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DEMONSTRATION OF THE EARLY-ON MANPOWER REQUIREMENTS ESTIMATION METHODOLOGY: M1 ABRAMS MAIN BATTLE TANK

By

William P. Hutzler
Patricia A. Insley
Richard J. Boden, Jr.
Betty Lou Bantor

30 September 1983

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Prepared By:

MANAGEMENT CONSULTING & RESEARCH, INC.
Four Skyline Place
5113 Leesburg Pike, Suite 509
Falls Church, Virginia 22041
(703) 820-4600

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The contractor determined, very early in the acquisition process, the manpower demand over the life cycle of the M1 tank. The resulting estimates are analyzed and compared with the Army's current M1 manning requirements. Finally, the estimates, which are developed at the occupational specialty level, are translated into requirements for general categories of aptitude.

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PREFACE

Management Consulting & Research, Inc. (MCR) has been tasked by the Office of the Assistant Secretary of Defense for Manpower, Reserve Affairs and Logistics, OASD (MRA&L), under contract MDA903-82-C-0400, to:

- develop and implement a methodology for projecting the long-term supply of manpower, by categories of aptitude, in the non-prior service youth population;
- design a procedure for determining, very early in the acquisition process, manpower demand over the life cycle of an individual weapon system;
- implement and validate the demand projection methodology by estimating manpower requirements for that weapon system; and
- recommend ways in which to generalize the manpower demand methodology to weapon systems in all four Services.

Implementation of these manpower supply and demand methodologies is intended to provide the Department of Defense with a means of identifying probable weapon system manning constraints while systems are still in the earliest stages of their acquisition planning.

This report addresses the third task above and demonstrates the feasibility of implementing a manpower requirements estimation technique very early in the acquisition cycle. The methodology previously proposed by MCR[1/] is briefly reviewed in this report and, using data available in the early to mid-1970s, is applied

1/ TR-8217-1, Estimation of Manpower Requirements for Weapon Systems in the Concept Exploration Phase, Management Consulting & Research, Inc., Falls Church, Virginia, 15 April 1983.

to estimate manpower requirements for the Army's M1 Main Battle Tank. The resulting estimates are analyzed and compared with the Army's current M1 manning requirements. Finally, the estimates, which are developed at the occupational specialty level, are translated into requirements for general categories of aptitude.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd.)

LIST OF EXHIBITS

LIST OF EXHIBITS (CONT'D.)

I. INTRODUCTION

Estimation of the manpower requirements for weapon systems that are in the early stages of their acquisition process is very important to defense planners. There are several reasons for this. First, weapon systems are becoming increasingly complex technologically. Since it takes a number of years to train individuals to operate and maintain complex systems, planning lead-time is needed to effectively plan for the impact of the new weapon system on the force and fully staff the operator and support pipelines. Second, the supply of young men and women eligible to enter military service is declining and will continue to do so until the mid-1990s. Acquisition managers and weapon system designers must be sensitive to that fact and recognize the necessity of designing weapon systems with these constraints in mind. Force planners and recruiters must plan to address the increasing competition for a scarce resource that will ensue. Finally, personnel costs have been and will continue to be the single largest portion of the Department of Defense budget. We should expect those costs to increase, especially in light of the declining supply of non-prior service youth. Early estimation of manpower requirements for a weapon system may ultimately lead to better (i.e., more maintainable) designs and ensure the availability of appropriate numbers of skilled operator and support personnel.

Expected constraints in manpower, in terms of potentially available numbers (both in occupation types and levels of expertise, i.e., apprentices, journeymen, etc.) have led to much greater emphasis on the development of manpower requirements estimates early in the development of a weapon system design. The availability of estimates earlier in the system acquisition process allows for the reflection of particular constraints in the design decision-making process. Trade-offs can be more effectively made at the Program Office level among manpower requirements drivers such as required reliability and maintainability characteristics, maintenance philosophies and system performance requirements. At the policy level, trade-offs can be made among the mix of weapon systems in the force, deployment schedules, quantities of systems acquired and organizational unit doctrine. In addition, such issues as recruiting goals, retention goals and enlistment and reenlistment incentives can be more effectively addressed with earlier information on weapon system manpower requirements.

In an effort to structure the weapon system resource requirements estimating process, OASD (MRA&L) has issued a military standard entitled Logistics Support Analysis (LSA) (MIL-STD-1388-1A). This standard delineates the various elements of LSA to be conducted in the weapon system acquisition process, including manpower, personnel and training (MPT) requirements analysis. Detailed direction on the level of detail and data to be developed and maintained in the program documentation is given. The analyses are also described in light of the acquisition phase in which they can be conducted, however, the actual phase in which analysis is initiated is left to the decision of the individual Services. In several cases, particularly the MPT analysis, it is highly desirable to make preliminary requirements estimates earlier than suggested in order to maximize planning opportunities. In addition to making earlier MPT estimates it is also desirable to analyze the impact of different operating tempos, namely the differences between peacetime readiness requirements and wartime operational requirements. The military standard addresses in detail the kinds of wartime and peacetime requirements estimates that should be developed.

A. BACKGROUND

Management Consulting & Research, Inc. (MCR) has been tasked by the Office of the Assistant Secretary of Defense for Manpower, Reserve Affairs and Logistics, OASD (MRA&L), to develop a methodology for projecting weapon system-specific manpower requirements in the Concept Exploration Phase of a weapon system acquisition. The purpose of this study is to determine:

- if weapon system manpower requirements estimates can be developed earlier than the Services generally develop them;
- how much earlier they can be developed;
- what kind of data is minimally required to develop the estimates;
- whether existing Service documentation is sufficient for generating an earlier estimate;
- whether life cycle manpower estimates can be developed; and
- what level of detail is sufficient to generate a useable estimate, reasonably indicative of future needs.

MCR has developed a structured analytical approach for performing weapon system manpower requirements estimating. It is designed to facilitate estimating when there is little detailed information on system characteristics and such other data as planned usage rates and reliability and maintainability rates are tentative. It is compatible with MIL-STD-1388-1A in that it is based on the use of comparability analysis, comparing the planned hardware, operational and maintenance characteristics of the new system to existing systems.

Development of this estimating methodology is part of an overall study to develop and demonstrate methodologies for estimating the long-term supply and demand for enlisted military manpower, presented in terms of selected aptitude categories. Four tasks are involved in this study:

- develop and implement a methodology for projecting the long-term supply of manpower, by categories of aptitude, in the non-prior service youth population;
- design a procedure for determining, very early in the acquisition process, manpower demand over the life cycle of an individual weapon system;
- implement and validate the demand projection methodology by estimating manpower requirements for that weapon system; and
- recommend ways in which to generalize the manpower demand methodology to weapon systems in all four Services.

The Early-on Manpower Requirements Estimation Methodology (EMREM) was developed in response to the second task. This methodology is designed to:

- focus on enlisted military personnel involved in the operation and support of a weapon system,

- consider changes in manpower requirements that can occur during the operational life of a weapon system, and
- use readily available data.

In addition to recognizing MIL-STD-1388-1A analytical requirements, this manpower requirements estimation methodology is also designed to be compatible with MCR's proposed manpower supply projection methodology.[2] For this reason, manpower requirements described in this report are also presented in terms of aptitudes, as defined by the Aptitude Cluster definitions developed in the first task. Aptitude Clusters are general groupings of similar skills and capabilities needed to qualify for jobs in the military. A brief review of the definition of these Aptitude Clusters is included as an appendix to this report.

As noted above, MCR has also been tasked to demonstrate and validate EMREM on an actual weapon system, the M1 Abrams Main Battle Tank. The M1 was chosen because it permits an immediate test of the methodology since it is an already fielded system and actual manpower data are available for that system.

This report documents MCR's application of EMREM on the M1 Abrams Main Battle Tank system. In applying the methodology, we have attempted to use only data that were available in the early stages of the M1 acquisition. A true test of the methodology would have been achieved if all the data used were from before November 1972, the end of the M1 Concept Exploration Phase.

2/ TR-8217-2, Aptitude Content of the Non-Prior Service Youth and Enlisted Apprentice Populations: 1982-2010, Management Consulting & Research, Inc., Falls Church, Virginia, 30 September 1983.

However, because the complete historical file on the M1 is unavailable, certain concessions were made in this demonstration of EMREM. The result is a demonstration of the methodology as it could have been performed later in the M1 acquisition cycle. However, we believe that, if the historical record were intact, a "Concept Exploration Phase estimate" of the M1 manpower requirements could have been made using EMREM.

B. ORGANIZATION OF THIS REPORT

Section II of this report provides a brief overview of the EMREM methodology that MCR has proposed. A more detailed description of the methodology and considerations relating to its use are contained in the MCR report documenting the first task of this study.[3/] The structure of EMREM is reviewed, availability of data for general application of the methodology is discussed, and the problems associated with the unavailability of data for the current application are also considered in Section II.

We begin the application of EMREM to the M1 in Section III by reviewing the development of the mission need statement that led to the M1. In that section, we develop a hardware characterization for the weapon system that eventually became the Army's M1 Main Battle Tank. Included in that hardware characterization is identification of the predecessors of the M1 whose components could be used in building a manpower estimate for the M1.

3/ TR-8217-1, Estimation of Manpower Requirements for Weapon Systems in the Concept Exploration Phase, Management Consulting & Research, Inc., Falls Church, Virginia, 15 April 1983.

Section IV contains the EMREM estimate of operator and support manpower required for the M1 system. Also included there is a development of the estimate, documentation of the sources of data used, and a comparison of the EMREM estimate to the Army's experience since fielding the M1 as an operational system. Overall conclusions regarding this demonstration of EMREM are presented in Section V.

Following these sections is a set of appendices which provide additional technical information and document the references used in this analysis.

II. AN OVERVIEW OF THE EARLY-ON MANPOWER REQUIREMENTS ESTIMATION METHODOLOGY

This section describes the basic structure of MCR's proposal for a DoD Early-on Manpower Requirements Estimation Methodology (EMREM). This discussion concentrates on the structure of the methodology. Particular attributes of the model, especially its underlying assumptions and the sources of uncertainty involved in its estimates, are discussed throughout the remainder of this report in the context of the model application.

Before describing the basic structure of the methodology, it is useful to briefly review the intended purpose of the methodology. As noted earlier, DoD policy states that weapon system manpower estimating must be conducted throughout the design process, progressing from preliminary estimates to more detailed requirements and workload analysis. These estimates must relate the manpower that will be needed to operate and support a system throughout its operational life to design characteristics and operational requirements. The basic approach of using comparability analysis reflects the assumption that new systems reflect the experience gained from existing systems. An early weapon system manpower requirements estimating methodology, compatible with required logistic support analyses should:

- comprehensively incorporate consideration of the hardware, organizational unit, and operational and maintenance characteristics of both the new system and any related baseline system;
- identify differences among the system characteristics of the new and baseline systems;

- utilize data which are normally generated and accessible in the weapon system design process;
- apply across Services and to a broad spectrum of weapon systems; and
- reflect the potential for changes in system manpower requirements during the operational life of the system due to changes in support requirements.

MCR's proposed methodology has been constructed to address these concerns. It is based on the premise that there may be a need to go beyond the typical data analyses generally performed by the Services in developing initial weapon system manpower estimates.

Exhibit II-1 depicts the earliest approximate point in the weapon system acquisition process at which the methodology can be used. As indicated, the methodology is designed to be used only after the mission need statement is approved, since information developed in that statement is necessary for the implementation of the methodology.

A. STRUCTURE OF THE METHODOLOGY

The structure of the proposed manpower demand projection methodology is illustrated in Exhibit II-2. There are two major parts to the methodology, comprising a sequence of six analytical steps. These are:

Part 1. Hardware Characterization

- a. Identify Baseline Weapon System
- b. Determine Baseline Weapon System Characteristics Changes
- c. Develop New Weapon System Description

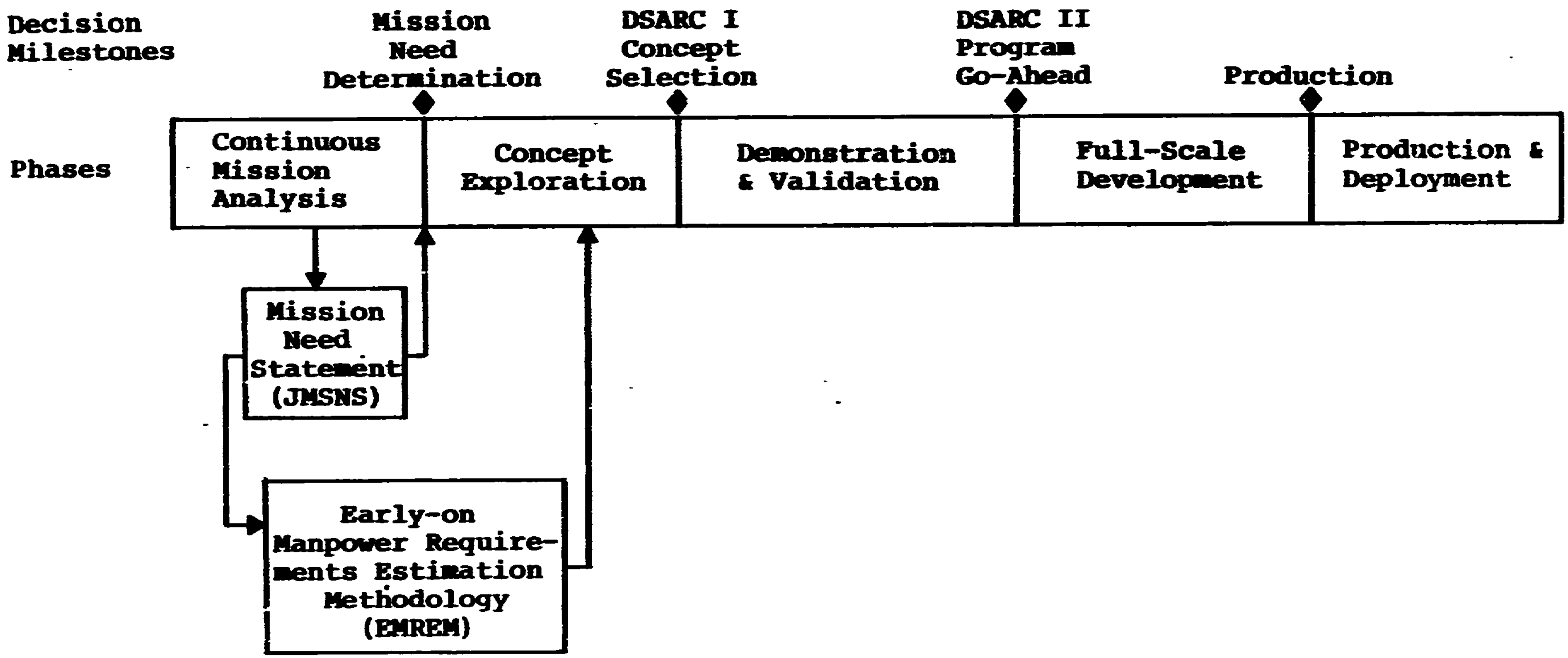

Exhibit II-1. LOCATION OF PROPOSED MANPOWER REQUIREMENTS ESTIMATING METHODOLOGY IN THE WEAPON SYSTEM ACQUISITION PROCESS

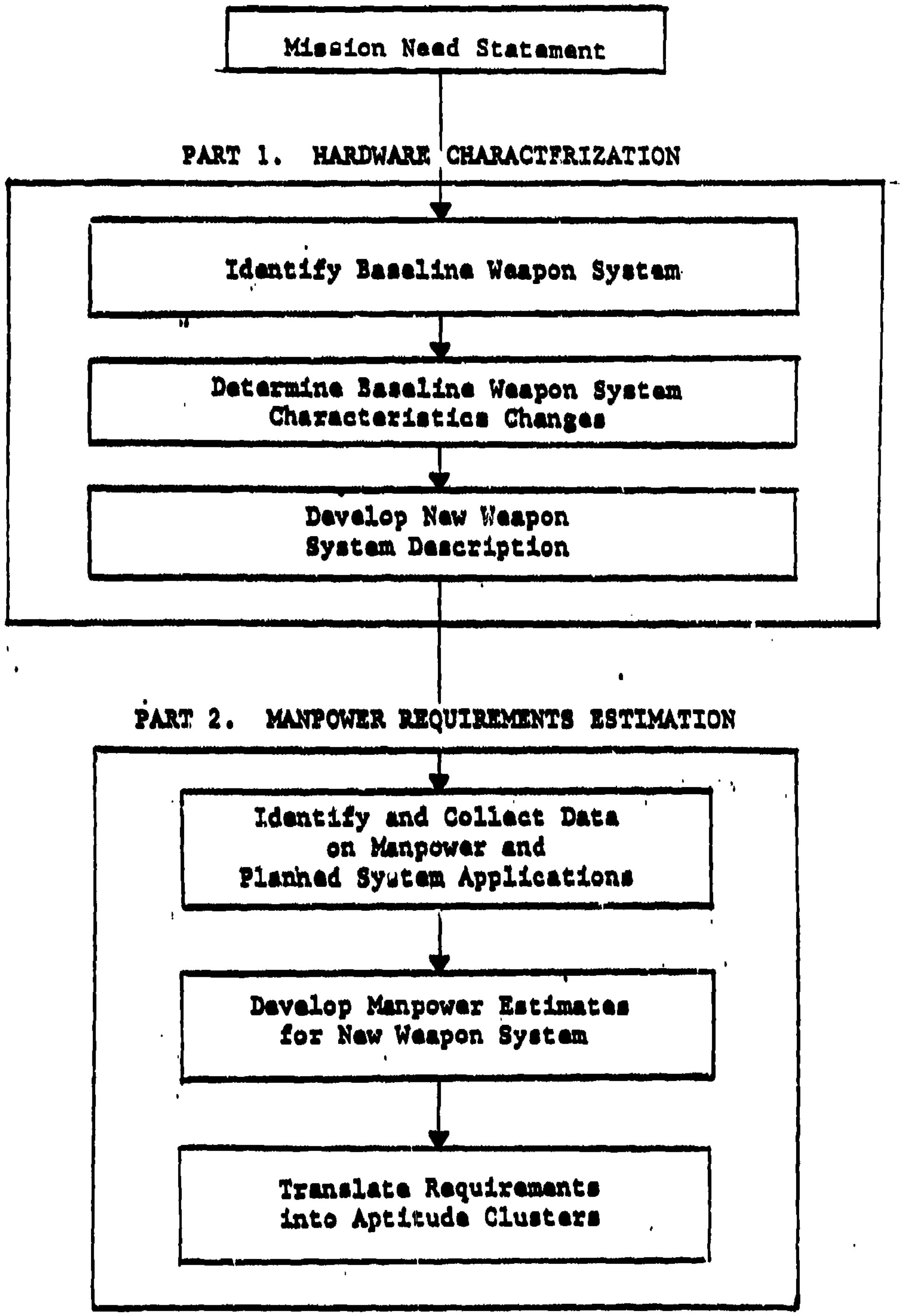

Exhibit II-2. SUMMARY OF THE EARLY-ON MANPOWER REQUIREMENTS ESTIMATION METHODOLOGY (EMREM)

Part 2. Manpower Requirements Estimation

a. Identify and Collect Data on Manpower and Planned System Applications
b. Develop Manpower Estimates for New Weapon System
c. Translate Requirements into Aptitude Clusters

A brief description of the methodology is provided below.

