboratory recommendations on which remedial action has not been taken and identification of noncomplying customer units. The report is provided to battalion commanders monthly. Presumably, the battalion will initiate follow-up action on delinquent and noncomplying units.

SELECTION CRITERIA FOR MEASURES

It was anticipated that the information taxonomy and subsequent analyses of information requirements would yield a large and fairly diverse set of candidate I&ES measures. The planned strategy was to generate as comprehensive a list as possible, with the intent of later selecting I&ES measures from this list by applying selection criteria.

Selection criteria were formally defined during the information analysis, although they would not actually be applied until later (see Figure 1). Many of the criteria derived directly from I&ES constraints. Others were based on various essential measure properties (sensitivity, reliability, etc.) and on cost factors. It was recognized that most of these criteria would have to be applied subjectively during measure selection. There would be no way at that point objectively to compare competing measures, although there would be some objective basis for measures that were derivative of the MPS(DS). Later during the project, I&ES measures will undergo a formal evaluation and objective data will be collected to assess measure stability, sensitivity, and measurement error.

Selection criteria were defined in the form of a checklist of questions that could be asked concerning each candidate measure. This checklist consists of the following questions:

- Is the measure specifically designed as a research measure to support development and/or evaluation of several products? (If so, it should be included in the I&ES.)

- Have combat unit personnel expressed interest in the measure?

- Is the information this measure provides available via other Army systems, manual or automated? (If so, the measure should be dropped.)

- Is the measure redundant with other measures? (If so, one or more of the measures may be dropped.)

- How much data are available to compute the measure?

- How much effort is involved in collecting data and generating the measure?

- How sensitive is the measure?

- How stable is the measure?

- What measurement error is expected?

These selection criteria were applied to the candidate measures and were also considered in preliminary planning of I&ES evaluation.

Additional criteria had to be defined and applied to determine the manner and method of handling each required I&ES measure--minicomputer, manual system, mainframe computer, or other. A measure might safely meet the checklist selection criteria and still not be included in the minicomputer-based I&ES. General assumptions and guidelines for making measure assignments are as follows:

- The minicomputer-based I&ES will eventually be turned into a management information system for use by the Army. Therefore, to the extent possible, measures selected for minicomputer implementation should lend themselves to this application.

- Measures requiring infrequent data input (for example, measures of personnel characteristics) are good candidates for manual implementation. This is also true of measures requiring labor-intensive, short-term data-collection efforts (for example, measures requiring an observer).

- Measures requiring sophisticated, short-term statistical treatments are not good candidates for permanent minicomputer implementation.

INFORMATION REQUIREMENTS

Information requirements were defined along two separate paths. The first was to consider research needs--information needed to support development and evaluation of various project deliverables. These could be termed **research** information requirements. The second path was to consider the management information needs of combat unit I&ES users (commanders, managers, trainers)--the information they would need to help them improve maintenance management and training in their unit. These could be termed **management** information requirements.

Research information requirements were defined primarily based on very close analysis of each of the project products. The I&ES is to be the primary vehicle for developing and evaluating most of these products. It follows that research measures should be defined based upon the development and evaluation requirements of the products.

The list of management information requirements was built in four separate ways:

- By interviewing combat unit commanders, maintenance managers, and supervisors to find out what information they wanted.
- By reviewing measures used in MPS(DS) and considering their modification for use at organizational level.
- By reviewing the subjective indicators in FM 43-1 (Test), **Organizational Maintenance Manager's Guide**, and assessing their translatability to the I&ES.
- By inventing original measures.

Research and management information requirements are described in greater detail in the sections that follow.

RESEARCH INFORMATION REQUIREMENTS

The following paragraphs describe the analysis that was made of each of the project products. First, the product is defined. Next, if applicable, the most probable experimental paradigm that would be used during product development and evaluation is described. Required experimental and concomitant variables are defined. Finally, possible experimental results are given.

Information and Evaluation System

The I&ES will be developed to obtain, analyze, tabulate, and disseminate information pertaining to three major areas of organizational maintenance—maintenance effectiveness, technical proficiency, and application of resources. The system will serve as both a research and management tool. As a research tool it will be used to develop and evaluate products produced during the project. As a management tool it will be used to disseminate information useful to maintenance managers. I&ES will undergo development and evaluation but will not use itself as a development or evaluation tool. I&ES evaluation factors will be discussed at the end of the Selection of Measures section, and will eventually be the subject of a separate report.

Task Assignment Procedures

This product is directed at improving task assignment procedures used by company motor sergeants. Procedures will be designed to maximize skill acquisition rates of mechanics by prescribing exposure to a broad range of tasks within an MOS. New procedures will be taught to several motor sergeants. The product will be evaluated by measuring effects of new procedures upon skill development and maintenance effectiveness. Measures of skill and skill growth will be derived from type and number of tasks mechanics perform.

Ultimately, higher skill acquisition rates should influence maintenance effectiveness measures such as job completion speed and number of maintenance jobs performed per time period. Characteristics of personnel and of the maintenance situation may moderate the relationship between skill acquisition and maintenance effectiveness. Moderating variables include experience of motor sergeant, success of motor sergeant in implementing new task assignment procedures, and mechanic experience. Previous studies performed by Anacapa Sciences at direct support level indicated that shop workload strongly affected maintenance effectiveness. Measurements will be made to clarify further the effects of these moderating variables on the relationship between skill acquisition rates and maintenance effectiveness.

Baseline measurements will be made of maintenance effectiveness, personnel skill and experience, and task assignment procedures. After implementation of new task assignment procedures, measures will be taken at regular intervals of skill acquisition rates, task assignment procedures, workload, and maintenance effectiveness. Follow-up measurements will be made at longer time intervals.

Results are expected to show that skill acquisition rates increase substantially as new task assignment procedures are used. Increases in skill acquisition rates should lead to long-term increases in maintenance effectiveness.

On-the-Job Training Methods

This product will consist of a set of on-the-job training methods designed to maximize skill development and proficiency of new mechanics. New methods will be taught to selected supervisors. Methods will be evaluated by comparing technical proficiency and maintenance effectiveness of mechanics receiving new on-the-job training with those of mechanics receiving existing unit training.

Skill growth of new mechanics will be measured by assessing skill acquisition rates. Maintenance effectiveness can be measured in several ways. Candidate measures include measures of efficiency such as job completion times, measures of productivity such as number of jobs completed per unit time, and measures of quality such as false replacement rates and number of errors per job.

Implementation of new on-the-job training methods should result in greater maintenance effectiveness and higher skill acquisition rates when compared with existing on-the-job training. This relationship may be moderated by factors such as characteristics of mechanics, characteristics of supervisors administering training, and workload. Accurate measures of training time are essential. High workload or lack of experienced supervisors may preclude effective implementation of an on-the-job training program; these factors must be closely monitored.

Performance of mechanics trained by various methods will be tracked across time. Differences in skill acquisition rates and maintenance effectiveness will be assessed at regular time intervals, with follow-up measures made at longer time intervals. Results will be used to assess whether new training methods produce long-term increases in maintenance effectiveness that are higher than those produced by existing on-the-job training.

Maintenance Incentives

This product will provide a motivational framework for organizational maintenance that will incorporate goal setting and feedback of information on goal attainment performance. Product evaluation will be achieved by measuring the effects of the maintenance incentives program on goal attainment, job satisfaction, personnel activities, and participation in goal setting by mechanics and supervisors.

Specific goal attainment measures will depend upon goals chosen by units. We anticipate that goals and related measures will concern work productivity, efficiency, and quality. Technical measures of proficiency may be included. Team effectiveness measures, such as participation in goal setting at meetings and measures of attitudinal changes, will be taken to assess the impact of the product on job satisfaction. Effect of the incentives program should also be reflected in total direct man-hour statistics. Measurement will begin with the incentives program and continue at regular time intervals. Follow-up measurements will be made at longer time intervals.

Effectiveness of the incentives program in bringing about increases in goal attainment, job satisfaction, and maintenance effectiveness will depend on several factors. Among these are adequacy of participation in goal setting by mechanics and supervisors, experience and background of mechanics and supervisors, and shop workload. These factors will be measured to take into account their potential moderating effects. Shop workload is a particularly important factor since large increases in workload may preclude goal attainment. Results will be used to portray changes in attitudes, maintenance effectiveness, and goal attainment as they relate to goal setting behaviors.

Integration of School and On-the-Job Training

This product is concerned with defining the optimal balance between formal school training and training received on the job. The product will be evaluated by comparing performance of mechanics trained under the current system with performance of mechanics trained in accordance with new school/OJT transition procedures. Optimal transition procedures should yield higher skill acquisition rates and greater maintenance effectiveness. Results should be reflected in measures of skill growth and maintenance effectiveness.