1. Hardware Characterization

The first part of the MCR methodology focuses on the identification of the hardware characteristics of the "new" system. By "new," we mean a weapon system concept that is being considered for acquisition and is the focus of the new design effort. The system may be required to face a completely new threat, to replace an existing system or systems, or to exploit emerging technology. The need for this system is presented in its mission need statement. The Justification for Major System New Start (JMSNS) is the document used to present the explanation of the new mission need. As indicated in Exhibit II-1, the JMSNS or some other statement of mission need is necessary to initiate application of EMREM. Acceptance of this statement initiates the Concept Exploration Phase of the weapon system acquisition process.

As the first specifically system-related document in the program, this statement plays a critical role in the analysis of the new system's hardware characteristics. While not necessarily containing particular hardware specifications, it does contain a discussion of the nature of the need. With this information, the basic type of system can be characterized through a three-step process:

- one, identify the baseline weapon system or systems;
- two, determine the baseline weapon system characteristics that may change relative to new requirements identified in the mission need statement; and
- three, develop the new system description.

Each of these is discussed below.

a. <u>Identify the Baseline Weapon System</u>

The suitability of existing systems to meet the mission requirement is considered in the mission need analysis. The baseline system[4/] is that system (or systems) already in the force structure which most closely relates to the design, operational and support characteristics of the new system. That system is, in effect, the baseline from which new designs or concepts are evaluated.

The purpose of the baseline system is to establish a starting point for considering hardware characteristics and manpower data that may be extrapolated to the new system. In determining the baseline system, the objective is to achieve the most detailed description of performance parameters and hardware characteristics that can be developed from the mission need statement. This allows greater confidence in using the baseline system manpower requirements as an analog in establishing the new system manpower estimates.

4/ The reference to a single baseline system is made only to simplify the discussion. In actual practice, the "baseline" may be constructed using portions of several systems, representing specific capabilities required of the new system. This application of EMREM to the M1 provides an explicit example of such a situation.

b. Determine the Baseline Weapon System Characteristics Changes

Having identified the baseline system, which serves as the principal source of historical hardware and manpower data, it is important to isolate the elements of the baseline system that are shared with the new system. This is not an easy task; however, it is important to construct an initial foundation upon which to build. The basic approach taken in analyzing potential differences between the new and existing systems is to identify those hardware features of the baseline system that are inconsistent with the postulated mission need.

In order to facilitate this analysis, it may be useful to prioritize the baseline systems or subsystems, if there are two or more. This may necessitate identifying other "in-service" systems or subsystems that share some functional or hardware commonality with the new system but are not part of the baseline. That will allow a weighting of information drawn from several source systems should they exist. In any case, judgement must be used in maintaining this analysis at the appropriate level of detail.

c. Develop New Weapon System Description

Having identified those characteristics of the baseline system that can be considered functionally similar to (or wholly in common with) the new system, the next step is to complete the hardware characteristics definition of the new system. This will involve completing the list of new system subsystems and identifying subsystem functions that appear to require new or modified hardware.

An additional condition may exist whereby a new system requirement may have no functional relationship with any existing system or subsystem. These requirements must be classified as developmental, in that no baseline or in-service system data is available for any functional hardware. In these instances, a proxy for the system characteristic would be selected based on the perceived similarity of manpower requirements. In all cases, the historical data ultimately used may require tailoring to "fit" the new system. Information concerning the definition of the new system hardware characteristics and the relationship of these to in-service and developmental subsystems usually comes from system designers or other specialists.

The ultimate product of the first part of the EMREM methodology, the Hardware Characterization, is a description of the new system. This description is provided as a list of the set of subsystems contained in the system, associated with a general description of the performance parameters and operational requirements contained in the mission need statement. In addition to subsystems, this list should also include design elements which could impact manpower requirements for the new system. Examples of these elements are system software, special test or diagnostic equipment or special ground support equipment. These elements may impact maintenance manpower requirements just as baseline-to-new subsystem characteristics may impact manpower requirements.

The list of hardware characteristics developed in this part of the EMREM methodology acts as the guide for developing the manpower estimates in the next part of the analysis.

2. Manpower Requirements Estimation

The analysis as developed thus far lays the groundwork for developing an initial estimate of weapon system manpower requirements. This estimate involves determining the total number of enlisted operators, or crew, and enlisted maintenance personnel required by the system. It is presented in the context of the organizational unit in which the system will be deployed.

The manpower estimate is developed in the following three steps:

- Identify and collect data on historical manpower requirements for the baseline system and other relevant systems. Also develop an understanding of the planned applications of the proposed new system.
- Develop an estimate of the manpower requirements associated with the operational life of the weapon system.
- Translate the new weapon system manpower estimates into aptitude clusters. These clusters are intended to represent the specific requirements projected for the new system in terms that relate to the types of aptitudes required personnel must have.

The steps involved in developing the estimates of manpower requirements are discussed below.

a. Identify and Collect Data on Manpower and Planned System Applications

In order to develop early-on estimates of manpower requirements, a variety of data, in addition to that already mentioned, must be identified. Information on the planned operational environment, the general structure of the organizational unit, the number of systems to be assigned to organizational units, maintainability and repairability goals, and actual manpower data must be collected. The methodology relies on the use of historical manpower data, particularly for estimating maintenance manpower requirements.

b. <u>Develop Manpower Estimates for the New Weapon System</u>

The hardware characteristics developed for the new weapon system form the basis for developing estimates of manpower requirements for that system. As explained in the discussion of the hardware characterization, the list of subsystems developed for the new system is related to a baseline system. Subsystem functions common to both are identified after comparing the functional requirements of the new system to the baseline. Those subsystems not found to be similar to baseline subsystems are compared to other in-service systems. The purpose of this analysis is to identify historical manpower data that can be used as the basis for developing subsystem manpower "modules" for the new system in the same way that hardware characteristic groups are developed in the first part of the methodology. There may, of course, be elements of the new system that have no direct analog in already operational equipment. A proxy for those functions will be identified from the set of subsystems actually in the force structure in order to allow the maximum use of historical manpower data. Otherwise an original estimate of the manpower for these functions must be developed.

The maintenance manpower requirements experience associated with those subsystems common to both the baseline and new weapon systems is discerned by examining the historical (actual) data on the baseline system. For those in-service subsystems, a similar approach is used. Attributable manpower requirements can be obtained by extrapolating from other weapon systems the maintenance experience peculiar to the new features.

c. Translate Requirements into Aptitude Clusters

Having developed the set of new weapon system operational life manpower estimates, the final step in the EMREM process is the translation of those estimates from Service occupations to aptitude cluster requirements. The purpose of this step is to present the requirements in terms compatible with MCR's proposed supply projection methodology. The Aptitude Clusters represent the aggregation of the aptitude composites for the four Services into a single set of seven groupings. These components represent the capabilties the Services have determined to be most closely associated with their particular occupations. The definitions of these Aptitude Clusters are summarized in an appendix in this report.

B. APPLICATION CONSIDERATIONS AND ANALYSIS OF DATA AVAILABILITY

As mentioned above, the Army's M1 Main Battle Tank is the focus of this initial test and validation of applicability of EMREM. The M1 was chosen for this application for two reasons. First, it is a recently fielded system and so actual manning data against which to compare EMREM estimates should exist. Second, because it is a relatively new system in a continuing tank development program, it was felt that sufficient data would be available to support the EMREM test and validation. The second assumption, however, proved to be troublesome. The historical file of data needed to provide a test of EMREM, using only data that pre-dates the M1's DSARC Milestone I[5/] decision, was incomplete in several cases. The reasons for this are explained below. However, the principal aim of this task was an early test of EMREM, and the M1 has served as a useful testbed. If a preDSARC I system had been chosen, it would be several years before we could determine of the accuracy of the EMREM estimate.

In this subsection, we identify and describe the types of manpower documents collected for this demonstration and validation of the EMREM on the M1 tank. After discussing the purported contents of the various documents, we highlight a pattern among the data which has complicated our analysis. As we shall see, only some of the acquired data were appropriate for this analysis, and other sources that would have been appropriate, and are known to have been prepared, were unobtainable.

The availability of data for this application is discussed at this point in the report because we believe there may be inherent problems associated with reconstructing historical data. Application of EMREM on a weapon system currently in concept exploration would not confront these problems since appropriate data for actual or analog systems could be developed for the analysis at the time. In normal applications, the analysis of the availability and appropriateness of manpower data would occur

5/ The Defense System Acquisition Review Council (DSARC) Milestone I is the point in the weapon system acquisition cycle at which a decision is made to proceed from concept exploration to system demonstration and validation.

after the characterization of the hardware, as part of the development of the manpower estimates.

Exhibit II-3 summarizes the documents and document types that are prepared for Army weapon systems. Several of these documents are fairly recent additions to the Army manpower requirements document roster. The documents have been divided in three categories:

- regularly generated or standard documents,
- programmatic documents, and
- special studies.

The distinguishing criterion among these three document types is the consistency or uniformity of the data contained in the reports categorized.

As used here, the term "standard documents" refers to those documents prepared on a regimented basis for Army weapon systems. They have contents that are of a substantially uniform nature across weapon systems. It is this group of documents which the EMREM is proposed to most heavily utilize. There are four standard Army documents considered to be potential sources of data for the EMREM:

- the Qualitative and Quantitative Personnel Requirements Information (QQPRI),
- Manpower Authorization Standards and Criteria (MACRIT),
- Tables of Authorization and Equipment (TOE), and
- Army Modernization Information Memorandum (AMIM).

Programmatic documents are those documents that are typically prepared for Army weapon systems, but have contents that

DOCUMENTS / CONTENTS		LEVEL OF DETAIL: HARDWARE: Subsystem	Component	MANPOWER DATA: MOS	ORG	DS	GS	DATA: DATA ELEMENTS: ANNUAL MAINT. MANHOURS	PERSONNEL	MEAN TIME BETWEEN FAILURE	MEAN TIME TO REPAIR	TYPE: ACTUAL	PREDICTED
STANDARD DOCUMENTS	QQPRI	X		X	X	X	X	X	X				X
	MACRIT	X		X	X	X	X	X	X			X	X
	TOE			X	X				X			X	X
	AMIM			X	X	X	X	X				X	X
PROGRAM DOCUMENTS	SDC	X	X		X	X	X			X	X	X	
	DT Reports			(Contents Vary)						(Contents Vary)			
	OT Reports			(Contents Vary)						(Contents Vary)			
SPECIAL STUDIES	MAINTAINABILITY PROGRAM PLANS	X	X					X					X
	SPECIAL/TASK FORCE REPORTS	X		X					X				X
	LIFE CYCLE COST ANALYSES	X	X		X	X	X	X		X			

QQPRI - Qualitative and Quantitative Personnel Requirements Information
MACRIT - Manpower Authorization Standards and Criteria
TOE - Table of Organization and Equipment
AMIM - Army Modernization Information Memorandum

SDC - Sample Data Collection
DT - Developmental Test
OT - Operational Test

need not be uniform across weapon systems or even across repeated preparations for the same weapon system. Often their contents reflect specially tailored data collection efforts as opposed to a standard data collection. Three types of reports are developed that fall into this category:

- Sample Data Collections (SDC),
- Developmental test (DT) reports, and
- Operational test (OT) reports.

The final category, special studies, includes documents prepared on an ad hoc basis, often without any sort of specified guidelines. Typically, information from this category will supply tertiary support to EMREM applications. Examples of these special studies are task force reports or special cost analyses.

The extent to which any type of data influences the EMREM estimates depends largely on the data availability profile. For the M1 application, for example, regularly generated documents and special studies play the largest roles. But, for future applications of EMREM to Army weapon systems, particularly those in the Concept Exploration Phase, it is plausible that programmatic documents such as the Sample Data Collection (SDC) reports (discussed below) would play a major role.

In the following discussion, we briefly describe the contents of the various documents referenced in Exhibit II-3. In reviewing this information, it is useful to recall how these documents are used in the EMREM analysis. Specifically, the documents provide a set of manpower requirements data for systems that are used as analogs for the proposed acquisition.

1. Regularly Generated Documents

At this point, we outline the contents of specific regularly generated documents. The four documents discussed below are regularly generated documents for Army weapon systems, and their contents and format are rigorously established by Army Regulations and guidance.

a. Qualitative and Quantitative Personnel Requirements Information

The first regularly generated manpower requirements statement prepared for an Army weapon system is the Qualitative and Quantitative Personnel Requirements Information (QQPRI). This document is prepared for DSARC II of the acquisition process. It contains Direct Productive Annual Maintenance Manhour (DPAMMH) predictions by Military Occupational Specialty (MOS), at Organizational (ORG), Direct Support (DS) and General Support (GS) levels. It contains similar data pertaining to the weapon system operators or crew. Generally, the QQPRI lists manpower requirements for a Line Item Number (LIN) pertaining to an entire weapon system, and does not contain manpower data broken out by subsystem. However, one may often identify the requirements imposed by each subsystem by recognizing that many MOSs are subsystem specific. Sometimes, though, a LIN appearing in a QQPRI refers to a piece of materiel which might be thought of as a subsystem or even part of a subsystem (e.g., a machine gun).

b. Manpower Authorization Standards and Criteria

The Manpower Authorization Standards and Criteria

(MACRIT) studies are developed for each subsystem of a weapon system after the system has been fielded. These studies, summarized in regularly published tables, contain DPAMMH predictions by MOS for maintenance and support functions at ORG, DS, and GS levels. However, whereas the QQPRI documents are generated once, a MACRIT's contents are reviewed every three years and are revised with the same frequency, if appropriate. MACRITs can be thought of as including not only the manpower requirements captured by the QQPRI, but also the indirect workload associated with personnel working on a weapon system.

It should be noted that MACRIT requirements are intended to reflect the military manpower requirements imposed by a weapon system in a wartime environment. During peacetime, different tasks, operating tempos, and workweeks typically prevail. Similarly the mix of preventive vis-a-vis corrective maintenance tasks is different. In a wartime environment, maintenance requirements would be affected by deferral of scheduled (preventive) maintenance, increased failures due to higher operating tempos, battle damage repairs and longer workweeks. Moreover, many maintenance functions, which would be conducted by Reserve component tactical logistics support units in wartime are performed by civilians at fixed-site base-level maintenance activities in peacetime. This must be considered when attempting to set peacetime requirements for active duty military personnel.

c. Table of Organization and Equipment

The Table of Organization and Equipment (TOE) contains personnel requirements for the organizational unit into which the weapon system is deployed. The personnel are listed by MOS, skill level and grade, and also by generic job title. However, they are not directly related to specific systems. TOE figures are given for three strength levels, where Level 1 refers to the most intensive use of full-time military personnel--a pattern of usage that would prevail during wartime. TOEs are generated once for an organizational unit, providing there are no major changes in materiel components deployed into the organizational unit. They are reviewed every three years. Initial estimates of the personnel impacts of introducing a new system into a TOE unit are based on the QQPRI, augmented to include other requirements driven by the system's presence in the unit.

d. <u>Army Modernization Information Memorandum</u>

The Army Modernization Information Memorandum (AMIM) contains maintenance manpower requirements specified in the same manner as the QQPRI (i.e., by MOS, at the ORG, DS and GS levels). AMIMs are generated annually and are influenced by manpower data drawn from the field experience of the weapon system, which makes them somewhat more credible indicators of manpower requirements than the QQPRI, at least in theory. While these documents have, until now, been the major documentation available, the Army has several efforts currently underway to develop earlier manpower estimates and improved data on maintenance and manpower requirements for systems. Examples of these are the Army's investigation of a HARDMAN-like approach for developing weapon system manpower estimates, Early Comparability Analysis (ECA) of critical tasks, the revised Manpower Authorization Requirements Criteria (MARC) system, replacing MACRIT, and the Man Integrated Systems Technology (MIST) efforts.

2. Programmatic Documents

Another group of documents correspond to programmatic data collection efforts. The three types of reports discussed below are all generally developed for new systems; however, the format and content frequently vary from system to system.

a. Sample Data Collections

One programmatic type of data collection effort is the Sample Data Collection (SDC). SDC summary reports contain a variety of reliability and maintainability composites on weapon systems in the field. Army Regulation AR 750-37, which is the regulation governing SDC programs, does not state the exact type of data or data format of SDCs. Thus, the exact contents of SDC summary reports should not be expected to be uniform across weapon systems and time.

b. Developmental Tests and Operational Tests

Another group of potentially useful data is the set of Developmental Test (DT) and Operational Test (OT) documentation. These tests are performed on major Army weapon systems at key points in the design development process. The extent to which DT and OT reports contain data useful for predicting manpower requirements varies widely across weapon systems, and reflects varying amounts of resources available and allocated to generate such data during the tests. Manpower considerations have thus far been a secondary focus in these tests.

3. Special Studies

The third group of documents that are possible EMREM data sources are "special studies." We have designated as "special studies" that group of documents which are ad hoc in nature. Examples of these documents are highlighted below.

a. Special Study Group and Special Task Force Reports

A noteworthy type of special study documentation is the set of documents developed by Special Study Groups or Special Task Forces. These groups are composed of weapon system and mission area specialists who are assigned to assist in, (among other things), mission area analyses or the development of statements of mission need. For example, the Materiel Need (Engineering Development), or MN(ED), of August 1972, the mission need statement that prompted development of the M1 tank, was one of several reports prepared by the Main Battle Tank Task Force (MBTTF) convened in the early 1970s.

The reports of the study groups or task forces examined to date in this research include surveys of available weapon systems and subsystem technologies. They also include evaluations of lessons learned from previous weapon system programs, and address the logistics considerations associated with a proposed weapon system.

b. Engineering and Maintainability Predictions

Other types of data falling under the heading of Special Studies are those manpower requirements predictions supplied in maintainability and reliability studies prepared by hardware contractors. An example of such a study is the MBT/XM803 Maintainability Program Plan relating to the MBT-70 and XM803, both of which were used as baseline systems for this analysis. This document, prepared by General Motors, contains, among other things, an allocation of a target vehicle maintenance manhour value among the various components of the XM803.

Contractor-prepared engineering estimates or predictions of maintenance manhour requirements are sometimes considered to be of questionable utility because they are frequently considered to be low. This may be due to the fact that they are based on assumptions which are inconsistent with the actual environment in which the Army will operate and maintain the weapon system. Some of the Services are considering the development of factors to scale contractor-prepared engineering estimates into more reliable predictors of the weapon system's future manpower requirements. A list of the contractor studies used in this analysis is contained in the appendix of references at the end of this report.

Another example of a data source that would be categorized as a special study is the Life Cycle Cost Analysis Report I, which is part of the MBT-70 Producibility/Cost Reduction (P/CR) Study. That report was prepared by Battelle Memorial Institute, Columbus Laboratories, the integration contractor for the MBT-70 P/CR Study. Report I details the methodology employed in the MBT-70 life cycle cost analysis. As part of the process of developing maintenance cost estimates, manpower requirements were generated from a simulation model, also documented in that report. The simulation model draws from the experience of the MBT-70 prototypes and from fielded M60A1s. Average maintenance manhours per 6000 miles (averaged over a ten-year operating scenario) are presented in the Life Cycle Cost Analysis Report I. Some of these data have been used in generating the EMREM estimates for the M1.

Examination of the contents of the documents mentioned above revealed some discrepancies that merit discussion. Exhibit II-4 indicates those documents, by weapon system, that were able to be acquired during the data collection phase of this study. In the process of evaluating these documents for suitability as input into the analysis, a pattern was identified between MBT manpower requirements data prepared by the Army, and like data prepared by other groups such as hardware contractors.