Effects of school training and on-the-job training may be moderated by two types of variables: personnel characteristics, and unit characteristics. Mechanic experience and skill, MOS complexity, time in service, age, and similar variables may influence training. Unit characteristics such as training time available, staffing level, and equipment availability will also influence training. These characteristics will be assessed during product development and evaluation.

Results will be an assessment of merits of new school/OJT transition procedures in terms of skill acquisition rates and maintenance proficiency. Assessment will be made by comparing results of existing training approaches to the new approach. Measures will be made at regular time intervals of maintenance effectiveness and skill acquisition rates. Additional measures will be made of mechanic and unit characteristics.

Management Development

This product concerns development of new management techniques for motor sergeants. Product tasks include determining the path to becoming a motor sergeant, and identifying required motor sergeant skills and knowledge. Discrepancies between training and required skills and knowledge will be examined. Recommendations will be made concerning motor sergeant training and new management techniques.

We do not anticipate that the I&ES will be used to support development or evaluation of this product, although it may be used to identify units with high levels of maintenance efficiency. Motor sergeants in such units may be studied to determine if their management methods can be incorporated in the product.

Officer Technical Training

Objective of this product is to provide critical technical knowledge to officers. Recommendations made will be based on analysis of officer training gaps. We do not anticipate that the I&ES will be used to support development or evaluation of this product.

Knowledge of Results (Feedback)

This product will provide a program for application of knowledge of results (feedback) to mechanics and supervisors. The program will specify how feedback is to be applied, who should receive feedback, and method of feedback presentation. Result of this effort will be a how-to guide. Development and evaluation of this product will be linked to that of of maintenance incentives.

Diagnostic and Prescriptive Techniques

This product is an extension of the I&ES that provides maintenance managers and trainers with diagnostic and prescriptive information concerning the overall health of their maintenance operation. Diagnostic and prescriptive techniques will consist of a combination of manual and automated procedures for problem identification and resolution in the areas of maintenance effectiveness, technical proficiency, and application of resources. This product is a part of the I&ES, which will undergo development and evaluation as described in the Introduction and Selection of Measures sections of this report.

Structure of Maintenance in Units

Objective of this product is to determine optimal unit maintenance structure, where structure is defined in terms of assignment of responsibility and authority among individuals and organizational entities in the maintenance system. Goal of changes to existing structures will be to increase maintenance effectiveness.

Specific measures to be monitored before, during, and after restructuring will depend on maintenance deficiencies present in the selected units. Impact of restructuring will be monitored via a range of general and specific measures reflecting maintenance effectiveness and resource use. Maintenance effectiveness will be determined with measures reflecting maintenance efficiency, productivity, and quality. Application of resources can be monitored with measures which reflect use of personnel, repair parts, tools, TMDE, and publications.

Changes occurring after restructuring may depend largely on initial conditions found in the unit; these will be reflected in factors such as workload, mechanic skill and experience levels, and availability of resources. The I&ES will be used to assess these factors.

Checkout Procedures

This product consists of procedures for checking out preventive and corrective maintenance. Preventive maintenance procedures are needed to assure that appropriate inspections, tests, and actions are taken. Corrective maintenance procedures are needed to verify that a malfunction has been properly corrected. Research will be conducted to determine how best to design and teach check-out procedures, how to translate technical manual data into useful checkout performance aids, and how to manage maintenance in such a way that appropriate checkout procedures are employed in a timely manner. Target population for this product will be equipment operators/crews. The new procedures are expected to enable more effective checkout and fault diagnosis.

Selected operators and crews will be taught the new procedures. A standard item of equipment with known faults may be presented to operators/crews for checkout; percent correct fault identification would be used to assess checkout adequacy. Operator/crew experience and skill are important in evaluating the new procedures; crews already performing checkouts extremely well might not benefit from new procedures as much as those with low skill. Experience and skill will be assessed before introducing new procedures.

Maintenance Management Indicators

This product will consist of a set of indicators that enable maintenance managers to inspect various aspects of their maintenance operation to determine maintenance status. FM 43-1 (Test), **Organizational Maintenance Manager's Guide**, contains a large set of such indicators. These will be reviewed for use in this product. We do not anticipate that the I&ES will be used to support development or evaluation of this product.

Operator Fault Diagnosis Aids

Objective of this product is to improve operator fault diagnosis ability. Methods for fault diagnosis will be developed and taught to operators/crews. Types of information now available to operators to assist them in fault diagnosis will be reviewed and assessed. If required, more effective fault diagnosis aids will be developed and evaluated. A standard item of equipment with known faults may be presented to operators/crews. Their task will be to identify the fault correctly and diagnosis its cause.

Measurements will be made of percent correct fault diagnoses and elapsed time to diagnose each fault. Measures will then be related to task difficulty. Effectiveness of the new procedure may be moderated by crew proficiency; crews already proficient at fault diagnosis may not benefit as much as those less proficient.

Management of Preventive Maintenance

A set of procedures will be developed to improve preventive maintenance. This product can be evaluated in many different ways. One method would be to identify units with preventive maintenance deficiencies by monitoring I&ES measures such as preventive maintenance man-hours expended per time period, rate of unscheduled maintenance, number of equipment breakdowns during operations, etc. The new preventive maintenance program would be evaluated in terms of these same measures. Initial effect of the program would likely be an increase in the number of preventive maintenance man-hours expended. Long-term effects might be a drop in number of unscheduled maintenance man-hours and in equipment breakdowns. Later still, preventive maintenance man-hours might decline to only those levels necessary for routine preventive maintenance activities. Number of faults per vehicle should also decline, as should equipment breakdowns and unscheduled maintenance man-hours.

Measures such as those mentioned will be influenced by several factors unrelated to the preventive maintenance program such as level of equipment usage and operating conditions. Similarly, several factors will influence success of the new preventive maintenance program, including workload, manpower available, and availability of resources. These factors will have either to be controlled or measured in order to determine their effects.

Time Management Techniques

Objective of this product is to determine principles of time management suited to the organizational maintenance environment which can be converted to a series of techniques which tell maintenance supervisors how best to manage time in their unit. We do not anticipate that the I&ES will be used to support development or evaluation of this product.

Mechanic Certification

Objective of this product is to examine the potential payoffs, problems, limitations, and costs of a mechanic certification program. The issue of how to certify mechanics will also be addressed. End product will be a set of recommendations regarding mechanic certification. We do not anticipate that the I&ES will be used to support development or evaluation of this product.

Mechanic Training Modules

This product addresses the training needs of mechanics, and will consist of problem solving techniques, "tricks of the trade," and procedures for solving maintenance problems. The product will also address methods/media for conveying technical information in the working environment. We do not anticipate that the I&ES will be used to support development or evaluation of this product.

Management Training Modules

Training modules will be produced which cover use of the I&ES, diagnostic and prescriptive techniques, application of maintenance incentives, maintenance structure, time management techniques, and application of knowledge of results in support of maintenance incentives.

Development of training modules depends in part upon results of previous I&ES-based evaluation efforts. However, training modules themselves will not be evaluated with measures derived from the I&ES.

MPS(O) Packaged for Army Use

The MPS(O) will be developed for handover to the Army as a fully documented "turn-key" system. Part of the MPS(O) will be a streamlined I&ES with diagnostic and prescriptive capabilities and supporting documentation (guides for system users, trainers, and operators). We do not anticipate that the I&ES will be used to support development or evaluation of this product.

MANAGEMENT INFORMATION REQUIREMENTS

Combat Unit User Preferences

Two sets of interviews were conducted with Fourth Infantry Division (Mechanized) personnel at Ft. Carson, Colorado. The first was conducted in the 5-13 March time period with eight maintenance management "experts" who had been identified by divisional G-4 staff. The strategy was to interview a few experts rather than a large number of personnel of mixed qualifications. Preliminary conclusions were drawn, based on these interviews, but we felt the need to verify findings with a larger sample. Subsequently, interviews were conducted with 20 personnel in the 2/34 Armor during the 24 March - 8 April time period. Personnel interviewed, their positions, and units are listed in Appendix A.

Before interviewing combat unit personnel, a list of candidate measures was generated based on measures used in MPS(DS), indicators contained in FM 43-1 (Test), and original invention. This list was not meant to be comprehensive, but rather to be used as an interviewing aid. All interviews were conducted informally, and without a detailed protocol. Two general questions were asked:

- What maintenance management and training information do you presently use (or might you use) that could be enhanced through computerization?
- How would you employ a minicomputer to improve management of maintenance and training?

Both questions are broad and somewhat open-ended. This permitted interviewees to give free reign to their imagination and resulted in a diversity of responses. The first question relates to the use of a minicomputer in a management information system. The second question is far broader, encompassing essentially any application of a minicomputer at unit level in a way that relates to maintenance/training management. Results of these interviews are summarized in the paragraphs that follow.

Equipment/fleet historical information — Most interviewees felt that a computer could help them greatly by providing a maintenance history of each equipment they maintained. At present, several manual equipment records are maintained such as equipment log books, mileage records, histories of services, and records of when maintenance was last performed. Retention requirements for such records vary, and in some cases are as short as 90 days. Moreover, manual records are not generally maintained with completeness or accuracy. There is at present no single record to which the maintenance manager can turn to find a complete maintenance history of an item of equipment. Important information is spread across many different records.

Maintenance managers would find it useful to have a maintenance history on each equipment because this would let them identify recurrent maintenance problems that are relatable to equipment deficiencies or inadequate maintenance. The computer could act as a sort of automated filing cabinet and, in addition, could flag recurrent maintenance problems, past-due services, and similar departures from acceptable maintenance practice.

Once historical information was in the computer, fleet statistical summaries could be generated that revealed types of maintenance problems most commonly experienced by various organizational sub-entities such as individual companies, sections, and the like.

Training information — Training information of the type provided by the MPS(DS) was thought to be potentially useful at organizational level. An overview report such as MPS Table 6 (Skill and Growth Indexes) was thought to be potentially of value to commanders and managers; and Tables 8 (Individual Skill History) and 9 (Training Requirements Summary) to be so to supervisors who conduct training.

Some interviewees felt a computer could be used to store training plans and lesson plans. This would permit them to be modified and then printed out, and save complete rewriting each time there were changes.

Some interviewees thought that a computer could be used in preparing training schedules.

Materiel condition status report preparation — Though the DA Form 2406 (Materiel Condition Status Report) need only be submitted to DARCOM quarterly, it must be prepared monthly and many battalion commanders require daily updates from their battalion motor officer (BMO). The BMO prepares these from feeder reports provided by company motor officers. One BMO estimated that it took him about two hours per day to do DA Form 2406 paperwork. Daily 2406's must be consolidated into monthly and quarterly reports; the same BMO estimated that the quarterly report took two days to prepare. A number of managers involved in preparing these reports (BMO's, Maintenance Technicians, Motor Sergeants) thought that a computer could simplify report preparation and save them time. With it, instead of having to produce a new report from scratch each day, they could simply update an old report in the computer and have the computer generate a hard copy for submission to the commander. Even more time would be saved in generating monthly and quarterly reports--the computer could query its memory, determine available/non-available days, and generate a consolidated report for whatever time interval was specified.

Prescribed Load List (PLL) and budget management — At present, the Division Materiel Management Center (DMMC) at Ft. Carson tracks parts usage and provides periodic updates to individual companies indicating the number of parts of each type on hand, number authorized, and suggesting additions to or deletions from the PLL. The problem is that these updates are two to four weeks out of date when received. Many interviewees felt that a dedicated minicomputer at company level would permit each PLL to be updated as parts were used or the PLL was replenished. This way the unit would have current PLL status information, and could generate its own internal use statistics for PLL modification. Daily updates generated for each PLL would also permit efficient PLL management--sources of a needed part not in one company's PLL could be identified by examining listings for other companies.

Some interviewees suggested computerizing the Document Register for Supply Action (DA Form 2064). The Document Register is a running list of all Requests for Issue (RFI) or turn-in of parts that lists, among other things, request date, part identification information, quantities, and completion date. Several Document Registers may be maintained within a battalion, one for each entity authorized to requisition parts. If this were computerized, it could generate parts usage statistics such as those cited above, and keep track of requisition request completion times. In addition, by adding cost information, a report could be generated indicating how much of the PLL budget had been expended as of any particular date, whether or not budget had been exceeded, and what percent of budget remained. This sort of analysis must presently be done manually.

Resource management — Many inventory lists of various types must be maintained in combat units. An example is the accountability receipt. Lead supervisors such as battalion and company motor sergeants must personally sign for every tool their subordinates use. Supervisors have subordinates sign a hand receipt listing tools provided, quantities, and condition. A single supervisor may keep several such lists. For example, the Squadron Motor Sergeant of 1/10 Cavalry said that he personally maintained about 20 lists--for all the toolboxes of his subordinates, for all the tools in 10 vehicles, and for the 200 tools in the tool room. There were thousands of items on these receipts. Such receipts must periodically be changed as new tools arrive, tools are broken or replaced, and as personnel enter and leave the unit. Each hand receipt changes at least once every six months. At present, such receipts are maintained manually and when a new one is needed it is manually generated. This requires substantial clerical and supervisory time. If such lists were maintained by computer, they could be readily generated and updated.

A similar suggested application would be to use a computer to keep track of publications. A combat battalion is responsible for a formidable number of publications and seldom does it have everything authorized. The difference between authorized and available publications does not have particularly high visibility. Supervisors and managers are responsible for assuring that their mechanics have what is needed, but it would be unusual for any one of them to do an inventory of publications and order what was missing. However, a computer could easily maintain bibliographies which listed authorized publications versus those available. From this it could generate lists of needed publications.

Many interviewees felt that a computer would be an aid in managing the personnel resource. In today's Army, there is usually a significant difference between TO&E and actual strength, both in terms of number of personnel and paygrades. Matters are further complicated by the widespread practice of assigning personnel to work outside their actual MOS. These factors make it difficult for commanders and maintenance managers to determine differences between authorized and assigned personnel. There is also some difficulty in anticipating the effects of future personnel losses. Often these do not become apparent until very shortly before they occur. Some interviewees suggested that a computer could be used to keep a TO&E that showed authorized versus assigned personnel, paygrades, and projected future losses--for example, at 30, 60, and 90 day intervals from a particular date. This could be used at various levels within the battalion to keep tabs on personnel strengths, deficiencies, and projected losses.

Responses to MPS(DS) management measures — As noted above, interviewees showed considerable interest in the MPS(DS) training-related measures (contained in MPS(DS) Tables 6-9). (One copy of each MPS(DS) report is contained in Appendix D.) Interest was also shown in manpower-related measures such as those in the MPS(DS) roster. In general, however, less interest was shown in maintenance management reports than in training reports.

Table 1 (Assigned, Available, Direct, Overtime Man-hours) probably aroused greater interest than other management reports. The Army's most important resource is its personnel, currently in short supply, and Table 1 highlights deficiencies of this resource. This table is extremely important at direct support level. Possible reasons this information is of less interest in combat units is that they have fewer personnel, do not manage them in the same way, and might have difficulty generating meaningful statistics on their personnel. The DSU can generally plan on working an eight-hour day, but this is not as true of the combat unit. Fewer people typically are involved, and long-term man-hour statistics have less meaning in this environment.

MPS(DS) Tables 2 and 3 (Man-hours per Job and Man-hours per Task) reflect maintenance efficiency. Initial reactions to this type of information were mixed, although follow-up interviews revealed fairly strong positive responses, particularly at the command level. Interest was also expressed in relating unit-generated man-hour statistics to external standards so that a particular unit could assess its performance.

MPS(DS) Tables 4 and 5 (Job Completion Time and Time in Each Status) aroused mixed but generally positive responses. Again, these tables were thought to be more attuned to the factory-like environment of the direct support shop than to the uncertainties of the combat unit. (It should be noted that Table 5 could not be used directly, though an analog can be conceived in which the various status times would be transformed to times at each stage of maintenance--fault detection, repair parts supply, corrective maintenance, etc.)

An Observation On Interviewee Preferences

It ought to be noted that many of the computer applications suggested by combat unit personnel fall outside the realm of the I&ES as we conceive it. To a large degree, this is the result of the open-ended way user preferences were solicited. Resulting responses relate not only to a management information system, but also to the use of a dedicated minicomputer by maintenance managers and trainers. To be useful in the way that many combat unit personnel have suggested—for maintaining equipment/fleet historical information, materiel condition status report preparation, PLL and budget management, or maintenance of inventory lists--the computer would essentially become a maintenance manager's job aid. It would have to be readily available in the working environment. The applications cited are not really functions of a management information system such as the I&ES.

However, these are interesting applications, and they raise the question of whether or not the project should explore them further as a separate task. The functions suggested could probably be performed by a relatively low-cost micro-computer such as an HP 85 or Apple II. Cost of such a computer with necessary peripherals is low (less than $5,000), operation is simple, and the systems are robust. Presumably, programs developed to perform the functions users have suggested would have widespread application throughout the Army and could be adopted at relatively low cost.

Review of MPS(DS) Measures

MPS(DS) measures were examined for applicability at organizational level. (Parenthetically, it ought to be noted that in year one of our project to develop MPS(DS), four MPS(DS) measures actually were converted and applied at organizational level during data collection for the Minimum Equipment Level Training (MELT) program.)

Most of the MPS(DS) reports could be easily modified for use at organizational level. However, two factors should temper enthusiasm for wholesale adoption of MPS(DS) measures: difference in working environment, and number of personnel. Organizational level maintenance is **less structured** than direct support maintenance and is performed by **fewer personnel**. Both of these factors would seem to impact maintenance management reports (Tables 1-5) more than training reports (Table 6-9).