Army documents such as the QQPRI, MACRIT and AMIM all suggest total vehicle maintenance manhour (TVMMH) requirements (for the same usage rate) that, in relative terms, do not vary greatly for the same MBT. However, these same documents have TVMMH figures that are several times greater than TVMMH figures predicted by engineers in maintainability analyses. Army TVMMH requirements estimates in the above Army documents also differ significantly from Sample Data Collection findings. The major reason for these differences in TVMMH values is that they represent different portions of the manhours required by the system. As an example, the QQPRI includes system-specific DPMMH values,

WEAPON SYSTEM / DOCUMENT	M60A1	M60A3	MBT-70	XM803	M1
QQPRI		X			X
MACRIT	X	X			X
TOE	X	X			X
AMIM		X			X
SDC	X			X	
OT					
DT					
Maintainability Program Plan				X	
MBTTF Reports					X
Producibility/ Cost Reduction Study			X		

QQPRI - Qualitative and Quantitative Personnel Requirements Information
MACRIT - Manpower Authorization Standards and Criteria
TOE - Table of Organization and Equipment
AMIM - Army Modernization Information Memorandum
SDC - Sample Data Collection
DT - Developmental Test
OT - Operational Test
MBTTF - Main Battle Tank Task Force

Exhibit II-4. TANK-SPECIFIC DOCUMENTS

while the MACRIT includes not only these values but also other, indirect workload associated with the system. For this reason, MACRIT values will always be larger than the QQPRI. These differences are important to be aware of, since they can significantly confuse the compatability and comparability of data sources.

Examination of the similarity of the different estimates for the two tanks, shows that the manpower requirements data at the subsystem level in the FY82 AMIM for the M60A3 are nearly identical to those in the much earlier 1980 Amended Final QQPRI for the M60A3. This is despite the fact that M60A3 AMIM data are supposed to be based on Sample Data Collections. A similar relationship exists for the M1 tank. There is so strong a similarity between the MOS manpower requirements estimates of the QQPRI and the AMIM, that coincidence seems unlikely, but the actual circumstances for this are unknown.

This data situation presents two areas of consideration for the EMREM application to the Army's M1 tank:

- First, it is desirable to draw from a combination of input data sources, so that compatibility of the data is attractive.
- Second, a related problem arises in the choice of benchmark requirements to which EMREM results should be compared.

These considerations are taken up in the next subsection. There, the inability to locate data on many of the baseline systems and subsystems from the ideal time frame is addressed. That is, MCR has been largely unable to obtain historical documents, of the above types, that were prepared prior to 1972 (i.e., prior to the M1 DSARC Milestone I). Some of these documents were first generated substantially after that date. For example, the AMIM was first prepared for an MBT in fiscal year 1979. Other documents, which are believed to have been prepared, are now unavailable since much of the historical file is only maintained for a five-year period.

For these reasons, in the current application of EMREM to the M1 tank system, both the hardware characterization and manpower requirements estimation parts of the methodology were "driven" by the available data. This resulted in making it impossible to reproduce a pure "pre-DSARC I estimate" of M1 manpower requirements.

C. APPROPRIATE DATA FOR THE M1 APPLICATION

At this point, the set of potential input data is narrowed down to those actually incorporated in the EMREM program. In doing so, the reasons why only some data were suitable input are explained.

Exhibit II-5 recapitulates the documents containing suitable input for the EMREM in a way that shows the availability status of these documents for the baseline weapon systems. A "UA" denotes that a document may have been prepared for the baseline system, but was unavailable for use in this analysis for the M1. An "X" signifies that the referenced report was obtained and appropriate for the current application of EMREM. An "NA" denotes that a document was not appropriate for this EMREM application because of its age (i.e., the document was prepared for the weapon system well after Milestone I for the M1).

In this analysis, the intention has been to use M60A1 data exclusively. To the degree possible, this has been followed. However, a full set of M60A1 data is no longer available. If a full set of data on the M60A1 had been available, then it is doubtful that any M60A3 data would have been used. Unfortunately, some data on the M60A1 are unavailable due to the age of the manpower requirements estimates associated with this weapon system. As a result, M60A3 data on some subsystems were used as if they were data on the M60A1.

The assumption has been that data for some subsystems of the M60A3 will serve as reasonable surrogates for unavailable historical data on the corresponding subsystems of the M60A1. It is acknowledged that, while the subsystems may be similar or identical between the M60A3 and the M60A1, the data may still not be representative of the maintenance experience of M60A1 subsystems since there may have been improvements in training for maintenance personnel, more effective technical manuals, etc. Nevertheless, the data availability situation is such that this scheme is unavoidable. The ultimate hardware characterization required for this demonstration was, in part, driven by the availability of supporting manpower data.

In the next section, the hardware characterization required by Part 1 of the EMREM application is developed. The link is made there to the actual availability of manpower data for M1 predecessors and how that led to the selection of the "New Weapon System Description" is described.

DOCUMENT	WEAPON SYSTEM				
	M60A1I	M60A3	MBT-70	XM803	M1
QQPRI	UA	X			NA
MACRIT	X	X			NA
TOE	X	X			NA
AMIM		X			NA
SDC		X			NA
OT	UA	UA			NA
DT	UA	UA			NA
Maintainability Program Plan				X	
MBTTF Reports					X
Producability/ Cost Reduction Study			X		

QQPRI - Qualitative and Quantitative Personnel Requirements Information
MACRIT - Manpower Authorization Standards and Criteria
TOE - Table of Organization and Equipment
AMIM - Army Modernization Information Memorandum
SDC - Sample Data Collection
DT - Developmental Test
OT - Operational Test
MBTTF - Main Battle Tank Task Force
UA - Report unavailable
X - Report used in EMREM M1 Analysis
NA - Report not appropriate for EMREM M1 Analysis

Exhibit II-5. AVAILABLE MANPOWER REQUIREMENTS DATA

III. ANALYSIS OF MISSION NEED AND CHARACTERIZATION OF HARDWARE

In order to apply EMREM to a new weapon system, an analysis of the mission need for that system must be performed. The analysis of the mission need serves as the first step or input to assessment of the potential hardware features of the new system. In EMREM, the resulting hardware characterization serves as the basis for beginning the manpower requirements estimation process. The EMREM analyses that result in a system hardware characterization are discussed below in terms of their general application in EMREM, and their specific use in our demonstration of EMREM on the M1 Main Battle Tank.

In the text that follows, assumptions made and procedures used (e.g., choices of baseline systems and subsystems) are those of MCR unless otherwise designated.

A. IDENTIFICATION OF THE MISSION NEED

For new weapon systems, the primary documentation prepared prior to DSARC Milestone I is the Justification for Major System New Start (JMSNS). This "mission need statement" is prepared by the Services, generally as a result of ongoing mission analysis. A mission need statement may be prepared for a variety of reasons including:

- identification of a new threat,
- weapon system innovation, or
- exploitation of new technology.

The mission need statements for requirements which are considered major are currently called the Justification for Major System New Start (JMSNS). In the past, they have also been called Mission Element Need statements (MENs) and Materiel Need Statements (MNs). These documents are the initial motivating force behind the weapon system development process.

Although acceptance of the mission need statement initiates the development of a new major weapon system, it is not a design proposal in that no specific hardware or software characteristics are included in it. The method for fulfilling the need is addressed in terms of the adequacy of existing systems to meet the requirement. In applying EMREM, a mission need statement is used as the basis for identifying:

- the basic type of the new weapon system and the associated baseline weapon system, and
- disparities between the new weapon system and the baseline system.

In performing the EMREM analysis on major weapon systems, the degree of specificity contained in the mission need statement may not prove to be adequate for sufficiently delineating the hardware characteristics of the new system. In such cases, this basic information must be augmented by review of the supporting analyses developed in preparation of the original statement and any additional insight available from specialists familiar with those analyses. The degree to which this information is available is largely dependent upon the circumstances surrounding the development of the mission need statement. However, task force and special study group findings relating to the analysis of the need are a significant source of additional detail.

Key areas addressed in mission need statements are generally:

- an identification of relevant defense guidance elements which indicates how the new system will be part of overall U.S. military defense posture;
- a review of the potential mission and threat to identify mission area and functional deficiencies of existing systems;
- a review of alternative concepts, including information on innovative advancements or product improvements to existing weapon systems;
- a description of the potential technology involved, i.e., the degree to which technology will compensate for the remaining areas of risk;
- a discussion of funding implications and estimates of pertinent weapon system acquisition costs;
- a discussion of constraints or limitations associated with meeting the need; and
- a discussion of acquisition strategies summarizing elements of the proposed program structure, competition, and contracting arrangements.

For the M1, the Materiel Need and the Materiel Need (Engineering Development), MN(ED), were the official materiel need statements during the Concept Exploration Phase. The latter document was used as the starting point for this demonstration. They indicate the general direction of the Main Battle Tank (MBT) program in the U.S. That orientation is summarized in Appendix A.

Since the M1 is the focus of this demonstration of EMREM, certain information in its mission need statement is of primary interest. Of particular relevance is the information pertaining to the ability of existing weapon systems to meet the required operational capability and hardware characteristics. The M60A1(AOS)[6/] was cited as deficient in meeting those requirements. As indicated in Exhibit III-1, the system characteristics cited for improvement include:

- size of the silhouette,
- acceleration and cross-country speed,
- mobility and firepower systems,
- firepower capability, and
- ballistic protection.

These parameters of operating capability establish standards of the operational effectiveness of the proposed system. Embedded in this are physical characteristics the new system must possess. These include:

- maximum combat weight of 49 to 58 tons,
- maximum height (to turret roof) of 95 inches,
- maximum width of 144 inches and,
- minimum ground clearance of 17 inches.

Next, we develop the hardware characterizations required by EMREM. The result of that portion of the methodology is a description, using analogs, of a "weapon system" that will support the mission need. As we shall see, that "system" will be used in developing the estimate of manpower requirements for the M1.

B. HARDWARE CHARACTERIZATION

The identification of hardware features associated with the

6/ AOS is an acronym for Add on Stabilization.

Characteristics	M60A1(AOS)	MN(ED) MBT
General		
Gross HP/Ton	14.1	25-30
Cruising Range (mi.)	300	275-325
Ground Clearance (in.)	15.25	17-23
Width (in.)	143	120-144
Height (in.)	106.5	90-95
Weight (tons)	55	43-49
Armament		
Main Gun	105mm	105mm
Coaxial	7.62mm	20-30mm
Tank Commander	.50 cal	.50 cal
Loader	-	40mm
Stowed Load		
Main Gun	63 rounds	40-50 rounds
Coaxial	3800 rounds	500-700 rounds
Tank Commander	720 rounds	1000-1500 round
Loader	-	150-300 rounds
Mobility		
0-20 mph	15 sec	6-9 sec
Cross-country	18-20 mph	25-30 mph
Top Speed	30 mph	35-40 mph
Combat Survivability		
Kinetic Energy		
Front/Side	100mm @750M/Flank 100mm @2600M	115mm @800-1200
Sides/Rear	14.5mm @110M	23mm AP[1] @100M
High Explosive Anti-Tank		
Front/Side	None	76-115mm
Side/Rear	-	Max Degradation
Overhead	155mm VT[2] @10M	155mm VT Random

1/Armor piercing
2/Variable time

Source: HQ DA, "Main Battle Tank Task Force, Part 1: Executive Summary," 1 August 1972.

Exhibit III-1. SYSTEM CHARACTERISTICS FOR THE M60A1 AND NEW MBT new weapons system provides the framework from which manpower estimates may be developed. This section discusses the three steps, previously mentioned, which together lead to a hardware description of the new system. These steps are:

- Identify the Baseline Weapons System or System,
- Determine Baseline Weapon System Changes, and
- Develop New Weapon System Description.

Each of these is discussed below.

1. <u>Identify the Baseline Weapon System</u>

As we have seen in the mission need analysis, the suitability of existing systems to meet the stated requirement is considered. The system adopted by EMREM as the baseline system is that system already in the force structure which most clearly approximates the functions and capability required of the new system. That system is, in effect, the one against which new designs or concepts are evaluated. If the mission need statement implies that the "new" system is a product-improvement of an existing system, the latter is the baseline. In the text that follows, we categorically refer to all systems generated from mission need statements as "new" systems. Systems selected as analogs are referred to as baseline systems or predecessor systems.

The purpose of the baseline system is to establish a starting point for considering hardware characteristics and manpower data that may be applied to the new system. In determining the baseline system or set of systems, the objective is to achieve the most detailed description of performance parameters and hardware characteristics available. This allows greater confidence in using the baseline system manpower requirements to establish the new system manpower estimates.

For the M1, MCR selected primary and secondary baseline systems. The primary baseline system represents the existing system which most closely resembles the proposed new system. The primary baseline system provides a generic description of hardware information and specific engineering and manpower data on the existing system. The secondary baseline system provides additional information on those systems not currently found on the existing system but expected to be on the new system.[7/]

For this demonstration of EMREM, the primary baseline system chosen for the M1 is the M60A1(AOS). The secondary baseline system selected is the MBT-70. Collectively, the subsystems taken from these tanks most closely resemble the hardware features implied by the M1's mission need statement. The XM803, because of its similarity to the MBT-70, was a potential secondary baseline system. However, due to the lack of hardware information available for that tank, it was excluded from the analysis. As mentioned, the turbine engine from a helicopter was considered for use in the MCR analysis. However, it was rejected

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7/ In general, more than one secondary baseline may be chosen. In fact, the secondary systems may be from a completely different class of weapon system than the new system. For instance, in the analysis of the M1, the helicopter could have been chosen as a secondary system because of its turbine engine. However, the required modifications to the helicopter performance parameters made this selection infeasible in this case.

because of significant differences between its performance requirements and those that would be required for the M1. Instead, based on information contained in the mission need statement, the Daimler-Benz engine with a Renk transmission was selected for the power train.

While the baseline systems may not completely represent all the characteristics to be embodied by the new system, they do present the best starting point from which to identify hardware and manpower characteristics the new system will possess. Due to the lack of new-system detail available in the Concept Exploration Phase, the modular approach implemented by EMREM identifies the best approximation of the new system.

2. Determine Baseline Weapon System Changes

Having identified the baseline systems, which serve as the principal sources of historical hardware and manpower data, it is important to isolate the elements of those baseline systems that are not shared with the new system. In employing EMREM, the basic approach taken in analyzing potential differences between the new and existing systems is to identify those hardware features or subsystems of the baseline systems that are not able to satisfy the performance requirements specified in the mission need statement. Only subsystems of the primary baseline system have to be modified, since its function is to provide a generic description of hardware along with engineering and manpower data. The subsystems requiring change were identified by MCR through use of a three-level work breakdown structure (WBS). The WBS we have constructed is compatible with WBSs for full-tracked vehicles as described in various DoD and industry publications. The hardware portion of the WBS used in this deomonstration is shown here in Exhibit III-2. Eleven functional subsystems are listed.

Three levels of detail appear in this work breakdown structure. The first level identifies the primary weapon system being designed. The second level identifies the major subsystems or categories of equipments characterizing the weapon system. The third level contains specific equipments comprising the subsystems or categories of equipment in Level 2. Appendix B presents, at the third level of indenture, the complete WBS for the MBTs used in this study.

Generally, the more specific third level of detail (shown in Exhibit III-3) is not available in the Concept Exploration Phase. Hardware details are considered at the more aggregate second level, with details on individual components not developed until later in the design process. References to the vehicle's structure can only be made in aggregate terms such as fire control system. As the design process matures, additional levels of detail become available for each subsystem. Generally, by the end of the design cycle, detailed information to the third indenture level is available and the complete characterizations found in Appendix B would be used.

As indicated earlier, the major source of descriptive hardware information available at the Concept Exploration Phase

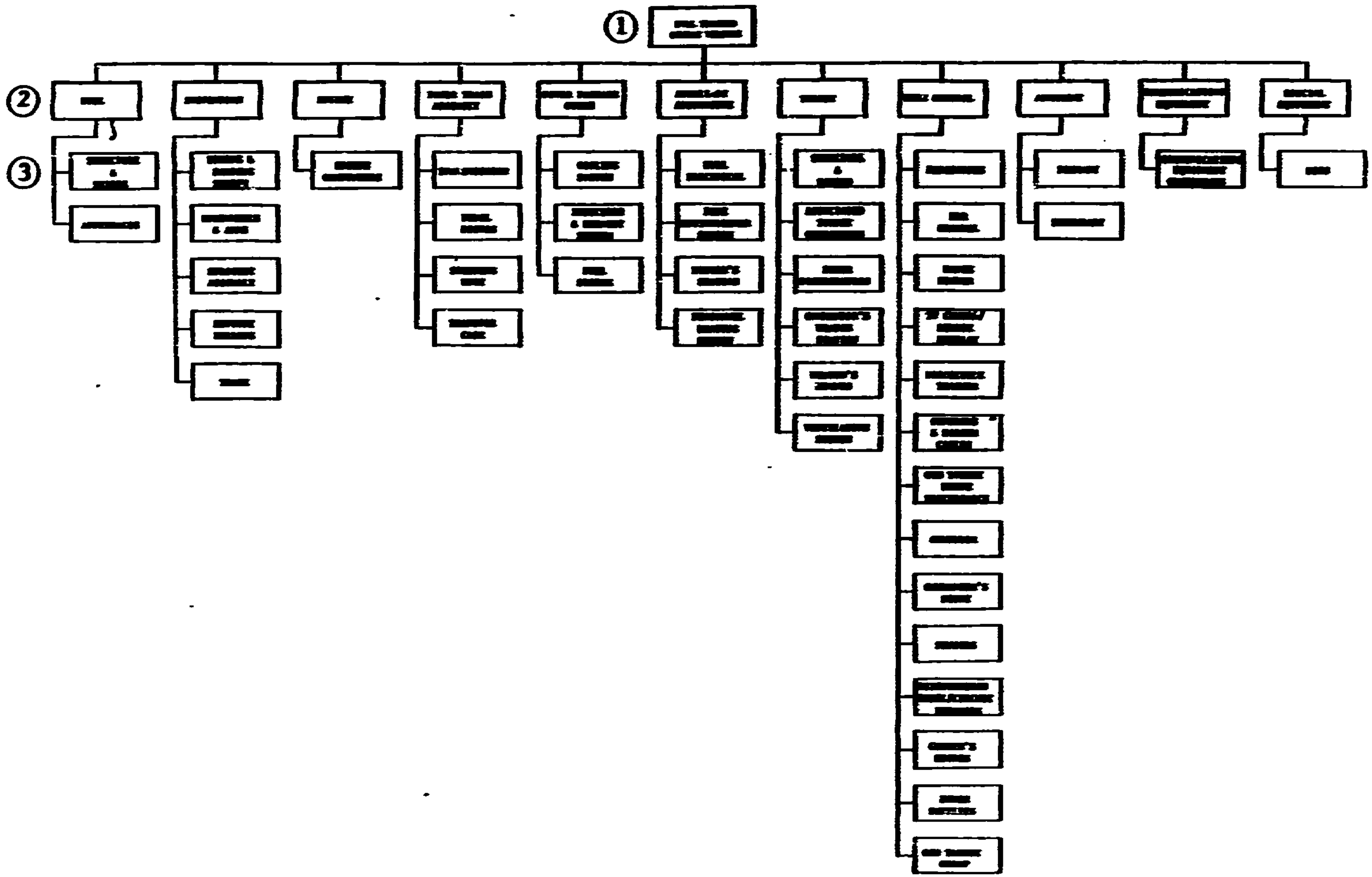

Exhibit III-2. THREE-LEVEL WBS FOR FULL-TRACKED COMBAT VEHICLE

Functional Subsystem: Fire Control
[illegible]

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• periscope M31	• periscope M31			
• periscope mount M15	• periscope M15			
• periscope sight M28C (Commander's)	• periscope sight M28C (Commander's)	• periscope sight M28C (Commander's)	• periscope sight M28C (Commander's)	
• periscope M27 (3) (driver's)	• periscope M27 (3) (driver's)	• periscope M27 (3) (driver's)	• periscope M27 (3) (driver's)	• periscope M27 (3) (driver's)
• infrared periscope M24 (driver's)	• infrared periscope M24 (driver's)	• AN/VVS-2 (passive) (driver's)	• AN/VVS-2 (passive) (driver's)	
• binocular M17A1 (& 1R)	• binocular M17A1 (& 1R)	• binocular M17A1 (& 1R)	• binocular M17A1 (& 1R)	• binocular
• periscope M36 (commander's)	• periscope M36/M36E1 (commander's)	• periscope M36 (infrared) (commander's)	• periscope M36E1 (commander's)	• periscope M36A1 (commander's)
• periscope M32 (1R) (gunner's)	• periscope M32 (1R) (gunner's)	• periscope M35E1 (passive) (gunner's)	• periscope M35E1 (passive) (gunner's)	
• infinity sight 44C	• infinity sight 44C	• infinity sight 44C	• infinity sight XM21	
• periscope mount 104A2	• periscope mount 104A2			
	• [illegible] M27			
• instrument light M30	• instrument light M30/M30	• instrument light M30/M30	• instrument light M30/M30	
	• loader's periscope M37	• loader's periscope M37	• loader's periscope M37	• loader's periscope M37
	• M24 periscope	• periscope M24 (infrared)		
	• AN/VSS-2 driver's sight		• driver's night vision viewer AN/VVS-2	
	• periscope M32E1 gunner's TC night sight			• stabilized day/thermal nightsight
			• periscope mount M118E1	• Night vision is provided by a parallel-scan Thermal Imaging subsystem which includes: - I.R. imager - scan & interlace - video mixer - N.S. scan - video control - bias regulator - pre/post amplifier (4) - control panel - CRT - indicator - electronics unit - scanner - power control unit - telescope - scan position sensor - detector/dewar - cooler
			• periscope mount M119	
			• periscope mount M114	
	• AN/TAS 2A Night Vision Sight			
			• image intensifier	
• AN/PAS-6 Metascope	• AN/PAS-6 Metascope • M[illegible] Articulated telescope	• AN/PAS-6 Metascope • Laser Tank Fire Control System 1/		

1/LTFCS is composed of two subsystems, laser/sight & computer. Laser/sight subsystem is composed of two main units: commander's integrated laser sight with optical unit and a laser electronics unit. The computer sub-system includes the ammunition selector [illegible].