The MPS(DS) generates nine generic types of reports plus a Roster and a set of Interpretation Comments. Let us consider each of these, in turn, in terms of its potential application at organizational level.

The Roster is used primarily by system operators to keep track of assigned personnel. This is important for generating MPS Table 1, and for maintaining accurate files on individual soldiers. This report is not presently disseminated to Army personnel. However, it could probably be modified to serve the personnel resource management functions interviewees mentioned (see above).

The Interpretation Comments report is used to list various factors that affect interpretation of MPS(DS) reports. Factors include type and location of operations, weather conditions, and the like. Many of these fall into the concomitant variables category--they are important for report interpretation, but are not necessarily readily quantifiable. This report, therefore, seems a strong candidate.

Table 1 (Man-hour Availability and Use) reflects not only what manpower resources are available, but how well they are being applied. Such information is useful in assessing resource availability and management.

Table 2 (Average Direct Man-hours per Job) and Table 3 (Average Direct Man-hours per Task) reflect maintenance efficiency. This is as important at organizational as at direct support level, despite the smaller number of jobs and personnel and different working conditions.

Table 4 (Average Job Completion Time in Days) and 5 (Average Days in Each Job Status) have analogs at organizational level. These are important indicators of maintenance effectiveness. It is unclear whether sufficient data can be collected to yield meaningful results at organizational level, however. (As noted earlier, Table 5 would have to be modified somewhat, as the combat unit does not employ the same formal job status progression as the direct support unit.)

The training reports (Tables 6-9) seem directly applicable at organizational level. These would probably not be affected by the differing working environment/smaller number of personnel factors that bring into question the applicability of Tables 1-5. Table 6 (Skill and Growth Indexes) could be adopted directly for use at organizational level. The same is true of Table 8 (Individual Skill History). Table 7 (Skill Development Summary) is a multiple-MOS summary of the skill and growth index information contained in Table 6. While this might be a candidate for inclusion in future versions of the organizational I&ES, it is probably premature to develop such a report for the first year I&ES. Table 9 (Training Requirements Summary) also seems inappropriate at this stage. Like Table 7, it is derivative of Tables 6 and 8. It should be considered for inclusion in the next generation of the I&ES, provided Tables 6 and 8 work out satisfactorily.

Subjective Indicators

FM 43-1 (Test), **Organizational Maintenance Manager's Guide**, contains a large number of indicators designed for use by commanders, maintenance managers, and trainers in assessing unit maintenance management. These indicators were derived by Anacapa from indicators contained in other Army documents, those in use in the field, and original invention. The larger list was then reviewed by a panel of maintenance experts, who expressed their preferences; from these preferences, FM 43-1 was developed.[3]

The majority of indicators in this document are either subjective in nature ("sufficient time is provided for PMCS on training schedule") or very difficult to quantify in a simple way ("operator/crew use DA Form 2404 and complete it correctly"). However, some of them can be recast in slightly different form to yield measures that could be used in the I&ES. Each of the FM 43-1 indicators was reviewed for applicability to I&ES. Results of this analysis are contained in Appendix B, which shows the original indicator and the candidate measure derived therefrom.

Original Measures

The Information Taxonomy provides the conceptual framework for measure development. Based on it, several original measures were conceived for inclusion. These are included in the Information/Measure Taxonomy given in Appendix C.

INFORMATION/MEASURE TAXONOMY

The various research and management measures derived, developed, discovered, and invented via the methods discussed above were fitted into the general categories in the information taxonomy. The resulting **Information/ Measure Taxonomy** is shown in Appendix C. Listed measures are candidates for inclusion in the I&ES.

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[3] This work is described in Simpson, H. K., & Fuller, R. G. **Development of "How To" organizational commander's guide for maintenance and repair parts supply management.** Santa Barbara, California: Anacapa Sciences, Inc., Final Report, May 1980.

EVALUATION MODEL

PURPOSE OF THE MODEL

The Evaluation Model (EM) can be broadly viewed as a means for using I&ES measures to evaluate maintenance. The model is a method, set of procedures, algorithm, or similar construct for processing and interpreting measures in order to reach conclusions. Practically speaking, this model could take a number of different forms. For example, it might consist of a list of standards which could be applied to each I&ES measure. These would be applied manually by the system user, who would complete a checkoff list as he went through a set of reports. This is EM at its simplest. At the other extreme, one can conceive of a fully automated EM which used various arcane algorithms to produce a maintenance Figure of Merit (FOM). Between these extremes are many other possible EM configurations. The shape the EM will eventually take depends to a large degree upon the factors discussed below.

EM DESIGN CONSIDERATIONS

High-Level Model, Information Taxonomy, and EM Design

The high-level maintenance system model discussed earlier in this report gave rise to the three categories of information that were included in the information taxonomy: maintenance effectiveness, technical proficiency, and application of resources. The taxonomy shows these three categories at the same hierarchical level. However, it is important to note that in the high-level model from which they were derived they are at different levels because a cause-effect relationship extends from application of resources to technical proficiency and to maintenance effectiveness. Given the first condition, the second is possible; given the second, the third. However, breakdown at lower levels precludes the higher-level result.

The high-level model and information taxonomy provide a basis for em design. the taxonomy is more than an outline; it mirrors the maintenance effectiveness model. Implicit in this model, and in the taxonomy, are the following general characteristics:

- That maintenance effectiveness depends upon technical proficiency which, in turn, depends on application of resources.
- That if there is a breakdown in any one of these factors, maintenance effectiveness cannot be achieved.
- That maintenance effectiveness is a function of three variables: efficiency, productivity, quality (EFF = f(E, P, Q)).
- That technical proficiency is a function of skill and of training (TP = f(S, T)).
- That success in application of resources is a joint function of several resources (APP. RESC = $f(R_1, R_2, \dots R_n)$).

The nature of the functional relationships among these variables is unclear, although it is reasonable to assert that relationships exist. In developing a maintenance effectiveness measure, one must surely pay attention to maintenance efficiency, productivity, and quality. Skill and training are certainly important aspects of technical proficiency. And application of resources is certainly influenced by each resource. The difficulty arises in attempting to establish the precise nature of these relationships--to determine, for example, the connection between improper application of a particular resource (such as a tool), and an upstream measure of maintenance effectiveness.

Development of EM Standards

The development of standards is basic to the EM. Standards provide the benchmarks against which individual measures can be compared. Departure from standards implies deficiencies in particular areas of the maintenance process. Generally, a history is the basis for standards development. Since we want our system to be evaluative, it follows that we should generate measures which provide historical perspective. This means accumulating data and generating long-term averages of any measure for which it is feasible. When sufficient history has been recorded, a standard can be developed. This requirement affects the candidate measures selected--as far as the EM is concerned, the measures most suitable are those which lend themselves to development of long-term histories from which standards can be derived. Eventually, such standards can be extracted from the system and put in the form of a checklist such as that described above.

EM Development Strategy

The EM will be developed in stages. The first stage is to accumulate historical records for each of the measures with the view of eventually developing standards. When sufficient data have been gathered, we will see if relationships can be established among measures to generate higher-order FOM-type indices. The near-term requirement is to generate the standards information. The development of FOM indices is dependent upon having stable, reliable, and accurate measures that reflect key aspects of the maintenance process in accordance with the high-level model and the information taxonomy. These relationships cannot be tested or evaluated until measures have been evaluated.

SELECTION OF MEASURES

GENERAL

Research Measures

Selection criteria developed earlier were applied to the candidate measures in the information/measure taxonomy. As noted, this was a subjective process, for the most part. The issue of greatest concern was to assure that adequate research measures would be provided to support product development and evaluation. This meant that research measures, by definition, had the highest priority. Many of the measures in the taxonomy are required for development and evaluation of several project products. These were the strongest candidates for inclusion in the I&ES. It is probably fair to say that virtually every measure in the taxonomy could be employed in some way to support one product or another. However, it was not feasible to include everything in the I&ES and it became necessary to rank the various research measures and decide which were needed the most.

Maintenance Effectiveness Measures

It became clear during the Information Analysis that almost every product would require measures of maintenance effectiveness. Product developers will need to assess the effect upon the maintenance system of their product. Maintenance effectiveness measures--such as direct man-hours per job, number of jobs performed per period, and false replacement rate--will be important in making this determination.

These measures will also be important in the management information system. This point, not obvious at the outset of the Information Analysis, is worth emphasizing: key management information system measures will also be important for product development and evaluation.

Measure Redundancies

Examination of the information/measure taxonomy revealed that many of the categories contain redundant measures. We have tried, to the extent possible, to select at least two measures from each category. Where there was a choice, selection was made based on the selection criteria: research needs, combat unit personnel interests, non-redundancy with other Army systems, data availability, effort in collecting data and generating measure, and best estimate of measure sensitivity, stability, and measurement error. It ought to be noted that many of these judgment calls were supported by prior experience with similar measures in the MPS(DS). Since we have experience with many of these measures and know how well they work, we have been inclined to support them rather than adopt something unknown.

Two-Stage Selection Process

We observed in the Introduction that the I&ES will be more than a minicomputer-based system. It might also employ manual procedures and a mainframe computer. Therefore, the measure selection process was more than simply deciding what measures would be developed for minicomputer implementation. Selection was actually a two-step process:

- Deciding which measures should be included in the I&ES.
- Determining manner and method of handling each required I&ES measure--minicomputer, manual system, mainframe computer, or other.

The following discussion covers both of these points. The fact that a particular measure is recommended does not imply that it should be part of the minicomputer-based system. Some recommended measures are not good candidates for this at all because of various reasons that will be described.

RECOMMENDED MEASURES

Maintenance Effectiveness

System-Level Measures — No system-level measures are recommended for inclusion in the I&ES. These are important indicators of maintenance effectiveness, but are being provided by existing Army systems. Required information, if needed, should be obtainable via Army sources.

Maintenance Efficiency Measures — Recommended measures are the following:

- Direct man-hours per job.
- Direct man-hours per task.
- Job completion time.
- Elapsed time in each job stage.
- Number of maintenance jobs completed per maintenance man-hour expended.

All of these measures except the last are derivative of measures currently in MPS(DS) Tables 2, 3, 4, or 5. Each was found to be of importance for at least four research products. Combat unit personnel expressed interest in all but the last.

Maintenance Productivity Measures -- Recommended measures are the following:

- Number of maintenance jobs performed per period.
- Number of maintenance tasks performed per period.

These measures can be derived from the same underlying data as the efficiency measures cited above. Each is required for at least four research products.

Maintenance Quality Measures — Recommended measures are the following:

- DSU acceptance inspection rejection rate.
- False replacement rate.
- Number of errors per job.

Quality measures are extremely difficult to develop, although we have had some experience with the first two listed above. These two should be included in the minicomputer I&ES. The third measure requires an observer and a fairly complex data-collection effort; this measure should be handled manually. At least three research products require quality measures. Related indicators are contained in FM 43-1. In general, rejected measures appear to impose more difficult data collection requirements than those selected.

Technical Proficiency

Skill — Recommended measures are the following:

- Skill index.
- Individual skill profile.
- Maintenance task completion time.
- Use of appropriate tools, publications, TMDE.

All of these measures are required by at least four research products. The first two, based on MPS(DS) Tables 6, 7, and 8, elicited high interest from combat unit personnel. All measures except the last can be developed from the same database used in generating efficiency measures. The last measure is highly specific, will probably require an observer, and data will not be available on a day-to-day basis; this makes it a poor candidate for inclusion in the minicomputer I&ES, although it remains a candidate for separate handling manually.

Two additional measures ought to be considered for inclusion in the future:

- Training requirements summary.
- Maintenance task procedural accuracy.

Training requirements summary, a derivative of MPS(DS) Table 9, is a logical extension of the skill index and individual skill profile; however, these two measures must prove their worth before additional effort is expended in developing the summary.

The measure of maintenance task procedural accuracy may be required for developing products 11 and 12, presently scheduled for Year Two of the project; this measure may be included at that time.

Training — Recommended measures are the following:

- Maintenance training man-hours expended per period.
- Overall skill growth index.
- Distribution of skill levels per team per maintenance task completed.

Recommended measures are required for at least four research products. Growth index is derivative of MPS(DS) Table 6, which was responded to positively by combat unit personnel.

The following measure was rejected but should be considered for inclusion in a future upgrade of the I&ES: exposure, training, performance indexes. This measure, a derivative of MPS(DS) Tables 6 and 7, derives from the same data base as skill index and individual skill profile. However, these measures must prove their worth before considering the subject measure for adoption.

Application of Resources

Personnel — Recommended measures are the following:

- Direct man-hours (overall) per period.
- Overtime man-hours per period.
- Preventive maintenance man-hours per period.
- Team effectiveness measures.
- Task assignment procedures.

The first two measures are derivative of MPS(DS) Table 1, and were requested by combat unit personnel. Each of the first three measures has an analogous FM 43-1 (Test) indicator. None of the listed measures is required for more than two research products.

The last two measures are required only for products two and four. Data collection for these two measures requires an observer and data are not available on a day-to-day basis; these measures should not be included in the minicomputer I&ES.

Repair parts supply — No candidate measures are recommended. Listed measures are all important, but at least four of these are presently provided by existing Army systems. Required information, if needed, should be obtainable from Army sources.

Other resources — One candidate measure is listed opposite each of the remaining resource categories. Such measures may be required to support development and evaluation of products nine, 11, and 12. In every case, however, data input would be required too infrequently to justify the presence of the measure in the I&ES at this point. Listed measures should, however, be considered for inclusion in future versions of the I&ES, where they are candidates for manual data collection.

Concomitant Variables

Recommended Concomitant Variables are the following:

- Unit operations.
- Fleet characteristics.
- Workload.
- MOS complexity.
- MOS maintenance task difficulty.
- Number of personnel assigned versus TO&E.
- Number of personnel available.
- Job satisfaction.

Four of these measures can be fairly easily developed: Unit Operations, Workload, Number of Personnel Assigned versus TO&E, and Number of Personnel Available. These measures are required for interpreting virtually every other measure, and support virtually all product development and evaluation. We also estimate that sufficient data will be available to generate a steady flow of reports. These measures are therefore candidates for the minicomputer I&ES.

The remaining concomitants are much less likely to change across time. These measures should be handled manually.

EVALUATION OF MEASURES

The measures chosen for the I&ES will be examined in terms of five criteria--sensitivity, stability, intercorrelation, comprehensibility, and usefulness.

Sensitivity

Measurement **sensitivity** refers to the degree to which a measure will reflect significant changes in the maintenance system. Sensitivity will depend in part on measurement frequency. For example, if a measure of maintenance productivity such as number of jobs performed per period is taken once a year, it would not be sensitive to changes in productivity that occur on a seasonal basis. There are important practical constraints on the frequency of measurement. Extra work involved in taking more frequent measurements must be weighed against potential benefits. More frequent measurement may also have an adverse effect on measure stability, as discussed below.

Another major determinant of measurement sensitivity is the relationship of the measure to the construct of interest. For example, number of tools may affect productivity; if insufficient tools are available, productivity may be reduced. However, increasing tools beyond the number needed may not affect productivity. In other words, number of tools may be a sensitive productivity measure when tools are a limiting factor and an insensitive measure when they are not.

Stability

Measure **stability** is the degree to which the measure is free of spurious fluctuation. Spurious fluctuation is change in measure not associated with corresponding change in process being measured. Such fluctuation may be due to measurement error. Measurement error may be caused by omission and/or distortion of data. For example, data that are difficult to obtain are prone to *reporting error*. Unit workload, motivation of personnel collecting data, ease of measurement, and availability of data will all influence whether data are collected in timely and accurate fashion. Any factor which adversely affects timely and accurate record keeping increases measurement error and decreases measurement stability.

Measurement stability may also be affected by measurement frequency. For example, measurements of number of jobs completed per day may show large variations from day to day, while measurements of number of jobs completed per week may show smaller variations. Accumulating measurements over time often increases stability of measurement through reduction in variance.

Measure Intercorrelations

Correlations among I&ES measures are important from several perspectives. First, high correlations may be due to measure redundancy. From a cost-effectiveness standpoint, redundancy should be kept to a minimum. Second, high correlations may signify underlying relationships which are useful in maintenance management and product evaluation.

Comprehensibility and Usefulness

Measure comprehensibility and usefulness must be considered for the two groups of I&ES users--Anacapa researchers, and Army commanders, maintenance managers, and trainers. Army users require comprehensible and useful measures which portray the facets of the unit maintenance of interest to them.

The focus of the researcher is more narrow in some respects. He needs measures which accurately reflect the effects of product implementation; these measures are used to assess product utility. Measures must be comprehensive enough to reflect the broad range of effects a product might have. Measures must show product effects in terms of maintenance system characteristics--for example, a product designed to change mechanics' attitudes needs also to be evaluated in terms of its influence on maintenance effectiveness.

Relationships Among Evaluation Factors

The criteria of measurement evaluation are linked together. To be useful, a measure must be sensitive and stable, although trade-offs must be made between sensitivity and stability. Measures which are redundant or prone to measurement error must be eliminated. Degree of correlation between measures depends heavily on proneness to measurement error. Usefulness of a measure depends on its comprehensibility, sensitivity, stability, and on how well it reflects key aspects of maintenance system performance. it follows that any set of candidate I&ES measures must be carefully evaluated against all five criteria.