Exhibit III-3. SAMPLE PAGE OF THIRD-LEVEL FULL-TRACKED COMBAT VEHICLE WBS is the mission need statement. This document outlines the performance parameters and hardware features required of the new system. Based on the information contained in the mission need statement for the M1, MCR chose six subsystems from the M60A1(AOS) as representative of subsystems to be found on the new system. This was based on a detailed analysis of the hardware aspects of the M60 series and MBT-70 tanks. Two of the M60A1(AOS) subsystems, suspension and fire control, were found inadequate based on mission need requirements. Appropriate replacements were found in the suspension and fire control systems of the MBT-70. All subsystems were selected from one of the two baselines with one exception, the vehicle power package. Based on explicit information stated in the mission need, the Daimler-Benz engine with a Renk transmission was to be used in the new system. The Army originally considered the gas turbine engine during Concept Exploration, but abandoned that concept in favor of a more familiar technology. The gas turbine engine concept was ultimately selected in the Demonstration and Validation Phase. This situation is illustrative of the manner in which design considerations change from concept exploration to production.

Although some of the subsystems of the primary baseline system (M60A1(AOS)) were cited as deficient in the mission need statement, they were still incorporated into this analysis. Those deficiencies related more to design considerations than to manpower requirements. The actual selection of subsystems for this analysis was based on the assumed similarity of their manpower requirements to those of the proposed new system.

The baseline subsystems discussed in this section are used in the next section to formulate the new weaponu system description.

3. <u>Develop the New Weapon System Description</u>

In the preceding section, the subsystems of the two baseline weapon systems were identified. This Section serves to refine the hardware characteristics definition of the new system.

As stated earlier, based on information contained in the mission need statement for the M1 tank, the M60A1(AOS) was chosen as the primary baseline weapon system. Subsystems were chosen from the M60A1(AOS) as representative of those subsystems to be found on the new system. However, two of the M60A1(AOS) subsystems were found inadequate. The MBT-70 was selected as the baseline for those two subsystems (see Exhibit III-4).

As noted earlier, one tank subsystem, the vehicle power package, could not be represented by either baseline system. That subsystem is best represented by the Daimler-Benz engine and Renk transmission found in the Leopard II tank.

Taken together, these nine subsystems provide the best functional description of the new MBT. The justification for choosing each of the subsystems used in this demonstration is discussed below:

- The M60A1(AOS) hull was chosen based on the arrangement of the crew. The three-man crew of the MBT-70 has a smaller silhouette when the driver is located in the turret, not the hull. This crew arrangement would significantly alter the reliability of resulting manpower estimates. Since the size of the tank's silhouette has a negligible effect on maintenance requirements, the M60A1(AOS) hull provides the best description of the proposed hull of the new system.

SUBSYSTEM	Baseline Systems	
	M60A1(AOS)	MBT-70
Hull	X	
Suspension		X
Vehicle Power Package[1/]		
Auxiliary Automotive	X	
Turret	X	
Fire Control		X
Armament	X	
Communications Equipment	X	
Special Equipment	X	

1/The vehicle power package includes the engine, power train assembly, and power package-other components. The Daimler-Benz engine with a Renk transmission was chosen to represent this subsystem in our analysis.

Exhibit III-4. HARDWARE CHARACTERIZATION SUBSYSTEM SELECTION: M1 MBT EMREM DEMONSTRATION

- The suspension of the MBT-70 was chosen because it meets the specified cross-country performance parameters. The M60A1(AOS) was cited as deficient and product improvements to its suspension were not expected (in 1972) to remove the deficiencies.

- The Daimler-Benz 1500 diesel engine was identified in the M1's mission need statement as the only feasible engine available for the vehicle power package. The gas turbine engine, although desirable, was afforded only secondary consideration during the M1's Concept Exploration.

- The auxiliary automotive subsystem was chosen from the M60A1(AOS). Information contained in the M1 mission need statement did not identify required changes to this subsystem.

- The M60A1(AOS) turret was chosen for the same reasons as the M60A1(AOS) hull.

- The MBT-70 fire control system most closely satisfies the performance parameters specified in the mission need statement. The infra-red fighting equipment and the ability to fire on the move, were illustrative of the requirements desired for the new tank.

- The desired primary armament for the new tank was a 105 mm or 120mm gun, with an emphasis on the former. The M60A1(AOS) was adequate for both the primary and secondary armaments. The similarity of armaments, along with mission need information, indicated no reason to expect a change between the baseline and new system.

- Based on information in the mission need statement, the last two subsystems, communications and special equipment, were not expected to change between the baseline and new system.

In this application of EMREM, the final hardware characterization was influenced by the availability of supporting manpower data. That was due to our inability to reconstruct the complete historical file of necessary information back to 1972. Although our principal goal in this demonstration of EMREM was to use manpower requirements data for the subsystems listed in Exhibit III-4, this was not feasible in two cases.

Exhibit III-5 lists the sources of the manpower data used in this analysis. Suitable data could not be found for the M60A1 hull and communications subsystem. The M60A3 was selected to be used as an analog due to the perceived similarity in maintainability characteristics. The FY82 AMIM data for the M60A3 was used in the analysis since it was more recent and closely approximated the other sources available, specifically MACRIT and the QQPRI.

The next section of this report explains how the information in Exhibit III-5 is processed into a manpower requirements estimate for the M1 tank.

Subsystem	Baseline	Manpower Document Used
Power Package	MBT-70	Life Cycle Cost Analysis Report I
Auxiliary Automotive	M60A1(AOS)	AR 570-2
Turret	M60A1(AOS)	AR 570-2
Suspension	MBT-70	Life Cycle Cost Analysis Report I
Armament	M60A1(AOS)	AR 570-2
Hull	M60A3	AMIM(FY82)
Communications	M60A3	AMIM(FY82)
Special Equipment	M60A1(AOS)	AR 570-2
Fire Control	MBT-70	Life Cycle Cost Analysis Report I

Exhibit III-5. FINAL BASELINE SUBSYSTEM SELECTION AND SOURCES OF MANPOWER REQUIREMENTS DATA

IV. MANPOWER REQUIREMENTS ESTIMATION

In this section, the development of estimated operator and support (below depot level) manpower required to operate and maintain a battalion of M1 tanks is described. This description includes the following steps:

- relate the products of the hardware characterization phase to the objectives of the manpower requirements estimation phase,
- calculate our estimates by MOS for manpower requirements below the depot level,
- translate those estimates into the MCR-defined aptitude clusters, and
- compare the EMREM results with actual observations of the maintainability characteristics of the M1 MBT.

A. <u>THE TRANSITION FROM HARDWARE CHARACTERIZATION TO MANPOWER REQUIREMENTS ESTIMATION</u>

The hardware characterization phase of the EMREM lays the groundwork for the collection of manpower requirements data, and the calculation of manpower requirements for the new weapon system. The principal product of the hardware characterization is the description, in terms of hardware features of baseline systems, of the weapon system for which manpower requirements estimates are to be calculated. Hardware features refers to combinations of subsystems or components, the elements of the various indenture levels of a work breakdown structure for the new weapon system. The level of indenture which is accommodated by the hardware characterization phase and, hence, the manpower requirements estimation phase, is determined by the specificity of Concept Exploration Phase information regarding the new weapon system.

For the M1 tank application of EMREM, we have been working at the subsystem level, largely due to the level of detail generally available at this phase of system development. The product of the hardware characterization phase for the M1 application was the list of subsystems presented in Exhibit III-5. That list of subsystems, chosen from the set of baseline weapon systems, comprises the best estimate of the collection of technologies expected (as of 1972) to be incorporated in the new MBT.

The initial objective of the manpower requirements estimation phase is to collect manpower requirements data for the baseline hardware features selected by the hardware characterization phase. So, for the M1 application, the first step towards calculation of the manpower data on the subsystems is shown in Exhibit III-5.

B. CALCULATION OF EMREM MANPOWER REQUIREMENTS ESTIMATES

The calculation of manpower estimates by EMREM is performed in three steps:

- identification and collection of data on manpower and planned system applications;
- development of manpower estimates for the new weapon system; and
- translation of the requirements into Aptitude Clusters.

The identification and collection of manpower data for this demonstration of EMREM on the M1 main battle tank was discussed separately in Section II of this report due to the significant impact data availability had on this analysis. This portion of the report focuses on the development of the actual manpower estimates and translation of those estimates into requirements by Aptitude Cluster.

The manpower requirements estimates intended to be developed using EMREM are to represent the different manpower required in the three periods of a system's life cycle:

- the initial deployment phase,
- the steady state phase, and
- the post production phase.

This demonstration of EMREM on the M1 necessitated focusing on the steady state portion of the overall life cycle manpower requirements, since there were not enough historical data on the baseline subsystems to calculate any but the steady--state manpower requirements. These latter requirements are calculated from maintenance manhour data per measure of usage or per unit of time. In the case of the M1, the qualitative, Service-specific breakout is represented by the first two characters of the (three character) Army Military Occupational Specialty (MOS) codes. In the discussion below, we use the term "MOS group" to refer to sets of MOSs represented by their first two characters.

1. <u>Development of the Manpower Estimate for the M1 Main Battle Tank</u>

EMREM is designed to determine manpower requirements at the weapon system level. At this level, the exact types of manpower to which we are referring are the weapon system operators (crew), support personnel, and below depot level maintenance personnel (i.e., organisational and intermediate maintenance personnel).

For the M1 tank application, the requirements for the crew were established quite readily from the MN(ED) which stated that the new MBT would have a four-man crew. That is, the new MBT would have the conventional crew combination of commander, loader, gunner and driver. Thus, the principal task of estimating manpower requirements for the new MBT focused on determining maintenance and support manpower requirements.

Steady-state manpower requirements were calculated for personnel involved in the below-depot-level maintenance and support of the new weapon system using historical manpower data and manpower requirements predictions. Several conventions where adopted in this process. These include:

- determination of an acceptable way to categorize manpower data, prior to the conversion to Aptitude Clusters;
- allocation of total manpower requirements to ORG, DS and GS echelons;
- manipulation of the data, which come from heterogeneous sources, so that they are more compatible with one another;
- determination of the number of weapon systems (tanks) that will be deployed into a given organizational unit (battalion);
- conversion of manhour data into numbers of personnel; and
- establishment of criteria to generate ranges of personnel requirements (by personnel type) that would be expected to contain actual personnel requirements.

The specific conventions used in this EMREM demonstration are explained in the discussion that follows.

a. Categorization of the Manpower Data

The manpower requirements estimates developed using EMREM are ultimately translated into Aptitude Clusters. Therefore, at some point, the manpower requirements must be grouped according to skills. Since it is simple from the outset to make the transition from a hardware-oriented breakout of manpower requirements to a breakout according to MOS and, since the latter categories may be related to skills, we have opted to do this from the start. That is, the historical manpower requirements information are rearrayed by MOS.

The manpower data are grouped by the first two characters of the MOS. The third character of the MOS has been suppressed because this character is typically peculiar to a given weapon system. For example, if the first two characters of an MOS code are "63", then the MOS code refers to a tank automotive mechanic. But, when this code is appended with a third (alpha) character, it refers to a tank automotive mechanic charged to specific activities for a specific type of tank, (e.g., M60 vs. M1). By ignoring the system-specific designator, the potential aptitude commonality of MOSs within the group is reinforced.

The relation between MBT hardware characteristics and specific occupations in maintenance and support functions is shown in Exhibit IV-1. The Army manpower data used for several of the baseline subsystems were originally arrayed in this analysis by the three-character MOS code. For those data, the

Occupation Title	MOS Group	Activity	Related Hardware Characteristics
Tank Commander, Driver, Gunner, Loader (Crew)	11 1/	• System operation/crew-level maintenance	• All subsystems requiring crew-level maintenance
Field Radio Repairer, Field General COMSEC Repairer, Tactical Comm. Systems Op./Mech.	31	• Maintenance	• Communications Equipment (Field radio and COMSEC Equipment)
Fire Control Instrument Repairer	41	• Maintenance	• Fire Control
Metal Worker	44	• Maintenance	• Hull and Turret (Structure)
Small Arms Repairman, Tank Turret Repairman, Tank Turret Mechanic	45	• Maintenance	• Turret (Armament)
Chemical Equipment Repairman	54	• Maintenance	• Special Equipment (Chemical Equipment protective masks, smoke generators, flame weapons, decontamination equipment)
Fuel & Electrical Systems Repairman, Automotive Repairman, Tank Systems, Mechanic	63	• Maintenance	• Suspension, Power Package, Auxiliary Automotive (Chassis, Fuel and Electrical Systems)
Unit Supply System	76	• Support	• Non-hardware specific

1/The MOS designator of 11 has, since the M1 Concept Exploration Phase, been changed to 19.

Exhibit IV-1. RELATIONSHIP OF OCCUPATIONS TO HARDWARE CHARACTERISTICS third character of the MOS code has been supressed and the related requirements have been combined under the first two characters. This was due to the inability to predict the specific designator which would be used for a future tank. For the requirements that were not identified by a specific MOS, such as those relating to maintainability predictions for the MBT-70, the relevant MOS group was deduced from AR 611-201. As can be seen in Exhibit IV-1, there are cases where multiple maintenance or support functions (i.e., occupation titles) were identified with a single MOS group. In those cases, individual requirements for the MOS group for each function were calculated and added together.

b. Allocation of Manpower Requirements to ORG, DS and GS Echelons

Another characteristic which must be incorporated in the manpower requirements estimate is the distribution of maintenance manhours in the three below depot echelons. Each of the different echelons has a different amount of wartime available productive manhours due to doctrinal assumptions about the frequency of unit relocations during combat operations. In order to convert the estimated maintenance manhours into the personnel required in each echelon, it is necessary to determine appropriate workload distribution rules. Allocation of below depot level maintenance during the very early stages of the acquisition process is likely to be hampered by lack of a definitive maintenance concept. In such instances it is useful to assume that the allocation of the below depot level maintenance tasks observed for the baseline system/subsystems will apply to the new weapon system. Given the below depot level manpower requirements estimates, adjustment of the allocation of these requirements among the ORG, DS and GS echelons may be made as more detailed maintenance plans are formulated and made available to the manpower analyst.

For the M1 demonstration of the methodology, disaggregation of the input data into the relevant echelons followed this scheme:

- Input data that came from Army manpower requirements documents (i.e., AMIM, AR 570-2) were originally broken out into ORG, DS and GS echelons. That breakout was preserved when processing this data into EMREM estimates -- with one exception which is noted below.
- Manpower requirements predictions taken from the life cycle cost analysis for the MBT-70 were not broken out by the Army into ORG, DS and GS echelons. For this study, these data were broken out into the relevant echelons in accordance with AR 570-2.

In the separation of the input data into the below depot level echelons, there was one exceptional case: MOS group 45, whose maintenance activities are chiefly associated with the tank turret. While the source of input data for this MOS group (AR 570-2) showed no ORG level maintenance manpower requirements, the MN(ED) makes it clear that there will be ORG level tank turret maintenance performed on the new weapon system (i.e., the M-1). For this MOS group the allocation appearing in the FY 82 AMIM for the M60A3 was adopted.

As a result of the above procedures, three sets of raw input data were obtained, one set for each relevant echelon. While the manner in which the input data were disaggregated into the below depot level echelons for this demonstration may appear subjective, it should be noted, for benchmarking purposes, that this allocation does not affect the aggregate, below depot level EMREM estimates.

c. Reconciliation of the Data

As noted earlier, the purpose of this study was the development and demonstration of a methodology for estimating weapon system manpower requirements early in the design process. A significant question that must be addressed is the type of manpower estimate to be developed. Part of the problem associated with determining this involves the identification of the version of manpower requirements to be approximated, namely staffing estimates, wartime or peacetime requirements. Greater emphasis has been placed more recently on distinguishing between wartime operational requirements as distinct from peacetime readiness needs. Generally speaking, currently generated organizational unit manning requirements are designed to reflect wartime staffing requirements. This is particularly true of the estimates developed for the time period of interest in this demonstration. For this reason our estimates have been designed to approximate the type of estimate the Army would ultimately develop, staffing estimates. This was somewhat unavoidable due to our necessary dependence on historical data. However, in an effort to explore the possibilities for estimating both wartime <u>and</u> peacetime requirements we have parametrically developed data for such a calculation. The demonstration of this experimental analysis is given in Appendix E.

The manpower data used in this application of EMREM come from three basic sources:

- AR 570-2, the Army Regulation containing the personnel authorization tables for the MACRIT,
- the FY 82 AMIM for the M60A3 Main Battle Tank, and
- the Life Cycle Cost Analysis Report I of the MBT-70 Producibility/Cost Reduction Study.

The first two data sources show maintenance manhours for various MOSs, given an annual usage rate of 1000 miles. The third source shows average manhours per mile for tank subsystems, with the average taken over a simulated 10 years of operation at 3000 miles per year.