Preview of Evaluation

I&ES evaluation will be conducted using several sources of information. Opinions of unit personnel will be of considerable use in assessing proneness to measurement error, comprehensibility, and usefulness. These opinions will be obtained with interviews and questionnaires. Proneness to measurement error may also be assessed through direct observation during data collection.

Stability and sensitivity trade-offs can be assessed by comparing time averages of frequently obtained measurements. Intercorrelation matrices and multiple regression equations can be generated to gain further understanding of the form and nature of measure intercorrelations.

Results of these and other efforts will be used to assess measure usefulness. Opinions of maintenance managers and researchers will be used to eliminate redundant measures and determine measure comprehensibility and usefulness.

APPENDIX A

PERSONNEL INTERVIEWED (5 - 13 MARCH)

NAME	POSITION	UNIT
LTC McWain	Sqdrn Cdr (former)	1/10 Cavalry
CPT Lachner	Sqdrn Mtr. Ofc. (former)	1/10 Cavalry
CPT Mott	Sqdrn Mtr. Ofc.	1/10 Cavalry
MSG Smith	Sqdrn Mtr. Sgt.	1/10 Cavalry
CW3 Nelson	Bn. Maint. Tech.	1/8 Mech. Inf.
MAJ Moore	Bn. XO	1/77 Armor
CW2 Babcock	Bn. Maint. Tech.	1/22 Mech. Inf.
SSG Clauson	Bn. Mtr. Sgt.	4/61 ADA

PERSONNEL INTERVIEWED (24 MARCH - 8 APRIL)

LTC Montgomery	Bn. Cdr.	2/34 Armor
MAJ Molino	XO	2/34 Armor
1LT Garver	Bn. Mtr. Ofc.	2/34 Armor
CW3 Leub	Bn. Maint. Tech.	2/34 Armor
CPT Stutler	Co. Cdr.	HHC, 2/34 Armor
1LT Nichols	Co. XO/Mtr. Ofc.	HHC, 2/34 Armor
SSG McTamney	Co. Mtr. Sgt.	HHC, 2/34 Armor
CPT Evans	Co. Cdr.	CSC, 2/34 Armor
1LT Seay	Co. XO/Mtr. Ofc.	CSC, 2/34 Armor
SSG Matthews	Co. Mtr. Sgt.	CSC, 2/34 Armor
CPT Gerheiser	Co. Cdr.	A Co., 2/34 Armor
1LT Rivers	Co. XO/Mtr. Ofc.	A Co., 2/34 Armor
SSG Kinney	Co. Mtr. Sgt.	A Co., 2/34 Armor
CPT Hamm	Co. Cdr.	B Co., 2/34 Armor
1LT Scott	Co. XO/Mtr. Ofc.	B Co., 2/34 Armor
SSG Weaver	Co. Mtr. Sgt.	B Co., 2/34 Armor
CPT Wheeler	Co. Cdr.	C Co., 2/34 Armor
2LT Cobi	Co. XO/Mtr. Ofc.	C Co., 2/34 Armor
1LT Shaw	Co. XO/Mtr. Ofc. (designate)	C Co., 2/34 Armor
SGT Morris	Co. Mtr. Sgt.	C Co., 2/34 Armor

APPENDIX B

SUBJECTIVE INDICATORS (FM 43-1 TEST) AND RELATED CANDIDATE MEASURES

SUBJECTIVE INDICATOR		CANDIDATE MEASURE
6-4.c.	Operators/crews are present during scheduled periods of preventive maintenance.	Assigned, available, direct PM Man-hours (e.g., MPS (DS) Table 1).
6-4.h.	Maintenance faults are promptly reported.	Elapsed time from fault occurrence to reporting.
6-10.h.	Equipment is usually accepted at first DSU acceptance inspection.	DSU acceptance inspection rejection rate.
6-13.c.	Assigned maintenance personnel are working in their MOS.	Roster/"automated TO&E" showing authorized slots and how they are filled.
6-13.d.	Mechanics are accounted for during working hours.	Assigned, available, direct man-hours (e.g., MPS (DS) Table 1).
6-13.e.	Mechanics are present for duty in shop and have high work output.	See previous measure; also, number of jobs completed.
6-13.f.	Mechanics are attentive to quality of work.	Percent of corrective maintenance jobs passing final inspection, false replacement rate, maintenance job repetition rate per equipment.

6-17.c.	Low percentage of requisitions is rejected for errors.	Supply requisition rejection rate.
6-32.f.	Personnel availability forecast is made.	Roster or "automated TO&E," showing projected personnel losses in 30, 60, and 90 days.
7-4.b.	Maintenance faults are promptly reported by operators/crews.	Elapsed time between fault occurrence and reporting (e.g., MPS (DS) Table 5).
7-7.e.	Faults are correctly diagnosed, rather than randomly replacing parts.	False replacement rate.
7-16.b.	DSU seldom refuses to accept equipment for repair due to organizational maintenance deficiencies/shortcomings.	DSU acceptance inspection rejection rate.
8-13.b.	Low percentage of requisitions is rejected for errors.	Requisition rejection rate.
8-13.c.	Few requisitions are open (unfilled) for long periods of time.	Requisition suspense distribution.

APPENDIX C

INFORMATION/MEASURE TAXONOMY

I. MAINTENANCE EFFECTIVENESS

A. System-Level Measures

1. Equipment Materiel Readiness
2. Average Available Days per Period
3. Average NORM Days per Period
4. Average NORS Days per Period

B. Maintenance Efficiency

1. Average Job Backlog
2. Equipment Deficiencies and Shortcomings
   (a) Number of equipment deficiencies
   (b) Number of equipment shortcomings
3. Repair Speed
   (a) Direct man-hours per job
   (b) Direct man-hours per task
4. Job Completion Speed
   (a) Job completion time
   (b) Elapsed time in each job stage (fault identification, diagnosis, supply action, corrective maintenance)
5. Number of Maintenance Jobs Completed per Maintenance Man-hour Expended
6. Number of Maintenance Deficiencies and Shortcomings Identified per PM Man-hour Expended

C. Maintenance Productivity

1. Number of Maintenance Jobs Performed per Period
2. Number of Maintenance Tasks Performed per Period
3. Number of Maintenance Deficiencies and Shortcomings Identified per Period

D. Maintenance Quality

1. DSU Acceptance Inspection Rejection Rate
2. Percent of Corrective Maintenance Jobs Passing Final Inspection
3. False Replacement Rate
4. Maintenance Job Repetition Rate per Equipment
5. Number of errors per job

II. TECHNICAL PROFICIENCY

A. Skill

1. General Indicators
    (a) Skill index
    (b) Individual skill profile
    (c) Training requirements summary
2. Specific indicators
    (a) Maintenance task procedural accuracy
    (b) Maintenance task completion time
    (c) Use of appropriate tools, publications, TMDE in performing maintenance tasks
    (d) Fault diagnosis accuracy

B. Training

1. General Indicators
    (a) Maintenance training man-hours expended per period
    (b) Number of maintenance training man-hours received per soldier
2. Specific Indicators
    (a) Overall skill growth index
    (b) Exposure, training, performance indexes
    (c) Distribution of skill levels per team per maintenance task completed

III. APPLICATION OF RESOURCES

A. Personnel

1. Direct Man-hours per Man per Period
2. Direct Man-hours (Overall) per Period
3. Overtime Man-hours per Period
4. Preventive Maintenance Man-hours per Period
5. Team Effectiveness Measures
   (a) Goal setting
   (b) Feedback
   (c) Meeting participation
   (d) Goal attainment rate
   (e) Attitudes
6. Task assignment procedures

B. Repair Parts Supply

1. Average Request for Issue Suspense Time
2. RFI Rejection Rate
3. NORS Days per Period
4. Percent of PLL Parts Requests Immediately Available in PLL
5. Percent of PLL Items Demanded per Period
6. PLL Zero Balance
7. Number of PLL Lines

C. Tools

1. Average Number of Inoperable/Non-Available Tools Required per Maintenance Job

D. Test, Measurement, Diagnostic Equipment (TMDE)

1. Average Number of Inoperable/Non-Available Items of TMDE Required per Maintenance Job

E. Publications

1. Average Number of Non-available Publications Required per Maintenance Job

IV. CONCOMITANT VARIABLES

A. Maintenance Effectiveness Concomitants

1. Unit Operations
   - (a) Types of operations
   - (b) Intensity of operations
   - (c) Location of operations and availability of resources
2. Fleet Characteristics
   - (a) Age
   - (b) Condition
   - (c) Maintenance history
3. Workload
   - (a) Number of scheduled maintenance demands made per period
   - (b) Number of unscheduled maintenance demands made per period
   - (c) Number of equipment breakdowns
   - (d) Number of jobs evacuated to DSU
   - (e) Organizational structure

B. Technical Proficiency Concomitants

1. Availability of Training Resources
2. Availability of Time to Conduct Training
3. Average Number of Personnel per Repair Team
4. Unit Operations (see above)
5. Workload (see above)
6. MOS complexity
7. MOS maintenance task difficulty

C. Application of Resources Concomitants

1. Number of Personnel Assigned vs TO&E
2. Number of Personnel Available
3. Job Satisfaction
4. Unit Operations (see above)
5. Workload (see above)
6. Personnel Demographic Characteristics

APPENDIX D

MPS(DS) REPORTS

'E' CO. 704 MAINT. BN.

ROSTER

REPORTING PERIOD ENDING: 1065 (6 MAR 81)

MOS	STATUS	CODE#	NAME	HIST	START DATE	STOP DATE
31E	ASSIGNED	10	*BARB(35E-E5)	N	1013	
		20	CLARE(35E-E4)		0021	
		30	EBLE(36H-E2)		0353	
		1050	FERDIG(35E-E5)	N	0001	
		50	FERNANDEZ(35E-E5)		0120	
		60	FLECK(31E-E5)		0001	
		920	MORGAN(35E-E4)		0012	
		990	NORFLEET(35E-E5)	N	1030	
		70	SALDANA(36K-E4)		0001	
		80	USSERY(36K-E5)		0340	
41C	ASSIGNED	100	MULLIS(41C-E4)		0035	
		1040	WRIGHT(41C-E5)		1065	
44B	ASSIGNED	120	JACKSON(44B-E3)		0156	
		130	MORALES(44B-E3)		0084	
		730	P.PAYNE(63H-E2)		1006	
		140	R.PAYNE(44E-E4)		0070	
		150	WEAVER(44E-E5)		0284	
		160	WHITE(44B-E3)		0267	
45B	ASSIGNED	980	CALHOUN(45B-E4)		1020	
		170	MERILLO(45B-E5)		0268	
		180	MUIR(45B-E1)		0003	
		190	VELOS(45B-E3)		0098	
		200	WARREN(45B-E3)		0266	
45K/L	ASSIGNED	210	CORONADO(45K-E5)		0252	
		1000	FLAVIN(45L-E2)		1030	
		220	GONZALES(45K-E4)		0247	
		230	HARTMAN(45K-E3)		0063	
		240	JACQUAY(45K-E4)		0343	
		250	MARLETTE(45K-E3)		0224	
		260	PERRY(45K-E4)		0224	
		270	PITROSKI(45K-E1)		0310	
		280	QUACKENBUSH(45K-E5)		0078	

REF# 1 DIST 10

'E' CO. 704 MAINT. BN.

INTERPRETATION COMMENTS

DATE: 1065* (6 MAR 81)

REPORTING INTERVAL JULIAN DATES	
0264-0277	
0278-0291	
0292-0305	
0306-0319	
0320-0333	
0334-0347	1. DATA COLLECTION COMMENCED DURING THIS PERIOD.
	2. PARTIAL DATA DURING 0341-1002 DUE TO HOLIDAYS.
0348-0361	
0362-1009	
1010-1023	1. FULL-SCALE DATA COLLECTION RE-STARTED 1012.
	2. MANY ARMAMENT PERSONNEL DOWNRANGE 1016-1022.
1024-1037	1. PAYDAY ACTIVITIES 1030.
	2. BATTALION TRAINING DAY 1035.
1038-1051	1. BATTALION TRAINING DAY 1042.
	2. HOLIDAY FOR PRESIDENT'S DAY 1047.
	3. BATTALION TRAINING DAY 1049.
	4. QUARTERLY INSPECTION 1050.
1052-1065*	1. BATTALION TRAINING DAY 1056.
	2. PAYDAY ACTIVITIES 1058.
	3. BATTALION TRAINING DAY 1063.

REF# 2 DIST 1 2 3 4 5 6 7 8 9 10

'E' CO. 704 MAINT. BN.

TABLE 1 (45K/L): MAN-HOUR AVAILABILITY AND USE

REPORTING PERIOD ENDING: 1065* (6 MAR 81)

REPORTING INTERVAL JULIAN DATES	ASSIGNED MAN-HRS	AVAIL-ABLE MAN-HRS	DIRECT MAN-HRS	OVER-TIME MAN-HRS	PERCENT AVAIL/ ASSIGNED MAN-HRS	PERCENT DIRECT/ AVAIL MAN-HRS
0264-0277	720	0	0	0	0.0	0.0
0278-0291	720	0	0	0	0.0	0.0
0292-0305	720	0	0	0	0.0	0.0
0306-0319	784	0	0	0	0.0	0.0
0320-0333	800	0	0	0	0.0	0.0
0334-0347	920	998	992	0	108.5	99.4
0348-0361	960	328	296	0	34.2	90.2
0362-1009	960	84	84	0	8.7	100.0
1010-1023	960	792	792	0	82.5	100.0
1024-1037	1008	740	732	0	73.4	98.9
1038-1051	1040	600	600	41	57.7	100.0
1052-1065*	1040	600	600	10	57.7	100.0
AVERAGE FROM LISTED TIME PERIODS						
0264-1051	872	590	583	7	67.7	98.7

REF# 7 DIST 1 3 4 5 7

'E' CO. 704 MAINT. BN.

TABLE 2 (41C/45B/45K/L): AVERAGE DIRECT MAN-HOURS PER JOB

REPORTING PERIOD ENDING: 1065* (6 MAR 81)

REPORTING INTERVAL JULIAN DATES	MOS 41C AVG. HRS.	MOS 41C NO. JOBS	MOS 45B AVG. HRS.	MOS 45B NO. JOBS	MOS 45K/L M60 FAMILY AVG. HRS.	MOS 45K/L M60 FAMILY NO. JOBS	MOS 45K/L M109 AVG. HRS.	MOS 45K/L M109 NO. JOBS	MOS 45K/L OTHER AVG. HRS.	MOS 45K/L OTHER NO. JOBS	AVG. HRS. 45K/ JOBS
0264-0277											
0278-0291											
0292-0305											
0306-0319											
0320-0333											
0334-0347	1.9	10	2.1	73	9.3	13			6.0	1	9.1
0348-0361	1.5	2	1.3	4	34.0	2	3.0	1			23.7
0362-1009	1.5	1	2.0	3	3.5	15					3.5
1010-1023	2.8	42	7.0	3	5.3	14					5.3
1024-1037	2.2	30	1.1	30	7.2	12					7.2
1038-1051	2.1	46	1.6	34	9.0	11	22.5	5			13.2
1052-1065*	2.6	12	1.3	14	10.5	4	59.0	1			20.2
AVERAGES FROM ALL PREVIOUS TIME PERIODS											
0337-1051	2.3	131	1.9	147	7.5	67	19.3	6	6.0	1	8.4

REF# 12 DIST 2 3 4 5 7

'E' CO. 704 MAINT. BN.

TABLE 3 (45K/L):AVERAGE DIRECT MAN-HOURS PER JOB BY EQUIPMENT AND TASK

REPORTING PERIOD ENDING: 1065* (6 MAR 81)

EQUIPMENT/TASK	MAN-HOURS PER TASK				
	NO. JOBS	AVG. FROM PREV PERIODS	CURRENT AVG.	NO. JOBS	SPEC. PRIORITY FLAG
M60 FAMILY					
1 REPR WIRING HARNESS	2	3.0			
2 REPR STABILIZATION SYS	1	1.5			
3 REPR CUPOLA RING GEAR & BRG					
4 REPL ELEC PWR SUP MTR	1	12.0			
5 REPR TURRET PWR RELAY BOX					
6 REPR GUN/CDR'S CONTR ASSY	1	2.0	10.0	2	
7 REPR ACCUMULATOR	1	2.0			
8 REPR SUPERELEVATION ACTUATOR					
9 REPL HYD SYS (RES) OIL PUMP	2	4.5			
10 REPR TRAVERSING GEAR BOX	5	5.6	20.0	1	
11 REPR HAND ELEV PUMP ASSY					
12 REPR NO-BACK	3	3.3			
13 EVAL 105/165MM TUBE (BSCOPE)	38	5.2			
14 REPL 105MM GUN TUBE	3	23.3			
15 REPR REPLEN ASSY	2	1.8	2.0	1	
16 REPR RECOIL MECH	3	32.0			
17 REPR AMMUNITION RACKS	1	26.0			

REF# 21 DIST 2 3 4 5 7

'E' CO. 704 MAINT. BN.