Our reconciliation of the data so that they are more compatible is a two-step process:

- First, we convert the data to a common usage rate, 1000 miles per year, by multiplying the manhour per mile data for the MBT-70 by 1000.
- Second, the EMREM objective is to predict personnel requirements that are compatible with those obtained by the Army for staffing purposes (i.e., MACRIT). Thus, the AMIM and Life Cycle Cost Analysis Report I data on total vehicle maintenance manhour requirements are inflated to 3000 productive manhours per 1000 miles of vehicle operation in order to then adjust the individual subsystem values in these two documents so as to be suitable for use as analogs. This produced a total vehicle maintenance requirement of approximately one and one quarter productive manyears per 1000 miles per year. That estimate is more consistent with MACRIT findings to date for main battle tanks.

In the first step above, the 1000 miles per year figure serves only to reconcile the data around the same usage rate so that the scaling to 3000 manhours may be done. The EMREM computer program is capable of applying a range of annual usage rates, converting input data specified as X-maintenance hours per Y-miles to a common number of hours over all input data.

Regarding the second step, while the 3000 productive manhours per 1000 miles figure has been used as the base for the various requirements, it is not meant to endorse this value. Rather, it is considered an appropriate assumption when the objective is to predict manpower requirements that are consistent with the Army's notion of MBT maintainability.

There is an additional embedded assumption imposed regarding the impact of usage rates in this application of EMREM. A linear relationship is assumed to apply between usage and manpower requirements. Specifically, if tank operation is increased n-times, in terms of miles per period of time, then manpower requirements increase n-times. Research to date has not revealed the documentation of the Army's assumption concerning this relationship.

Criticism of this assumption would undoubtably focus on its appropriateness for only certain tank components such as the engine, transmission, tracks, road wheels, suspension and other components whose usage rate is most directly tied to miles traveled by the tank. That is, while a tank might travel twice as many miles under an alternative operating scenario, it might only fire its main armament half-again as many times. Thus, strictly speaking, using miles traveled as an index of usage rate might lead to more meaningful scaling of engine maintenance requirements than, for example, main armament maintenance requirements.

Unfortunately, "miles traveled" data were the only available data on vehicle usage rates. To ignore miles traveled when looking at the input data on manpower requirements would be a less satisfactory procedural assumption. Should more complete usage rate data become available for EMREM applications to other weapon systems, the EMREM computer program could be easily modified in order to exploit this information.

d. <u>Determination of the Number of Tanks per Battalion</u>

In the change from H-series TOEs to J-series TOEs, the number of tanks per battalion rose from 54 to 58. This is a doctrinal change which could not have been predicted during the M1's Concept Exploration Phase. So, although this violates the intention of developing a "pure" Concept Exploration Phase estimate, the 58 tank battalion was used as the basis for developing the battalion manpower requirements for the M1. Had the 54 tanks per battalion been used, the manhour estimates would be decreased by approximately seven percent due to this assumption alone.

e. <u>Conversion of Manhours to Numbers of Personnel</u>

The conversion of manhours to numbers of personnel is accomplished by means of average available productive manhour (AAPMH) factors, such as those described in AR 570-2. These factors reflect the estimated number of hours available for productive work per year for the individuals engaged in particular types of maintenance. In calculating the requirements for each echalon, the EMREM program uses a range of AAPMH factors as input, since there is considerable doubt cast on the applicability of currently available AAPMH factors. There is also some question as to the effectiveness of using a single factor, versus a range, in calculating organizational unit requirements.

For ORG echelon maintenance and support personnel requirements calculations, the AR 570-2 TOE Category I AAPMH value of 2500, plus and minus 10 percent, was employed. Similarly, DS echelon calculations use an AAPMH value of 2700 (TOE Category II), plus and minus 10 percent, and GS echelon calculations use a value of 3100 (TOE Category III), plus and minus 10 percent. The purpose of using the AR 570-2 factors plus and minus 10 percent is to acknowledge that other factors besides unit type (i.e., ORG vs. DS vs. GS) influence availability of productive manpower.

While the quotient of the manhour requirements and the AAPMH factor need not be a whole number, the personnel authorizations for a particular unit (e.g., a DS maintenance company) must be expressed in terms of whole people. Therefore, these quotients must be rounded. A convention has been used in this analysis concerning rounding to the next whole person. Since rounding down always results in greater workloads (per man), explicit consideration was given to the situations in which rounding was required.

The criterion used in applying the rounding rule has been if rounding down means more than ten percent more work per year, per man, then rounding upward is to be done. However, use of this rule was modified in that if satisfaction of the former condition implies that personnel involved are each working at less than 90 percent of the AAPMH factor, then rounding downward prevails. This latter stipulation prevents over-estimation of personnel requirements. This convention was used rather than simply rounding to the nearest integer, since it allows for the more explicit balancing of workload. For further details on these calculations, consult Appendix C.

f. Selection of Personnel Range-Generating Criteria

To establish a range of personnel requirements for each occupation (i.e., MOS) group, EMREM uses as input a range of values for usage rates and for the AAPMH factor. In the Concept Exploration Phase only a tentative estimate of the planned usage rate is available. For this reason a range of usage rates has been used in this analysis. Regarding the use of a particular AAPMH factor, questions concerning the validity of any one factor value induce the use of a range of values in this study.

Strictly speaking, practically any of the assumptions that are invoked in the calculation of these manpower requirements estimates could serve as the basis for generating ranges. For example, the number of MBTs per organizational unit could have been varied. Users of EMREM, such as the Program Manager, have the option of varying any of the assumptions used to develop the estimates. However, varying such key parameters was deliberately restricted in this demonstration so as to avoid obscuring the results.

By following through the discussion of the assumptions made in EMREM calculations, it should be clear as to how the raw data is used to develop an estimate of personnel requirements. These requirements are displayed in Exhibit IV-2. For further elaboration on the mechanics of the calculations, consult the EMREM computer program documentation in Appendix C.

2. Translation of Manpower Requirements Estimates into Aptitude Clusters

The final step in the development of the EMREM estimates involves the translation of these estimates into Aptitude Clusters. In this demonstration of the methodology, a subset of the total steady-state manpower requirements estimates was translated. This subset consists of ORG apprentice enlisted personnel. Apprentice personnel are defined to be those personnel at pay grades E-4 and lower, or, equivalently, skill level 1. Only ORG apprentice personnel requirements could be mapped into Aptitude Clusters. There are two reasons for this. First, the translation of the estimates into aptitude clusters requires pay grade or skill level information on those MOS groups for which estimates are calculated. This is because the Aptitide Clusters, in their present stage of development, apply only to apprentice enlisted personnel. Second, there is a lack of suitable pay grade and skill level data at DS and GS levels (discussed below) that would enable the calculation of apprentice requirements by cluster.

The translation of the EMREM estimates (broken out into MOS groups) into Aptitude Clusters is summarized by the following two steps:

MOS \ AAPMH USAGE RATE (MI/YR)	ORG Low	ORG High	DS Low	DS High	GS Low	GS High
AAPMH	2750	2250	2970	2430	3410	2790
USAGE RATE (MI/YR)	800	1200	800	1200	800	1200
11 1/	220	232	0	0	0	0
31	3	4	2	3	1	1
41	0	0	2	4	2	3
44	0	0	1	1	1	1
45	5	8	5	8	3	5
54	1	1	1	1	1	1
63	14	27	11	20	5	9
76	0	1	0	0	0	0

1/ The high value represents four enlisted crewman for each of 58 tanks. The low value recognizes that as many as 12 of the crewmen may be officers, and we are only estimating enlisted personnel requirements.

Exhibit IV-2. ENLISTED PERSONNEL REQUIREMENTS SUMMARY: ORG, DS AND GS LEVELS (PER 58 TANK BATTALION)

- determine the requirements for apprentice enlisted personnel, and

- aggregate apprentice personnel requirements into Aptitude Clusters.

Once again, it should be noted that this translation could only be performed for apprentice personnel at the ORG echelon.

a. Determination of Apprentice Enlisted Personnel Requirements

None of the documents that provided input data for the M1 tank demonstration of EMREM included pay grade or skill level information. (This information is provided in terms of MOS descriptions in AR 611-201.) However, by virtue of being able to inspect an M60A1 tank battalion TOE, the pay grade or skill level structure for ORG echelon maintenance and support could be ascertained. The TOE used for this purpose in this study is TOE number 17-35H, dated November 1970. That TOE contains the personnel slots for ORG echelon maintenance and support activities associated with the M60A1 (the only deployed baseline system used in this study).

The apprentice personnel requirements are extrapolated from the EMREM ORG echelon estimates by:

- summing the personnel authorizations in the TOE for each MOS group,

- summing the personnel authorizations at pay grades E-4 and below for each MOS group -- i.e., summing the apprentice positions,

- calculating the ratio of apprentice authorizations to total number of authorizations for each MOS group, and

- multiplying the EMREM ORG personnel requirements (for each MOS group) by these ratios and rounding to the nearest integer, where necessary.

The results of applying these steps to the EMREM ORG echelon estimates are summarised in Exhibit IV-3.

MOS GROUP	EMREM Personnel Requirements Estimate	
	Low	High
11 1/	101	106
31	2	2
45	3	5
63	9	16
76	0	1

1/ MOS Group 11 is now MOS Group 19

Exhibit IV-3. APPRENTICE OPERATION AND MAINTENANCE PERSONNEL REQUIREMENTS (ORG ECHELON)

A similar approach for determining pay grade/skill level structure for maintenance personnel at the DS and GS echelons was not feasible because the TOEs containing the authorizations for maintenance personnel at those echelons are such that identification of M60A1-dedicated personnel is not possible. That is, DS and GS maintenance personnel for tanks are employed in units which also repair all other tracked vehicles (e.g., APCs, SP guns, engineer equipment, etc.). The TOEs for such units are summarized by MOS thus making it difficult to determine the skill level of MOS groups involved in maintenance of tanks but not other materiel. While the general lack of pay grade/ skill level information in the documents used as input for this study hampered the translation of manpower requirements estimates into Aptitude Clusters, this need not be the case for application of the methodology to other weapon systems. Moreover, it need not be the case for applications of the methodology on future MBTs.

b. <u>Aggregation of MOS Group Requirements into Aptitude Clusters</u>

The final step in the translation of our estimates into Aptitude Clusters involves the mapping of MOS groups into Aptitude Clusters. A review of the definitions of the Aptitude Clusters developed in Task 2 of this study is included in Appendix D of this report. The assignment of MOSs to Aptitude Clusters is presented in the MCR technical report <u>Aptitude Content of the Non-Prior Service Youth and Enlisted Apprentice Populations: 1982-2010</u>. Where there were two or more MOS groups in a single cluster, we have added the associated requirements.

Only one of the ORG level MOS groups appears in more than one Aptitude Cluster; MOS group 45 appears in the Technical and Mechanical Aptitude Clusters. This apparent ambiguity was easily resolved by noting that virtually all of the ORG level manpower requirements for MOS group 45 fall into the Mechanical cluster. These ORG level 45s are, using the three-digit MOS code (at least for the M60), 45Ns. These are dedicated (system-specific) tank turret mechanics.

Thus, this final step in the conversion to Aptitude Clusters is no more than a table look-up procedure. The final results of the conversion to Aptitude Clusters are summarized in Exhibit IV-4.

Cluster	MOS	EMREM Estimate		Cluster Total	
		Low	High	Low	High
Combat	19(B,E,K)1/	101	106	101	106
Technical	45(B,G,K)	0	0		
	31(E,S,V)	2	2	2	2
Mechanical	45(N)	3	5		
Maintenance	63(G,H,N)	9	16	12	21
Administrative/ Clerical	76(Y)	0	1	0	1

1/ MOS Group 11, crew, is now 19.

Exhibit IV-4. ORG LEVEL APPRENTICE OPERATORS & MAINTENACE PERSONNEL BY APTITUDE CLUSTER (PER 58 TANK BATTALION)

C. VALIDATION OF THE EMREM RESULTS FOR THE M1 TANK

In this subsection, the maintenance and support manpower requirements estimates produced by EMREM are compared with the Army's actual manpower requirements experience with the M1. The comparison is done at the MOS group level as opposed to the Aptitude Cluster level so as to allow a more complete and more rigorous evaluation of the results.

The initial consideration in this phase of the analysis was the choice of benchmark data. The choice was between the most recent Army Modernization Information Memorandum (AMIM) for the M1 tank and the most recent Sample Data Collection (SDC) results.

The FY82 AMIM was selected as the source of benchmark data, against which the estimates were compared. This choice was made because the AMIM is the document which the Army indicates is the most accurate summary of recent manpower requirements proposed for a major weapon system. Moreover, the AMIM plays an active role in annual programming decisions regarding manpower (and materiel) resources.

It should also be mentioned, however, that the manpower requirements suggested by the FY82 AMIM differ dramatically from those of the most recent SDC. The AMIM total vehicle manpower requirements per mile of vehicle operation are about 5.5 times greater than the SDC manpower requirements. However, it is unclear why this is so.

FY82 AMIM manpower requirements for the M1 are given as man-hours required for each relevant (three character) MOS to maintain and support the representative tank at the ORG, DS and GS levels for 1000 miles (one year) of operation. To make these data comparable with EMREM results, one must aggregate the AMIM manpower requirements within each MOS group; i.e., one must add the manpower requirements, for the first two characters of the MOS code, over the third character of the MOS code. The result of this process is a rearraying of the AMIM data by MOS group.

Given this rearraying, the ranges of below depot level man-hour requirements per tank can then be compared to the AMIM below depot level requirements. (This is a valid comparison even though the final results are expressed as numbers of personnel from each MOS group required to maintain and support 58 tanks.) Exhibit IV-5 shows the EMREM estimates and the FY82 AMIM data, as well as the QQPRI data. The MOS groups shown in Exhibit IV-5 are those represented in at least one of the Army documents used in this study.

Finally, Exhibit IV-6 shows the total vehicle maintenance manhour requirements per mile of operation estimated by EMREM against the same figure as reported by the AMIM, SDC, MACRIT and QQPRI. EMREM enlisted crew manpower estimates (numbers of personnel) are shown agains M1 TOE requirements.

These estimates are much greater than the findings of the SDC due to the reconciliation of the manpower data around a total vehicle maintenance manhour requirement of approximately one and one quarter productive manyears per 1000 miles per year of MBT usage. This is also responsible for the relative proximity of the EMREM estimates to the AMIM, QQPRI and MACRIT values.

MOS Group	M1 Annual Maintenace Manhours Per Tank[1]			
	EMREM Estimate		Dec 79 QQPRI	FY82 AMIM
	Low (800 mi/yr)	High (1200 mi/yr)		
31	202	303	106	305
34	*	*	19	*
35	*	*	7	*
41	184	276	*	84
44	19	29	*	24
45	614	921	894	890
54	40	60	10	*
63	1584	2376	1243	1243
76	4	6	*	*
TOTAL	2647	3971	2279	2546

*Not calculated by EMREM or not given in the Dec 79 QQPRI or FY82 AMIM.

Note: The QQPRI, AMIM and EMREM estimates each call for a four-man crew per tank.

1/ Fractional hours have been rounded for all estimates.

Exhibit IV-5. COMPARISON OF EMREM AND ARMY REQUIREMENTS ESTIMATES

Estimation Source	M1 TVMMH Per Mile
EMREM	3.31
AMIM	2.55
SDC	0.47
MACRIT	3.30 1/
QQPRI	2.28 1/

1/ MACRIT and QQPRI TVMMH values have been calculated based on the usage rate used by the Army (1000 miles per year).

Exhibit IV-6. M1 TOTAL VEHICLE MAINTENANCE MANHOUR (TVMMH) REQUIREMENTS PER MILE

V. SUMMARY AND CONCLUSIONS

This section briefly summarizes MCR's experience in demonstrating EMREM on the M1 Main Battle Tank, and presents the major conclusions resulting from this effort.

A. SUMMARY

As noted in Section I, there were a number of purposes associated with this study. This discussion focuses on the findings related to those points.

Of initial interest was determining whether weapon system manpower estimates could be developed earlier in the systems acquisition process than the Services generally develop them. This demonstration has verified that such estimates can be developed, in the case of the Army, before DSARC Milestone II, the point when these estimates are normally developed. How much earlier than this depends on a number of considerations. As noted in Section II, a data requirement of critical importance is the mission need statement, which initiates the program. No application of this analysis is possible without that document. However, since this is fundamentally a comparability analysis, the availability of data on the baseline system or systems is also essential. As shown in this historical reconstruction, lack of available data on the baseline system can sorely hamper the ability to construct an adequate estimate. The alternative is the more costly development of new data and the performance of new analyses.

Based on this experience, a preliminary list of minimum data requirements has been developed. For the new system to be developed the analyst needs:

- a description of the required performance characteristics, if possible, by subsystem;
- planned usage rates, preferably for both wartime and peacetime operating scenarios;
- the type and size of the organizational unit in which the system will be deployed;
- the planned size of the crew or intended number of operators per system, and
- the concept of operations and maintenance (wartime and peacetime separately, if they will be different).

In addition to these data on the new system, specific data are also required on the baseline system or systems, including:

- reliability and maintainability parameters and values for each baseline subsystem;
- system and subsystem (wartime and peacetime) usage rates;
- the quantity of manpower by occupational type and skill-level required by the system, within the organizational unit in which it is deployed;
- the (wartime and peacetime) concept of operations and maintenance; and
- any system peculiar maintenance characteristics of the fielded system.

While these are minimum data required to effectively estimate weapon system manpower requirements early-on, it is important to keep in mind that additional data is always desirable. Therefore, development of data bases such as those described in MIL-STD-1388-1A will almost certainly increase the effectiveness of the estimate development.

As noted in the discussion of the data availability, distinctions must be made between data currently generated by the Army in the Concept Exploration Phase, data developed in the M1 Concept Exploration Phase, and data now obtainable from the earlier period. The incompleteness of the historical file of M1 Concept Exploration Phase data severely influenced MCR's development of a "pure" pre-DSARC I estimate. However, documents available at that time would have allowed the development of such an estimate. Since that time, the Army has instituted the development of new data systems such as the AMIM and Sample Data Collection which will facilitate much more effective estimating for future systems. In addition, programs are underway to significantly improve the Army's early weapon system manpower requirements estimating. For these reasons we believe that early estimates can be developed using existing documentation.

However, the current ability to produce a comprehensive array of life cycle manpower estimates is somewhat impaired in the current documentation process. This is largely due to the lack of sufficiently detailed longitudinal data on subsystems to be able to effectively interpret the stage in the systems' life cycle represented by the data. Because the comparability analysis requires utilization of historical data on baseline systems, this strongly influences the development of life cycle estimates. Implementation of the MIL-STD-1388-1A requirements for development of system life cycle estimates will greatly enhance the Services' capability to produce similar manpower estimates.

Finally, concerning the question of the level of detail sufficient to generate a reasonable estimate, this demonstration has shown that major subsystem data are sufficient. While detailed data on components are useful for distinguishing similar subsystems from each other, alternative technical data sources were found to be sufficient. Also, in the very early stages of a system design, major subsystems are largely the only level of detail available, and these may frequently be tentative.

B. CONCLUSIONS

The following are MCR's conclusions associated with the development and demonstration of the Early-on Manpower Requirements Estimation Methodology (EMREM).

- Manpower estimates approximating ultimate staffing requirements can be developed in the Concept Exploration Phase for Army main battle tanks, given currently developed documents. However,
  - the confidence in the actual estimate largely depends on the reliability of the data sources used; and
  - peacetime and wartime manpower estimates will require more discretely developed and documented data on usage rates and AAPMH than are currently available.
- The EMREM approach developed in this study is consistent with the comparability analysis outlined in MIL-STD-1388-1A. The types of data required for EMREM are similar to those developed in the LSA except that:
  - EMREM requires generally less detailed data on subsystems; and
  - EMREM analysis is intended to be performed in a particular phase of the system acquisition, generally earlier than the LSA manpower requirements analysis is to be performed.

- MCR believes that it is desirable to perform this analysis as early as possible in the acquisition process, as the information produced can contribute to the development of a more supportable system. Particular analytical requirements of LSA can be effectively supported by the results of this analysis.

APPENDIX A

THE DEVELOPMENT OF U.S. MAIN BATTLE TANKS: 1958-1983

As part of the research required to develop the hardware characterization for the conceptual M1 MBT, MCR has documented the history of the recent development of the U.S. Main Battle Tanks. This is summarized below. Exhibit A-1 illustrates the evolution of U.S. Main Battle Tank development from 1958 to 1983.

In the late 1950s, it was determined that an upgraded version of the M48 series tanks was required. The new tank was to possess:

- an improved operational range and mobility,
- a minimum of refueling and servicing, and
- an improved main armament.

Modifications were made to three M48 tanks to incorporate a new powerpack and an M68 cannon. The redesigned M48s became the XM60, which was fielded by the U.S. Army in 1960.

In 1962, the M60 tank was replaced in production by the M60A1. The primary modifications included:

- a redesigned "needle-nose" turret,
- greater ballistic protection, and
- an increased ammunition payload.

Development of the M60A2 began in 1964. Major modifications were a new turret and the incorporation of the Shillelagh weapon system. Production began in late 1966. The majority of the output was unfit for use due to technical problems associated with the tanks. Retrofit and subsequent delivery of those tanks began in 1972. By 1981, all M60A2s had been withdrawn from service in Europe.

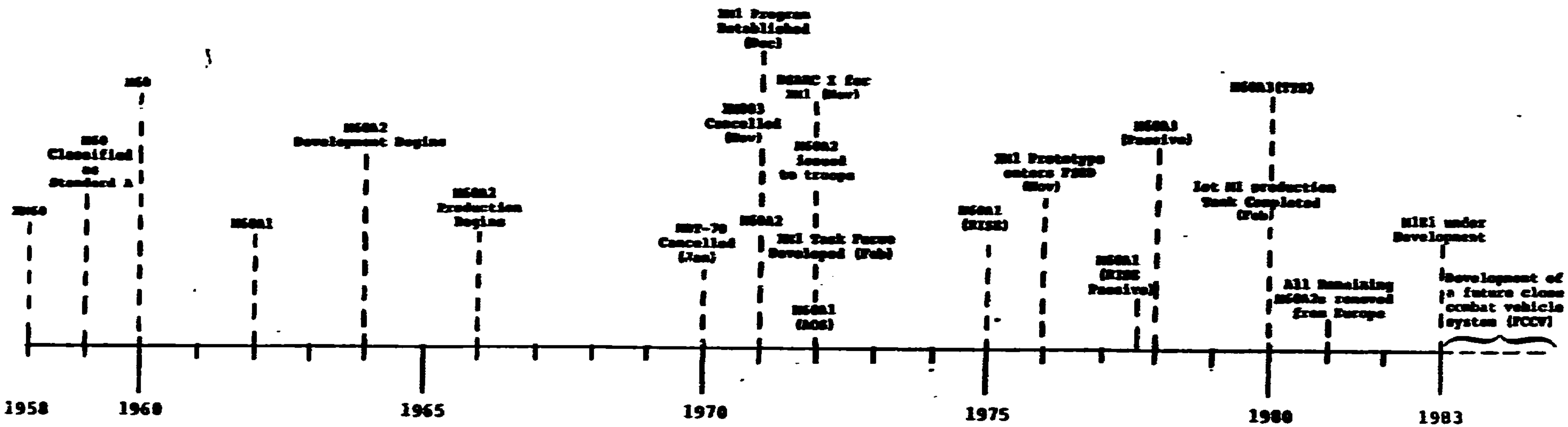

Exhibit A-1. THE EVOLUTION OF U.S. MAIN BATTLE TANKS: 1958-1983

In January 1970, the Anglo-German MBT-70 was cancelled. The two primary factors accounting for this were:

- cost considerations, and
- design complications.

The MBT 70 was designed to operate with a three-man crew. The redesigned turret accommodated an automatic loading device which eliminated the need for a loader, whose place was occupied by the driver. This was done for improved protection against nuclear, biological and chemical hazards. However, restructuring the controls of the power train assembly to accommodate the "new driver" created significant technical difficulties. This contributed significantly to cancellation of the MBT-70 program.

Following this cancellation, the U.S. Army sought development of a more austere tank. The resulting tank, which had significant similarities to the MBT-70, was the XM803. In November 1971, the XM803 project was cancelled by Congress due to excessive costs and unnecessary hardware complexity.

December 1971 brought about the establishment of the XM1 program. The DSARC I milestone for the M1 (XM1) Abrams tank system was achieved in November 1972. By November 1976, the M1 prototype had entered full-scale engineering development. The first production models were completed in February 1980.

Product improvements to the M60A1 tanks were initiated in the early 1970s. The addition of a top loading air cleaner, add-on stabilization and T142 track produced the M60A1(AOS). In 1975, a RISE (Reliability Improvement of Selected Equipment) engine and an improved electrical system were incorporated producing the M60A1(RISE) tank.

Modifications such as the

- commander's/gunner's passive sight,
- driver's viewer,
- smoke grenade launcher, and
- M240 coaxial machine gun

were subsequently added in producing the M60A1(RISE Passive).

In 1978, product improvements such as a laser range finder and solid state computer to the RISE Passive resulted in the M60A3(Passive). The addition of a thermal sight in 1979 resulted in the M60A3(TTS).

At the present time, pre-planned product improvements (P^3I) have been developed for the M1 Abrams. Beginning in 1985, the M1s will be fitted with a Rheinmetall 120mm XM256 gun, a smoothbore gun similar to that found on the West German Leopard II. Trials with this gun were begun on the first of six M1 prototypes in the first half of 1981. Upon acceptance, they will be standardized as the M1E1 Abrams.

APPENDIX B

HARDWARE CHARACTERIZATIONS OF U.S. MAIN BATTLE TANKS

Part 1: M60 Series and M1 Main Battle Tanks
(B-1 through B-47)

Part 2: MBT-70 and XM803 Main Battle Tanks
(B-48 through B-91)

Part 1: M60 Series and M1 Main Battle Tanks

Functional Subsystem: Hull Structure & Skirts

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) *(Qty > 1)	M1 (Qty > 1)
• homogeneous armor steel casting	• homogeneous armor steel casting			• rolled homogeneous steel armor (RHA)[1]
• driver's hatch	• driver's hatch	• driver's hatch	• driver's hatch	• driver's hatch
• headlights (2)	• headlights (2)	• headlights (2)	• headlights (2)	• head lights
• tow hooks (2)	• tow hooks (2)	• tow hooks (2)	• tow hook (2)	• tow hook
• tow pintle	• tow pintle	• tow pintle	• tow pintle (2)	• tow pintle
• tail lights (2)	• tail lights (2)	• tail lights (2)	• tail lights (2)	• tail lights
• transmission access grill doors	• transmission access grill doors	• transmission access grill doors	• transmission access grill doors	• transmission access grill doors
• engine access grill covers	• engine access grill covers	• engine access grill covers	• engine access grill covers	• engine access grill covers
			• low profile commander's cupola	
				• ballistic skirts (6 ea. side)
			* M60A3 w/M35E1 periscope	[1] layered w/plates of ceramic armor; similar to Chobham armor

Functional Subsystem: Hull
Appendages

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• fender stowage box	• fender stowage box	• fender stowage box	• fender stowage box	• fender stowage box
• headlight stowage bracket	• headlight stowage bracket	• headlight stowage bracket	• headlight stowage box	• headlight stowage box
• ammunition racks	• ammunition racks	• ammunition racks	• ammunition racks	• ammunition racks
• electrical components	• electrical components			
• cylinders & connecting lines	• cylinders & connecting lines			
			• driver's viewer stowage box	
			• gun travel lock	
		• periscope stowage basket	• periscope stowage basket	
				• engine compartment top deck

Functional Subsystem: Suspension
Spring & Damping System

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• Volute Double Bumper Spring	• bumper springs (2)			
• torsion bar (individual)	• torsion bar, suspended (individual live track)	• torsion bar (individual)	• torsion bar (individual)	• torsion bar (individual)[1/]
• shock absorber (2)	• hydraulic shock absorbers at 1st, 2nd, & 6th road wheel stations	• shock absorbers	• shock absorbers	• rotary hydraulic shock absorbers
			• tube over bar suspension at 1st, 2nd, & 6th road wheel stations	• hydromechanical suspension

[1/] (14) high-hardness steel (4350H) torsion bars

Functional Subsystem: Suspension
Roadwheels & Arms

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• roadwheels (12)	• roadwheels, dual aluminum alloy (12)	• roadwheels (12)	• roadwheels (12)	• roadwheels (14)
• support arm	• support arm	• support arm	• support arms	• road arm stations
• hub & arm assembly	• hub & arm assembly	• hub & arm assembly	• hub & arm assembly	• hub & arm assembly
• compensating idler wheels (2)	• compensating idler wheels (2)	• compensating idler wheels (2)	• compensating idler wheels (2)	• compensating idler wheel
• compensating idler support arm	• compensating idler support arm	• compensating idler wheel adjustment link	• compensating idler wheel adjustment link	• compensating idler wheel adjustment link
	• (6) dual rubber-tyred roadwheels w/the idler at the front			• jounce stops at wheel stations 1, 2, & 7

Functional Subsystem: Suspension
Sprocket Assembly

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• track drive sprocket	• track drive sprocket	• track drive sprocket	• track drive sprocket	• drive hub & dual sprockets
• drive sprocket	• drive sprocket	• drive sprocket	• drive sprocket	• sprocket assembly (2 per tank) – steel hub – sprockets
			• rubber tire sprocket	
• final drive sprocket	• final drive sprocket	• final drive sprocket	• final drive sprocket	• final drive sprocket

Functional Subsystem: Suspension
Support Rollers

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• track support rollers	• track support rollers	• track support rollers	• steel support rollers[1/]	• single wheel support rollers (2)
• track support axles	• track support axles			
	• track return rollers (3)			• retaining ring
• roller assembly	• roller assembly	• roller assembly		

[1/] replaced aluminum rollers

Functional Subsystems Suspension
Track

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• track T97E2	• track T97E2 28"	• track T142	• track T142 w/remove-able pads[1]	• track T142 – integral pad track w/2 rubber-bushed pins per shoe – 78 shoes per track
• hub assemblies	• hub assemblies			
• track adjusting link (L,R)[1]	• track adjusting link (L,R)	• track adjusting link (L,R)	• track adjusting link	
• individual rubber shod steel track links (81)	• individual rubber shod steel track links (81)			
• end connectors & center guides	• end connectors & center guides		• end connectors & center guides	• end connectors & center guides
			• track pins	• track pins
			• track pads	• track pads
• track shoe assembly	• track shoe assembly	• track shoe assembly	• track shoe assembly	• track shoes (78)
				• track adjusting link (L,R)
[1] (L,R) = Left & Right			[1] original track was T97	

Functional Subsystem Engine

Engine Components

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• continental AVDS-1790-2A or 2D (diesel)1/	• Continental AVDS-1790-2A or AVDS-1790-2D (diesel)	• AVDS-1790-2C, Rise engine (diesel)	• AVDS-1790-2C-Rise engine (diesel)	• AGT 1500 turbine - two spool gasifer/ free shaft power turbine w/recuperator
• engine air cleaners2/	• engine air cleaners2/	• engine air cleaners2/	• engine air cleaner2/	
• batteries (6,12-volt)	• batteries (6,12 volt)	• batteries (6,12 volt)	• batteries (6,12 volt)	• batteries (6,12 volt)
• Delco-Remy Model 110972 starter	• Delco-Remy Model 110972 starter	• starter	• starter	• starter motor
• Schwitzer Model D65 turbosupercharger	• Schwitzer Model D65 turbosupercharger	• turbosupercharged	• turbosupercharged	
• Jack & Heintz Model G22-6 generator 300 amp (air-cooled)	• Jack & Heintz Model G22-6 generator 300 amp (air-cooled)	• generator 650 amp	• generator 650 amp (air cooled)	
• bilge pump	• bilge pump	• bilge pump	• bilge pump	• bilge pump
• bilge pump assembly	• bilge pump assembly	• bilge pump assembly	• bilge pump assembly	• bilge pump assembly
		• alternator-650 amps, oil cooled	• alternator-650 amps, oil cooled	• alternator-650 amps
• voltage regulator 300 amp	• voltage regulator 300 amp	• voltage regulator 600 amp	• voltage regulator - solid state 650 amps	• voltage regulator-solid state
			• engine smoke generator	• engine smoke generator
			• solenoid relay	• solenoid valves
			• coupling assembly	
		• air cleaner restriction indicators	• air cleaner restriction indicators	
				• engine oil cleaners
				• speedometer sensor temp & level switches
1/no external differences exist between the 2 & 2A models 2/aluminum side loading & aluminum top loading & armored top loading	2/aluminum side loading & aluminum top loading & armored top loading	2/aluminum top loading & armored top loading	2/armored top loading	

<u>Functional Subsystem: Power Train Assembly</u>
<u>Transmission</u>

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• Allison model CD-850-6 cross-drive	• Allison model CD-850-6A cross-drive	• Allison model CD-850-6A cross-drive	• Allison model CD-850-6A cross-drive	• Detroit diesel X-1100-3B hydrokinetic
• transmission shroud		• transmission shroud		
	• Allison hydraulic torque converter			• torque converter TC-497
	• planetary gear trains			• planetary gear range package[1/]
	• hydraulically operated bands & clutches		• automatic transmission	• automatic transmission
				• automatic lockup clutch
				• primary transmission oil cooler
				• secondary transmission oil cooler
				• cooling fan - dual stage Vane Axial
				• fan clutch-electromagnetic

1/ includes:
multiple disc clutch packs (5)
planetary gear sets (3)

Functional Subsystem: Power Train Assembly
Final Drives

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• spur gear final drives	• spur gear final drives	• spur gear final drives	• improved final drives[1/]	• final drives - bolt flange for mounting to hull - paddle & cap - output shaft - disconnect input shaft - vent - oil fill system • coaxial planetary gear drive
• final drive assembly	• final drive assembly	• final drive assembly	• final drive assembly	
			[1/] includes additional support bearings stronger gears, improved shafts (from XM1)	

Functional Subsystem: Power Train Assembly
Steering Unit

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• mechanical/hydraulic steering control	• mechanical/hydraulic steering control	• hydraulic/mechanical steering control	• hydraulic/mechanical steering control	• hydraulic/mechanical steering control - hydrostatic & pivot
• multiple disk brakes				
• mechanically linked foot pedal brake	• mechanical brake foot pedal	• hydraulic mechanical foot pedal brake	• hydraulic mechanical foot pedal brake	
• differential	• differential	• steering differential	• differential	• steering differential
• brakes-mechanically connected to transmission	• brakes-hydraulically connected to transmission	• brake system-hydraulic	• brake system-hydraulic	• brake system-hydraulic/mechanical - oil cooled - multiple plate construction - hydraulic pistons 2 separate & independent systems - T bar control - variable displacement radial hydrostatic pump - radial fixed displacement hyurostatic motor - regenerative steer - cross-shaft
• brake system-hydraulic	• driver's steering unit - T bar pivot mounted • brake system-hydraulic			

Functional Subsystem: Power Train Assembly
Transfer Case

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)

No Information Available

Functional Subsystem: Power Package-Other
Cooling System

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• air cooling system	• air cooling system	• air cooling system	• air cooling system	• air cooling system

Functional Subsystem: Power Package-Other
Induction & Exhaust Systems

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• air cleaners (2)	• air cleaners	• air cleaners	• air cleaners	• air cleaner-high efficiency
• blower assembly	• blower assembly	• blower assembly	• blower motors	• mechanically driven scavenge blower
• accumulator assembly	• accumulator assembly	• accumulator assembly	• accumulator assembly	• accumulator
• Vehicle Engine Exhaust Smoke System	• Vehicle Engine Exhaust Smoke System	• Vehicle Engine Exhaust Smoke System	• Teledyne Engine Exhaust Smoke System	• engine smoke generator
				• interconnecting duct

Functional Subsystem: Power Package-Other
Fuel System

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• purge pump	• purge pump	• purge pump	• purge pump	• purge pump
• fuel tanks (385 gal. capacity)	• fuel tanks (375 gal. capacity)	• fuel tanks (385 gal. capacity)	• fuel tanks (385 gal. capacity)	• fuel tanks (498 gal. capacity)
• fuel pump	• Viking model FV492 fuel pump	• fuel pump	• fuel pump	• fuel pump
• American-Bosch PSB-12BT fuel injection pump	• American-Bosch PSB-12BT fuel injection pump			
		• bilge pump	• bilge pump	• fuel tanks-constructed of roto-cast high density crosslinked polyethylene

Functional Subsystem: Auxiliary Automotive
Hull Electric

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
No Information Available				• protection & control device • batteries & cabling • hydraulic power distribution system - pump - reservoir - filter manifold - (2) hydraulic valve manifold - auxiliary pump - hydraulic power components - heat exchanger - pressure return lines & fittings • NATO type slave electrical receptacle

Functional Subsystem: Auxiliary Automotive
Fire Extinguisher System

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• fire extinguishers (CO_2) – fixed (3) • fire extinguishers (CO_2) – portable	• fire extinguishers (CO_2) – fixed (3) • fire extinguishers (CO_2) – portable – engine compartment two 10 lbs CO_2 extinguishers – crew compartment two 5 lbs CO_2 extinguishers	• fire extinguishers (CO_2) (3) – fixed (3) • fire extinguishers (CO_2) – portable	• fire extinguishers (CO_2) (3) – automatic & manual – crew compartment 4 sensors & 1 bottle – engine compartment 3 sensors & 2 bottles – uses Halon • fire (CO_2) extinguishers – portable • fire (CO_2) extinguishers – portable	• fire extinguishers – automatic & manual – crew compartment 4 sensors & 1 bottle – engine compartment 3 sensors & 2 bottles – uses Halon • fire extinguishers – portable

Functional Subsystem: Auxiliary Automotive
Driver's Station

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• smoke generator • driver's control box C375/VRC	• smoke generator • driver's control box C2297/VRC	• smoke generator	• smoke generator	• smoke generator

Functional Subsystem: Auxiliary Automotive
Personnel Heating System

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• personnel heater	• personnel heater	• personnel heater	• personnel heater	• personnel heater (same as M60A3 heater)

Functional Subsystem: Turret Structure & Shield

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• homogenous armor steel casting	• homogeneous armor steel casting			• rolled homogeneous steel armor layered (RHA)1/
• cupola M19 – commanders cupola assembly – cupola electrical system – cupola sighting system – cupola armament system	• cupola M19 – commanders cupola assembly – cupola electrical system – cupola sighting system	• cupola M19	• cupola M19	• cupola M19 – commander's cupola assembly – turret electrical system 2/ – commander's sighting system
• inflatable hull-to-turret seal	• inflatable hull-to-turret seal	• inflatable hull-to-turret seal	• inflatable hull-to turret seal	• inflatable hull-to-turret seal
• turret platform	• turret platform	• turret platform	• turret platform	• turret platform
• turret seal pump	• turret seal pump	• turret seal pump	• turret seal pump	
			• muzzle position sensor	• muzzle reference system
				• loaders hatch (similar to M60A1)
				• turret exterior stowage racks
				• race ring
				• coaxial machine gun opening

1/w/plates of ceramic armor, similar to Chobham armor
2/centralized into the turret networks box (TNB) located @ loaders station

Functional Subsystem: Turret Structure & Shield (Cont'd.)