TABLE 4 (41C/45B/45K/L): AVERAGE JOB COMPLETION TIME IN DAYS

REPORTING PERIOD ENDING: 1065* (6 MAR 81)

REPORTING INTERVAL JULIAN DATES	MOS 41C		MOS 45B		MOS 45K/L						
					M60 FAMILY		M109		OTHER		AVG. DAYS 45K/L JOBS
	AVG. DAYS	NO. JOBS	AVG. DAYS	NO. JOBS	AVG. DAYS	NO. JOBS	AVG. DAYS	NO. JOBS	AVG. DAYS	NO. JOBS	
0264-0277											
0278-0291											
0292-0305											
0306-0319											
0320-0333											
0334-0347	3.4	10	.5	78	.7	12			.3	1	.7
0348-0361	19.5	7	5.1	4	8.6	3	6.0	1			8.0
0362-1009	12.5	2	.1	3	13.3	15					13.3
1010-1023	7.8	42	20.3	3	8.4	17					8.4
1024-1037	12.0	30	12.4	32	9.6	14			27.2	2	11.8
1038-1051	7.6	46	10.8	42	18.3	13	2.9	5			14.0
1052-1065*	14.5	11	19.1	15	18.4	4	14.0	1			17.6
AVERAGES FROM ALL PREVIOUS TIME PERIODS											
0337-1051	9.0	137	6.0	162	10.1	74	3.4	6	18.2	3	9.9

REF# 27 DIST 1 2 3 4 5 7

'E' CO. 704 MAINT. BN.

TABLE 5 (45B/45K/L): AVERAGE DAYS SPENT IN EACH JOB STATUS FOR SMALL ARMS AND TURRET/ARTILLERY JOBS

REPORTING PERIOD ENDING: 1065* (6 MAR 81)

DAYS IN EACH STATUS BY JOB TYPE

REPORTING INTERVAL JULIAN DATES	SMALL ARMS JOBS (45B)					TURRET/ART. JOBS (45K/L)				
	A	K	C	B	R	A	K	C	B	R
0264-0277										
0278-0291										
0292-0305										
0306-0319										
0320-0333										
0334-0347	.3			.3	.5	1.1			.6	3.[illegible]
0348-0361	5.0			.1	17.3	1.6		2.0	6.2	6.5
0362-1009	.1			.1		8.4	1.0	27.9	1.6	6.4
1010-1023	16.9			3.4	6.1	5.6	.9	1.0	.8	4.[illegible]
1024-1037	3.4	106.0		.5	1.5	5.6	54.0	6.9	1.0	4.[illegible]
1038-1051	3.0	16.4	6.3	.6	6.5	3.8	85.1	.1	1.0	1.4
1052-1065*	5.1	19.1		.4	.8	7.3	41.9	1.3	1.6	2.[illegible]
AVERAGES FROM ALL PREVIOUS TIME PERIODS										
0337-1051	2.2	21.1	4.2	.5	3.0	5.4	37.8	9.4	1.3	4.[illegible]

REF# 33 DIST 1 2 3 4 5 7

'E' CO. 704 MAINT. BN.

TABLE 6 (45K/L): SKILL AND GROWTH INDEXES

REPORTING PERIOD ENDING: 1065 (6 MAR 81)

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                                SKILL  GROWTH              SKILL INDEX
NAME   MOS-PAYGRADE             INDEX  INDEX   0-----------------50-----------------100
                                               ↓                  ↓                   ↓

ALL E1/2                          17     1.0    ------+
ALL E3                            41     1.2    --------------+
ALL E4                            61     0.7    ---------------------+
ALL E5                            61     0.5    ---------------------+
ALL E1-E5                         44     0.9    ---------------+

PERRY(45K-E4)                     94     0.5    ---------------‡-----------------+
CORONADO(45K-E5)                  75     0.0    ---------------‡-----------
JACQUAY(45K-E4)                   72     0.5    ---------------‡----------+
HARTMAN(45K-E3)                   69     0.0    ---------------‡---------
WARREN(45L-E4)                    52     0.0    ---------------‡---
QUACKENBUSH(45K-E5)               47     1.0    ---------------‡-+
SANFORD(45K-E3)                   39     3.4    ---------------‡
MARLETTE(45K-E3)                  33     1.0    -----------+   ‡
PITROSKI(45K-E1)                  24     0.0    --------       ‡
GONZALES(45K-E4)                  24     2.0    --------+      ‡
SOUTHERTON(45K-E3)                23     0.5    --------+      ‡
FLAVIN(45L-E2)                    18     1.0    ------+        ‡
VALDEZ(45L-E2)                     8     2.0    --+            ‡
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+ SKILL GROWTH DURING LAST 6 WEEKS

REF# 37 DIST 1 3 5 7

'E' CO. 704 MAINT. BN.

TABLE 7 : SKILL DEVELOPMENT SUMMARY

REPORTING PERIOD ENDING: 1065 (6 MAR 81)

		GROWTH INDEX COMPONENTS			
MOS	AVERAGE SKILL INDEX	EXPOSURE INDEX	TRAINING INDEX	PERFORMANCE INDEX	TOTAL GROWTH INDEX
31E	29	0.0	.0	.0	.0
41C	100	0.0	.0	.0	.0
44B	54	0.6	.0	.0	.6
45B	67	0.4	.0	.0	.4
45K/L	44	0.9	.0	.0	.9
52D	47	0.1	.0	.0	.1
63G	0	0.0	.0	.0	.0
63H/W	29	0.1	.0	.0	.1

REF# 40 DIST 1 3 5 6 7 8 9

'E' CO. 704 MAINT. BN.

TABLE 8 (45K/L): INDIVIDUAL SKILL HISTORY

NAME: SANFORD(45K-E3)

REPORTING PERIOD ENDING: 1065 (6 MAR 81)

EQUIPMENT/TASK	NUMBER OF CREDITS 1	2	3	4	5	6	7
M60 FAMILY							
1 REPR WIRING HARNESS	+						
2 REPR STABILIZATION SYS	*	*	*	*	+		
3 REPR CUPOLA RING GEAR & BRG	*	*	*	*			
4 REPL ELEC PWR SUP MTR	*	*					
5 REPR TURRET PWR RELAY BOX	*	*	*	*	*	*	*
6 REPR GUN/CDR'S CONTR ASSY	*	*	*	*	*	*	*
7 REPR ACCUMULATOR	*						
8 REPR SUPERELEVATION ACTUATOR							
9 REPL HYD SYS (RES) OIL PUMP	*	*	*	*	*	*	
10 REPR TRAVERSING GEAR BOX	*	*	*				
11 REPR HAND ELEV PUMP ASSY	+						
12 REPR NO-BACK	*	*	*	*	*	*	*
13 EVAL 105/165MM TUBE (BSCOPE)	*	*	*	*	*	*	*
14 REPL 105MM GUN TUBE	*	*	*	*	*	*	*
15 REPR REPLEN ASSY	*	*	*	*	*	*	
16 REPR RECOIL MECH	*	*	*	*	*	*	
17 REPR AMMUNITION RACKS	*	*	*	*	*		
M109 FAMILY							
1 EVAL GUN TUBE (BSCOPE & GAGE)							
2 REPR BREECHBLOCK GRP							
3 REPR RECOIL SYS	+						
4 REPR EQUILIBRATION SYS							
5 REPL GUNNER'S CONTR							
6 REPR HYD PWR PACK							
7 REPR ELEV CYL	+	+					
8 REPR TRAVERSING MECH							
9 REPR REPL MAG CLUTCH (NOBACK)							
10 REPR RAMMER							
11 REPR REPLEN ASSY	+						
12 REPR WIRING							

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'E' CO. 704 MAINT. BN.

TABLE 9 (45K/L): TRAINING REQUIREMENTS SUMMARY

THRESHOLD: 1

REPORTING PERIOD ENDING: 1065 (6 MAR 81)

PRIO-RITY	NAMES	EQUIPMENT/TASKS	TRNG. REF.
		M60 FAMILY	
1	FLAVIN(45L-E2) GONZALES(45K-E4) PITROSKI(45K-E1) QUACKENBUSH(45K-E5) SANFORD(45K-E3) SOUTHERTON(45K-E3) VALDEZ(45L-E2)	1 REPR WIRING HARNESS	B55/57
1	FLAVIN(45L-E2) GONZALES(45K-E4) HARTMAN(45K-E3) MARLETTE(45K-E3) PITROSKI(45K-E1) QUACKENBUSH(45K-E5) SOUTHERTON(45K-E3) VALDEZ(45L-E2) WARREN(45L-E4)	2 REPR STABILIZATION SYS	B55/57
1	FLAVIN(45L-E2) GONZALES(45K-E4) MARLETTE(45K-E3) SOUTHERTON(45K-E3) VALDEZ(45L-E2)	3 REPR CUPOLA RING GEAR & BRG	B55/57
1	CORONADO(45K-E5) FLAVIN(45L-E2) PITROSKI(45K-E1) VALDEZ(45L-E2)	4 REPL ELEC PWR SUP MTR	B55/57
1	FLAVIN(45L-E2) VALDEZ(45L-E2)	5 REPR TURRET PWR RELAY BOX	B55/57
1	FLAVIN(45L-E2) VALDEZ(45L-E2)	6 REPR GUN/CDR'S CONTR ASSY	B55/58

REF# 54 DIST 5 7