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• loader's assembly	• loader's assembly	• loader's assembly		
• Turret blower assembly	• turret blower assembly	• turret blower assembly	• turret blower assembly	

Functional Subsystem: Turret
Associated Turret Components

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• antennas (2)	• antennas (2)	• antennas	• antennas	• antennas
• searchlight AN/VSS-1 or	• searchlight AN/VSS-1 or			
• searchlight AN/VSS-3A	• searchlight AN/VSS-3A	• searchlight AN/VSS-3A	• searchlight AN/VSS-3A	
• oddment tray	• oddment tray	• oddment tray	• oddment tray	
• gunners control	• gunners control	• gunners control	• gunners control	
	•		• distribution box	
	• smoke grenade launcher M239	• smoke grenade launcher M239(2)1/	• smoke grenade launcher M239	• smoke grenade launcher M250

1/modification to MO6A1 system

Functional Subsystem: Turret Power Distribution

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• cupola electric power control	• cupola electric power control	• cupola electric power control	• cupola manually transversed	
• electrical-hydraulic controlled elevating & transversing system	• electrical-hydraulic controlled elevating & transversing system	• cupola elevating mechanism	• power transversing system	• electrohydraulic/manual turret power control
• manually operated hydraulic elevation system	• manually operated hydraulic elevation system			
• manually operated mechanics transversing system	• manually operated mechanics transversing system	• manually operated transverse control	• manually operated transverse control	
• superelevation actuator	• superelevation actuator			
• manual elevating accumulator	• manual elevating accumulator	• accumulator assembly	• accumulator assembly	
		• stabilization equipment	• Add On Stabilization(AOS)	
			• 10 HP turret motor	
	• 360 degrees electro-hydraulic or manual turret rotation			
		• elevating mechanism 1/		
• turret power distribution control box assembly	• turret power distribution control box assembly	• turret power distribution control box assembly	• turret power distribution control box assembly	• turret power distribution – pressure compensated pump – electrical auxiliary pump – line actuator – accumulator

1/ improved system from the M60A1

Functional Subsystem: Turret
Commander's Weapon Station

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• .50 machine gun M85	• .50 machine gun M85	• .50 machine gun M85	• .50 machine gun M85	• .50 machine gun
• gun mount M19				
• commander's platform	• commander's cupola M19	• commander's platform	• commander's platform	• commander's platform
• commander's gunners control C375/VRC			• compass/vehicle heading reference unit	
• commander's control handle	• commander's control handle	• commander's control handle	• commander's control handle	• commander's control handle
				• unity vision periscopes (6)
				• .50 cal. machine gun sight
				• commander's GPS extension
• commander's control assembly	• commander's control assembly	• commander's control assembly	• commander's control assembly	

Functional Subsystem: Turret
Weapon's Mounts

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• 105mm combination gun mount M116	• 105mm gun mount M140	• 105mm gun mount	• 105mm gun mount	• 105mm gun mount
- gun shield - cradle - breech operating cam - recoil mechanism	- gun shield - cradle - breech operating cam - concentric recoil mechanism			- operating crank handle - operating crank - breechblock crank - breech closing mechanism
- replenisher assembly	- replenisher assembly	- replenisher assembly	- replenisher assembly	- replenisher assembly
- 105mm gun tube	- 105mm gun tube	- 105mm gun tube	- 105mm gun tube	
- gunner's guard - loader's guard	- elevating mechanism - gunner's guard - loader's guard - gun tube	- gunner's guard - loader's guard	- gunner's guard - loader's guard	- gunner's guard - loader's guard
• bore evacuator	• bore evacuator	• bore evacuator	• bore evacuator	• bore evacuator
			• M119 weapons mount • M140 weapons mount	
	• gun mount recoil spring			• gun mount recoil spring
				• 7.62mm machine gun M240 mount

Functional Subsystem: Turret Ventilation System

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• gas particulate filter unit M13A1 • ventilating blower	• gas particulate filter unit 1/ • ventilating blower • centralized filter system	• gas particulate filter unit M13A1 • ventilating blower	• gas particulate filter unit M13A1 • ventilating blower	• gas particulate filter unit 1/ • ventilating blower 1500 cfm
	1/Five-man 20CFM M13A1/M13 or Three-man 12 CFM ADC-M80AZ-A3			1/includes: - M1A1 pre-cleaner - M19 particulate filter assembly - M18 gas filter cannisters

Functional Subsystem: Fire Control
Periscopes

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• periscope M31	• periscope M31			
• periscope mount M15	• periscope M15			
• periscope sight M28C (commander's)	• periscope sight M28C (commander's)	• periscope sight M28C (commander's)	• periscope sight M28C (commander's)	
• periscope M27 (3) (driver's)	• periscope M27 (3) (driver's)	• periscope M27 (3) (driver's)	• periscope M27 (3) (driver's)	• periscope M27 (3) (driver's)
• infrared periscope M24 (driver's)	• infrared periscope M24 (driver's)	• AN/VVS-2 (passive) (driver's)	• AN/VVS-2 (passive) (driver's)	
• binocular M17A1 (& IR)	• binocular M17A1 (& IR)	• binocular M17A1 (& IR)	• binocular M17A1 (& IR)	• binocular
• periscope M36 (commander's)	• periscope M36/M36E1 (commander's)	• periscope M36 (infrared) (commander's)	• periscope M36E1 (commander's)	• periscope M36E1 (commander's)
• periscope M32 (IR) (gunner's)	• periscope M32 (IR) (gunner's)	• periscope M32E1 (passive) (gunner's)	• periscope M35E1 (passive) (gunner's)	
• infinity sight 44C	• infinity sight 44C	• infinity sight 44C	• infinity sight M21	
• periscope mount 104A2	• periscope mount 104A2			
	• fuse setter M27			
• instrument light M30	• instrument light M30/M50	• instrument light M30/M50	• instrument light M30/M50	
	• loader's periscope M37	• loader's periscope M37	• loader's periscope M37	• loader's periscope M37
	• M24 periscope	• periscope M24 (infrared)		
	• AN/VSS-2 driver's sight		• driver's night vision viewer AN/VSS-2	• stabilized day/ thermal nightsight
	• periscope M35E1 gunner's/ TC night sight			

Functional Subsystem: Fire Control
Periscopes (Cont'd.)

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• AN/PAS-6 Metascope	• AN/VSS 3A Night Vision Equip. • AN/PAS-6 Metascope • M97C Articulated telescope	• AN/PAS-6 Metascope • Laser Tank Fire Control System 2/ 2/LTFCS is composed of two subsystems, laser/sight & computer. Laser/sight subsystem is composed of two main units: commander's integrated laser sight with control unit and a laser electronics unit. The computer sub-system includes the ammunition selector sensors.	• periscope mount M118E1 • periscope mount M119 • periscope mount M114 • image intensifier	• Night Vision is provided by a parallel-scan Thermal Imaging Subsystem which includes: - I.R. imager - scan & interlace - video mixer - h.S. mux - video control - bias regulator - pre/post amplifier (6) - control panel - CRT - indicator - electronics unit - scanner - power control unit - telescope - scan position sensor - detector/dewar - cooler

Functional Subsystem: Fire Control
FIR Channel

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)

No Information Available

Functional Subsystem: Fire Control
Range Finder

M60 (Qty > 11)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive (Qty > 1)	M1 (Qty > 1)
• optical range finder M17A1 • range finder blister • range finder M17C	• optical range finder M17A1/17C	• optical range finder M17A1 • range finder blister	• laser range finder AN/VVG-2 • ruby laser range finder • optical range finder	• Hughes laser range finder – Neodymium YAG coupled with a range receiver using a silicon avalanche diode detector

Functional Subsystem: Fire Control
TV Camera/Remote Display

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)

No Information Available

Functional Subsystem: Fire Control
Projectile Tracker

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)

No Information Available

Functional Subsystem: Fire Control
Controls & System Cables

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
			• elbow assembly • head assembly	

Functional Subsystem: Fire Control
Gun Turret Drive Electronics

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
				• gun elevation actuator assembly • gun gyro • turret elevation gyro • electronic units

Functional Subsystem: Fire Control Computer

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• ballistics computer M13A1D • ballistic drive M10A1	• ballistic computer M13A2 • ballistic drive M10A5	• ballistic computer M13A2 • ballistic drive M10A5	• ballistic computer XM-21 • ballistic drive M10A3 • continuous lead for XM-21 computer -	• digital computer (solid state) • balistic drive • continuous lead for computer

Functional Subsystem: Fire Control
Commanders Sight

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)

No Information Available

Functional Subsystem: Fire Control
Sensors

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty ≥ 1)	M1 (Qty > 1)
• elevation quadrant M13A1	• elevation quadrant M13A3	• elevation quadrant M13A3	• elevation quadrant M13A3	• elevation quadrant
• azimuth indicator M28A1	• azimuth indicator M28E2	• azimuth indicator M28E2	• azimuth indicator M28E2	• azimuth indicator
• gunner's quadrant M1A1	• gunner's quadrant M1A1			
			• communications security	
			• radiac alarm	• AN/VDR-1 Radiac Alarm
			• chemical alarm	• chemical alarm
			• muzzle position sensor	• muzzle reference sensor
			• wind sensor	• crosswind sensor (ionic drift)
				• cant sensor (pendulum static)

Functional Subsystem: Fire Control
Distribution Panel/Circuit Breakers

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)

No Information Available

Functional Subsystem: Fire Control
Gunner's Sights

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• telescope 105C or telescope 105D	• telescope 105D	• telescope 105D	• telescope 105D	• gunner's primary sight includes: – range finder – control panel – azimuth mirror drive assembly – gyro reticle – LOS cradle assembly – gunner's auxiliary sight (Kallmorgen, model 939)
• telescope mount M114	• telescope mount M114	• telescope mount M114	• telescope mount M114	
• gunner's control box assembly	• gunner's control box assembly	• gunner's control box assembly	• gunner's control box assembly	
• gunner's powerpack control assembly	• gunner's powerpack control assembly	• gunner's powerpack control assembly	• gunner's powerpack control assembly	

Functional Subsystem: Fire Control
Power Supplies

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)

No Information Available

Functional Subsystem: Fire Control
Gun Turret Group

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
No Information Available		• Add-On Stabilization • loader's Add On Stabilization shutoff (AOS) switch	• Add-On Stabilization	• Add-On Stabilization

Functional Subsystem: Armament
Primary Armament

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• 105mm cannon gun M68 - gun tube - evacuator chamber group - breach operating group	• 105mm cannon gun M68 - gun tube - evacuator chamber group - breach operating group - operating crank handle - breechblock crank w/breach block crank pivot - operating crank - breach closing mechanism - breech closing mech. detents	• 105mm gun M68 - breach block	• 105mm gun M68 - gun tube/gun tube coating - breech mechanism	• 105mm gun M68E1[1/]
		• M73 (T197E2) 7.62mm tank gun	• thermal shroud for 105mm M68 • fully stabilized in both elevation & transverse	

1/After 1985 will have the German Rheinmetall 120mm Smooth bore gun XM256. The first M1 of 6 prototypes w/120mm XM256 gun began trials in the first half of 1981 under the M1E1 designation. They will be standardized as the M1A1.

Functional Subsystems Armament
Secondary Armament

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• machine gun 7.62mm M73	• machine gun 7.62mm M73	• machine gun 7.62mm M73	• machine gun 7.62mm M73	• machine gun 7.62mm M73
• machine gun 12.7mm .50 caliber M85	• machine gun 12.7mm .50 caliber M85	• machine gun .50 caliber M85	• machine gun .50 caliber M85	• mach. gun .50 cal. 12.7mm Browning M8
• machine gun .50 caliber M2HB				
• machine gun M240	• 7.62mm machine gun M240[1]	• 7.62mm machine gun M240	• 7.62mm machine gun M240 (Belgian)	• 7.62mm machine gun M240 Belgian FN MAG
• submachine gun M3A1	• submachine gun M3A1	• submachine gun .45 cal. M3A1	• submachine gun 45 cal. M3A1	
• breech mechanism - breechring - breechblock - extractors - closing mechanism - breechblock crank - operating crank - operating shaft - operating handle - firing mechanism - breech closing mechanism detents	• breech mechanism - breechring - breechblock - extractors - closing mechanism - breechblock crank - operating crank - operating shaft - operating handle - firing mechanism - breech closing mechanism detents	• breech mechanism - breechring - breechblock - extractors - closing mechanism - breechblock crank - operating crank - operating shaft - operating handle - firing mechanism - breech closing mechanism detents	• breech mechanism - breechring - breechblock - extractors - closing mechanism - breechblock crank - operating crank - operating shaft - operating handle - firing mechanism - breech closing mechanism detents	
• reticle unit	• reticle unit	• reticle unit M21	• reticle unit M21	• reticle unit
			• M140 weapon's mount	

1/also known as the Belgian MAG 58

Functional Subsystem: Armament
Secondary (Cont'd.)

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
	• machine gun 7.62mm fixed • machine gun 7.62mm M219 • machine gun 7.62mm M73A1 • machine gun caliber .50 - vehicle heavy fixed	• machine gun 7.62mm M219	• machine gun 7.62mm M219	

Functional Subsystem: Communications Equipment
Communications Equipment Components

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• intercommunication sets	• intercommunication sets		• intercommunication set	• intercommunication set
– AN/VIC-1 (v)			– AN/VIC-1 (v)	– AN/VIC-1
– AN/VIC 4	– AN/UIC-2			
– C2296/VRC	– AN/UIC-2			
– C-2298/VRC				
• radio sets (found in various combinations)	• radio sets (found in various combinations)	• radio sets (found in various combinations)	• radio sets (found in various combinations)	• radio set (found in various combinations)
– AN/GRC 3,4,5,6,7,8			– AN/VRC 39	– AN/VRC 39
– AN/VRC 24 (ground-to-air)	– AN/VRC 24		– AN/VRC 24	– AN/VRC 24
– AN/VRC 44 }				
– AN/VRC 12	– AN/VRC 12	– AN/VRC 12	– AN/VRC 12	– AN/VRC 12
	– AN/VRC 25			
– AN/VRC 46	– AN/VRC 46	– AN/VRC 46	– AN/VRC 46	– AN/VRC 46
	– AN/VRC 47			
– AN/VRC 53	– AN/VRC 53	– AN/VRC 53	– AN/VRC 53	– AN/VRC 53
– AN/VRC 64	– AN/VRC 64	– AN/VRC 64	– AN/VRC 64	– AN/VRC 64
	• speech security equipment TSEC/KY-38			• speech security equipment TSEC/KY-57 (2)

Functional Subsystem: Special Equipment Kits

M60 (Qty > 1)	M60A1 (Qty > 1)	M60A1 (RISE) (Qty > 1)	M60A3 (Passive) (Qty > 1)	M1 (Qty > 1)
• searchlight kit xenon (2.2 kw)	• searchlight kit xenon (2.2 kw)	• searchlight kit (1 kw)	• searchlight kit (1 kw)	
• winterization kit				• winterization kit
• deep water fording kit	• deep water fording kit	• deep water fording kit	• deep water fording kit	• deep water fording
	• radiac kit			
• M9 bulldozer kit	• M9 bulldozer kit	• M9 bulldozer kit	• M9 bulldozer kit	
			• foliage brackets	
		• no-bak improvement & gear ratio kit		
• M13 CBR 1/	• M13A1 CBR 1/	• M13A1 CBR 1/		• CBR system 1/
				• NBC protection 2/
				• communications kit/system
1/Chemical-Biological-Radiological	1/Chemical-Biological-Radiological	1/Chemical-Biological Radiological		1/Chemical-Biological-Radiological 2/Nuclear-Biological-Chemical

Part 2: MBT-70 and XM803 Main Battle Tanks

Functional Subsystem: Hull
Structure & Skirts

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• driver's hatch	• driver's hatch
• headlights	• headlights (2)
• tow hooks	• tow hooks (2)
• tow pintle	• tow pintle/lugs (4)
• tail lights	• tail lights (2)
• transmission access grille covers	• transmission access grille covers
• engine access grille covers	• engine access grille covers
• ballistic skirts	• aluminum fenders
	• HP9-4-30 high performance armor steel & rolled homogeneous steel
	• armor plate

Functional Subsystem: Hull
Appendages

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• ammunition racks	• ammunition racks
• mounting devices	
• lifting eyes	
• bulkheads	• fender storage box
• brackets (headlight storage)	• brackets (headlight storage)

Functional Subsystem: Suspension
Spring & Damping System

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• suspension plumbing	• bumper springs
• hydraulic quick disconnect	• hydropneumatic suspension - hydropneumatic suspension unit - control manifold & disconnect assembly - disconnect assembly - quadrant pressure balancing valve - isolation reset valve assembly - suspension control console
• height control	• shock absorbers
• bumper springs	
• suspension units	

Functional Subsystem: Suspension
Roadwheels & Arms

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• road arm assembly	• roadwheels (12)
• road wheel hub assembly	• support arm
• idler arm assembly	• compensating idler wheels (12)
• road/idler wheel	• wheel assembly - forged aluminum wheel disc - solid rubber tire - steel wear ring
	• hub assembly - forged aluminum hub - tapered roller bearings (2) - face-typed seal

Functional Subsystem: Suspension
Sprocket Assembly

M803 (Qty > 1) (?)	MBT 70 (Qty > 1)
• sprocket hub	• sprocket hub
• drive sprocket	• drive sprocket

Functional Subsystem: Suspension

Support Rollers

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• support roller assembly	• track support rollers (3 dual wheel assemblies)

Functional Subsystem: Suspension
Track

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• track adjuster assembly	• track Diehl 170 - double pin, 25"
• track assembly	• track suspension
	• track shoe assembly (79 shoes)
	• track pins (steel alloy)
	• track adjuster

Functional Subsystem: Engine

Engine Components

XM803 (Qty > 1)

- engine - Continental AVCR 1100-3B diesel
- engine mounts
- generator
- turbo supercharged
- bilge pump

MBT 70 (Qty > 1)

- engine - Continental AVCR 1100-3A
- Air Research or Schweitzer Turbocharger
- supercharger
- Delco - Remy starter
- bilge pump
- batteries (8, 24 volt)
- alternator - Westinghouse rotating rectifier 700 amp
- regulator - solid state

Functional Subsystem: Power Train Assembly
Transmission

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• accessory drive	• Renk HSWL-354 Model A transmission
• XHM 1500-2B hydromechanical transmission	• planetary gear trains
• transmission mounts	

Functional Subsystem: Power Train Assembly
Final Drives

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• final drives	• planetary final drives

Functional Subsystem: Power Train Assembly
Steering Unit

XM803 (Qty > 1)	MBT 70 (Qty > 1)
No Information Available	• hydrostatic steering • differential • brake system - hydraulic brake operating system - hydrodynamic brake retarder - disc brakes (2)

Functional Subsystem: Power Train Assembly
Transfer Case

XM803 (Qty > 1)	MBT 70 (Qty > 1)

No Information Available

Functional Subsystem: Power Package-Other
Cooling System

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• air cooling system	• air cooling system
	• cooling fan - Continental CPR 105B

Functional Subsystem: Power Package - Other
Induction & Exhaust Systems

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• exhaust system	• air cleaners
• induction system	• induction system - includes all the components from the air inlet through the air cleaners - Air Research or Schweitzer turbocharger - supercharger - after coolers
	• accumulator
	• blower assembly

Functional Subsystem: Power Package - Other Fuel System

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• fuel system	• fuel injection
• bilge pump	• bilge pump
	• Viking-Booster fuel pump
	• vehicle fuel system
	• engine fuel system
	• fuel tank

Functional Subsystem: Auxiliary Automotive - Hull Electrical

XM803 (Qty > 1)	MBT 70 (Qty > 1)
No Information Available	• electrical starting device for the engine • alternator (28 volts DC, 700 amps) • battery installation (lead acid batteries, 24 volt DC 400 amps) • roadlighting & traffic signals • current distribution wiring, distribution boxes, circuit breakers, relays & fuses • electrical driving controls • instrumentation including remote control of automatic transmission

Functional Subsystem: Auxiliary Automotive
Fire Extinguisher System

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• fire extinguishers	• fire extinguishers - 4 fixed, contains freon agent • fire extinguishers - 1 portable, contains freon agent

Functional Subsystem: Auxiliary Automotive
Driver's Station

M802 (Qty > 1)	MBT 70 (Qty > 1)
• primary driving controls • emergency driving controls • driver's slip ring	• emergency driving controls - engine throttle - transmission steering & shift - brake controls • driver's vision components - vision blocks (3 fixed periscopes) - television (closed circuit, black & white) - night vision (passive direct view periscope)

Functional Subsystem: Auxiliary Automotive
Personnel Heating System

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• crew compartment heater	• electric resistance and combustion, multi-fuel heater

Functional Subsystem: Turret
Structure & Shield

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• scavenger system	• armor steel contruction
• electro-hydraulic slip ring	
• turret platform	• turret platform

Functional Subsystem: Turret
Associated Turret Components

XM803 (Qty > 1)	MBT 70 (Qty > 1)
No Information Available	• antennas

Functional Subsystem: Turret
Power Distribution

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• harness & cable	• power distribution panel
• junction box	• 400 HZ power supply
• transverse gear box	
• transverse motor valve	

Functional Subsystem: Turret
Commander's Weapon Station

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• commander's weapons control	No Information Available

Functional Subsystem: Turret
WEAPONS MOUNTS

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• primary weapon's mount • coaxial weapon's mount • gun shield • recoil mechanism	No Information Available

Functional Subsystem: Turret Ventilation System

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• blower assembly	• environmental control system (ECS) for heating, cooling & filtering • gas particulate filter unit - ventilation/dust separator unit - filter unit

Functional Subsystem: Fire Control
Periscopes

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• primary sight	• driver's periscopes (3)
• GPS periscope	• gunner's periscope
• image intensifier assembly	• commander's periscopes (6)
• GPS telescope	• zoom telescope
• driver's night vision device	
• gunner's auxiliary telescope	
• sight covers	

Functional Subsystem: Fire Control
FIR Channel

M803 (Qty > 1)	MBT 70 (Qty > 1)

No Information Available

Functional Subsystem: Fire Control
Range Finder

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• laser illuminator range finder	• laser range finder
	• laser electronics

Functional Subsystem: Fire Control
TV Camera/Remote Display

XM803 (Qty > 1)	MBT 70 (Qty > 1)
No Information Available	• driver's television system

Functional Subsystem: Fire Control
Projectile Tracker

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• missile tracker	• missile transmitter drive
	• missile transmitter drive electronics

Functional Subsystem: Fire Control
Controls & System Cables

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• F/C interconnect cables	• cable assembly set

Functional Subsystem: Fire Control
Gun Turret Drive Electronics

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• autoloader	• autoloader, Rheinmetall, electrohydraulic chain drive - remotely operated
• breech electrical unit	
• range electronics unit	
• gun turret drive system	
• gun trunnion synchronization	• gun trunnion synchronization
• hydraulic power supply	
• elevation servo	
• gyros & accelerometer	• turret gyro
• manual transverse	• elevation or roll rate gyro
• housing elevation drive & feed	• azimuth rate gyro
	• azimuth angular accelerometer
	• elevation angular accelerometer
	• turret azimuth resolver
	• gun turret drive electronics includes: - azimuth - elevation stabilization amplifier - elevation ballistic correction servo - gun indexing & rear deck clearance circuitry

Functional Subsystem: Fire Control Computer

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• ballistic computer	• ballistic computer (digital)
• continous logic electrical unit	
• C&D logic & IPPD system	

Functional Subsystem: Fire Control
Commander's Sight

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• commander's sight	• Panoramic sight (stabilized, head-day periscope sight)
• commander's sight azimuth	• night sight (passive direct view periscope)
• commander's sight telescope	• vision blocks (6 fixed periscopes)
• commander's sight elevation apparatus	
• commander's sight power support	
• commander's sight stabilization & optics	
• commander's sight alignment control	
• commander's sight control unit	

Functional Subsystem: Fire Control

Sensors

XM803 (Qty > 1)

- cant sensor
- wind sensor
- elevation actuator
- elevation quadrant
- azimuth assembly

MBT 70 (Qty > 1)

- air data sensor
- vehicle velocity sensor
- powder temperature sensor
- vertical sensor
- gun bend sensor
- azimuth indicator
  - coarse scale
  - fine scale
  - light scale

Functional Subsystem: Fire Control
Distribution Panel/Circuit Breakers

XM803 (Qty > 1)	MBT 70 (Qty > 1)

No Information Available

Functional Subsystem: Fire Control
Gunner's Sights

XM803 (Qty > 1)

- gunner's weapons control
- GPS[1/] control unit
- GPS electronics

1/Gunner's Primary Sight

MBT 70 (Qty > 1)

- gunners weapons control
- gunner's auxiliary control
- GPS[1/] electronics
- gunner's range control
- gunner's primary sight & sight cover
  - cover assembly
  - door assembly
  - worm gear assembly
  - handle assembly

1/Gunner's Primary Sight

Functional Subsystem: Fire Control
Power Supplies

XM803 (Qty > 1)	MBT 70 (Qty > 1)

No Information Available

Functional Subsystem: Fire Control
Gun Turret Group

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• gun turret drive system	• gun turret drive group includes: - turret bearing assembly - elevation actuator assembly - traverse gear box assembly - traverse motor valve assembly - turret lock assembly

Functional Subsystem: Armament
Primary Armament

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• XM150 gun-launcher	• XM150 gun-launcher
• Shillelagh missile system	• missile system

Functional Subsystem: Armament
Secondary Armament

XM803 (Qty > 1)

- machine gun 50 caliber
- M73 7.62mm machine gun
- grenade launcher

MBT 70 (Qty > 1)

- MK 20-Rh 202-8 20mm gun
- M73 7.62mm machine gun
- grenade launcher
- .45 caliber sub-machine gun M13A1 (3)

Functional Subsystem: Communications Equipment
Communications Equipment Components

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• intercommunications equipment • communications equipment	• intercommunications equipment AN/VIC-1 (v) - AM/1780/VRC audio frequency amplifier - C-2298/VRC intercommunications set (2) - C-2297/VRC intercommunications set • AN/VRC-12 radio receiver/transmitter

Functional Subsystem: Special Equipment
Kits

XM803 (Qty > 1)	MBT 70 (Qty > 1)
• bulldozer kit	• bulldozer kit
• chemical-biological warning unit	
• searchlight kit	• searchlight system XSW-30-U(P)1/
• navigation aid unit	• navigation kit
• radiological warning unit	
• bulldozer mounting kit	
• chemical-biological mounting kit	• chemical detection & warning kit
• searchlight mountng kit	
• navigational aid mounting kit	
• radiological warning unit mounting kit	• radiological detection & warning kit
• submergence kit	
• winterization kit	• winterization kit

1/ includes:
- searchlight w/mounting equipment
- regulator
- remote control
- cabling

APPENDIX C

EMREM PROGRAM DOCUMENTATION

This appendix documents the computer program used to calculate the weapon system manpower estimates developed in the second part of EMREM (see Exhibit II-2). The program is written in Apple-soft BASIC and has been run on the Apple II microcomputer.

The program consists of a short main program and four subroutines. The main program is primarily responsible for reading the input data. Four separate data sets were used in this analysis. The first three were used in determining the requirements for each maintenance echelon considered (i.e., ORG, DS and GS). The fourth was used to calculate total below depot level requirements. For the latter calculation, the program also reads data on manpower requirements that serve as a benchmark against which the EMREM estimates are compared. In this demonstration of EMREM, these benchmark data were taken from the FY82 AMIM for the M1.

The first subroutine is an interactive data input section. The user is prompted to supply the crucial parameters pertaining to the new weapon system and the organizational unit into which this system is to be deployed. Specifically, the user is first asked to enter the lower and upper bounds for the new weapon system usage rate. For the M1 tank application, the unit of measure for the usage rate is miles per year. The user is then prompted to supply the lower and upper bounds for the annual available productive manhour (AAPMH) factor. This factor, which varies by maintenance echelon, allows the conversion of annual maintenance manhour data to numbers of personnel. The final prompt in this subroutine asks the user to supply the number of weapon systems anticipated to be deployed into the organizational unit.

The second subroutine calculates the number of persons from each MOS group required to meet the scheduled and unscheduled maintenance requirements at each echelon below the depot level, as well as the total below depot level requirement. That calculation explicitly accounts for the number of weapon systems in the organizational unit.

There are a number of assumptions incorporated in the calculations that deserve elaboration. The most salient of them is that manpower requirements are directly proportional to the usage rate; i.e., doubling the usage rate doubles the associated maintenance manhour requirements. This seems a reasonable assumption when applied to small (relative) fluctuations in the usage rate. It is, however, a concession to data availability. Another assumption concerns the rounding of non-integer personnel figures into more meaningful integer values. That is, after dividing the required AMMH (for a given MOS) by the AAPMH factor, the result is an integer plus some fraction. We impose a couple of rules that apply in the conversion of this figure into an integer. The first of these assumptions can be interpreted in the following way. Let N be the number of weapon systems in the organizational unit. Then, if the rounding to the greatest integer less than or equal to (N*AMMH)/AAPMH implies that the each of the associated personnel must absorb an additional ten percent or more work load (due to rounding), then the figure may be evaluated for potential rounding upward to the next higher integer. This leads to the second rule imposed on rounding. The program does not allow the upward rounding if the result is that each of the associated personnel is contributing less than 90 percent of the lower AAPMH factor input. The product of the second subroutine is the number of below-depot-level maintenance and support personnel required for each MOS group. This estimate is determined for each of the four scenarios that reflect the pairwise combinations of the two extreme usage rates and AAPMH factors.

The third subroutine compares the EMREM below depot level estimates to the most recent observations on the weapon system to which EMREM is being applied. This subroutine determines where the benchmark (realized) manpower requirements lie with respect to the EMREM estimate interval. This subroutine allows expedient isolation of those MOSs (and, hence, subsystems) for which EMREM is proving to be less accurate. This will allow us to critically evaluate our choice of input data.

The fourth subroutine is essentially a report writer.

The baseline program may be modified or augmented so as to most fully exploit the data available for EMREM applications to other weapon systems.

```
REM   ********    EMREM PROGRAM    ********
PRINT  CHR$ (4)"BRUN AMPER INTERPRETER"
TEXT : HOME
REM   INITIALIZATION STATEMENTS
A = 0:B = 0:C = 0:D = 0:E = 0:F = 0:G = 0:H = 0:I = 0:J = 0:K = 0:L = 0
  :M = 0:N = 0
P = 0:Q = 0:R = 0:S = 0:T = 0:U = 0:V = 0:W = 0:X = 0:Y = 0:Z = 0
HOME : SPEED= 160: FOR I = 1 TO 10: PRINT : NEXT : PRINT "
  **** EMREM ****        ": HOME : PRINT "          ": SPEED= 255
REM    DIMENSION STATEMENTS
REM
 DIM C1$(30),C2(30),A1(30),A2(30),A3(30),A4(30),LL$(30),CV(30)
 DIM H1(30),H2(30),P1(10,30),P2(10,30)
 DIM MS$(30),MI(30),MH(30),B$(30),S$(30)
BELL$ = ""
 REM    READ STATEMENTS
 REM
 READ SY$,U$,NO
 FOR I = 1 TO NO: READ MS$(I),MI(I),MH(I),B$(I),S$(I): NEXT
 READ CS$,MLS,N1
 FOR J = 1 TO N1: READ C1$(J),C2(J): NEXT
 REM
 REM    ****** ESTIMATE INPUT DATA ******
 DATA  M1 TANK,MILES/YR,7
 DATA  31,1000,252.1,M60A3,FY82 AMIM
 DATA  41,1000,230,MBT-70,P/CR
 DATA  44,1000,24,M60A3,FY82 AMIM
 DATA  45,1000,767.4,M60A1,AR 570-2
 DATA  54,1000,50,M60A1,AR 570-2
 DATA  63,1000,1980,MBT-70,P/CR
 DATA  76,1000,4.6,M60A3,AR 570-2
 REM    **********************************
 REM
 REM    ******** COMPARISON DATA ********
 DATA  FY82 AMIM (M1),1000,5
 DATA  31,305.16
 DATA  41,84.0
 DATA  44,24.0
 DATA  45,890.0
 DATA  63,1243.3
 REM    **********************************
 REM
 REM
 REM
 REM      ==============================
  REM   PROMPT USER FOR SCENARIO INPUT
  REM     ==============================
  GOSUB 1000
  REM
  REM     ===============================
  REM   CALCULATE MANPOWER REQUIREMENTS
  REM     ===============================
  GOSUB 2000
  REM
  REM     ==============================
  REM   COMPARE ESTIMATES WITH ACTUALS
  REM     ==============================
  GOSUB 3000
  REM
  REM     ======================
  REM   GENERATE OUTPUT REPORT
  REM     ======================
  GOSUB 4000
```

```
REM      <<<<<< PARAMETER INPUT SUBROUTINE >>>>>>
ER$ = "ERROR -- LOWER WAS => UPPER!"
PRINT BELL$: HOME : FOR I = 1 TO 8: PRINT : NEXT I
PRINT "   ";: INVERSE : PRINT "       RECORD KEEPING INFORMATION
": PRINT : PRINT
NORMAL : PRINT "   ";: INVERSE : PRINT "TODAY'S DATE (MO/DA/YR)";: INPUT
D$
PRINT : NORMAL : PRINT "   ";: INVERSE : PRINT "PURPOSE:"
NORMAL : PRINT "    1   ORG ECHELON RUN": PRINT "    2   DS ECHELON
RUN": PRINT "    3   GS ECHELON RUN": PRINT : PRINT "   ";
INVERSE : PRINT "YOUR CHOICE?";: GET H: IF H < 1 OR H > 3 THEN  HOME
: FOR I = 1 TO 10: PRINT : NEXT : GOTO 1005
IF H = 1 THEN PP$ = "ORG ECHELON RUN"
IF H = 2 THEN PP$ = "DS ECHELON RUN"
IF H = 3 THEN PP$ = "GS ECHELON RUN"
FOR I = 1 TO 3: PRINT BELL$
HOME : PRINT : PRINT : INVERSE : PRINT SY$"-RELATED PARAMETER INPUT
SECTION": NORMAL
PRINT BELL$
PRINT : PRINT : SPEED= 180: PRINT "ENTER UPPER AND LOWER BOUNDS FOR
": PRINT SY$" USAGE RATE. "
PRINT : PRINT "LOWER BOUND = ";: INPUT M1: PRINT "UPPER BOUND = ";:
INPUT M2: PRINT : PRINT
IF M2 > M1 GOTO 1060
SPEED= 255: FOR I = 1 TO 2: PRINT BELL$: NEXT : SPEED= 25: PRINT : PRINT
ER$"     ": HOME : GOTO 1020
PRINT  SPC( 5)"*******************************" SPC( 5)
PRINT BELL$
PRINT : PRINT : SPEED= 180: PRINT "ENTER UPPER AND LOWER BOUNDS FOR
": PRINT "AAPMH FACTOR. "
PRINT : PRINT "LOWER BOUND = ";: INPUT F(1): PRINT "UPPER BOUND = "
;: INPUT F(2): PRINT : PRINT
IF F(2) > F(1) GOTO 1110
SPEED= 255: FOR I = 1 TO 2: PRINT BELL$: NEXT : SPEED= 25: PRINT : PRINT
ER$"     ": HOME : GOTO 1070
REM
PRINT BELL$
HOME : PRINT : PRINT : PRINT : PRINT : PRINT : PRINT "ENTER ANTICIP
ATED NO. OF "SY$"S": PRINT "PER ORGANIZATIONAL UNIT.";: INPUT N
FOR I = 1 TO 3: PRINT BELL$: NEXT
SPEED= 100: HOME : FOR I = 1 TO 10: PRINT : NEXT : INVERSE : PRINT
" --- NOW CALCULATING REQUIREMENTS. --- ": NORMAL : SPEED= 255
RETURN
```

```
 REM     <<<<<< CALCULATION SUBROUTINE >>>>>>
 REM   CALCULATE TOTAL MANHOUR REQUIREMENTS FOR ORG UNIT
 FOR J = 1 TO NO
H1(J) = N * (M1 / MI(J)) * MH(J)
H2(J) = N * (M2 / MI(J)) * MH(J)
 NEXT
 REM   CHECK FOR EXCESSIVE WORKLOAD DUE TO DOWNWARD ROUNDING
 FOR I = 1 TO 2: FOR K = 1 TO NO
 IF (H1(K) / F(I) -  INT (H1(K) / F(I))) / ( INT (H1(K) / F(I)) + .0
001) > .1 GOTO 2080
P1(I,K) =  INT (H1(K) / F(I)): GOTO 2090
P1(I,K) =  INT (H1(K) / F(I)) + 1
 IF (H2(K) / F(I) -  INT (H2(K) / F(I))) / ( INT (H2(K) / F(I)) + .0
001) > .1 GOTO 2110
P2(I,K) =  INT (H2(K) / F(I)): GOTO 2120
P2(I,K) =  INT (H2(K) / F(I)) + 1
 NEXT K: NEXT I
 REM   CHECK FOR DIMINUTIVE WORKLOAD
 FOR I = 1 TO 2: FOR K = 1 TO NO
 IF H1(K) / (P1(I,K) + .00001) < .1 * F(I) THEN P1(I,K) = P1(I,K) -
1
 IF H2(K) / (P2(I,K) + .00001) < .1 * F(I) THEN P2(I,K) = P2(I,K) -
1
 IF P1(I,K) < 0 THEN P1(I,K) = 0
 IF P2(I,K) < 0 THEN P2(I,K) = 0
 NEXT K: NEXT I
 RETURN
```

```
 REM      <<<<<< COMPARISON SUBROUTINE >>>>>>
 REM   DETERMINE WHETHER ESTIMATE INTERVALS CONTAIN BENCHMARK DATA
 FOR I = 1 TO N1:X = 0
X = X + 1
 IF X =  > NO + 1 THEN LL$(I) = "EMREM DID NOT ANTICIPATE THIS MOS G
ROUP.":CV(I) = 3: GOTO 3400
 IF C1$(I) = MS$(X) THEN  GOTO 3380
 GOTO 3330
 REM   THERE IS A MATCH BETWEEN COMPARISON AND EMREM MOS CODE
 IF C2(I) =  > (H1(X) / N) AND C2(I) =  < (H2(X) / N) THEN LL$(I) =
"YES": GOTO 3400
LL$(I) = "NO": IF C2(I) < H1(X) / N THEN CV(I) = 1: GOTO 3400
CV(I) = 2
 NEXT I
 RETURN
```

```
 REM     <<<<<< REPORT WRITING SUBROUTINE >>>>>>
 PR# 1
 PRINT  CHR$ (9)"80N": PRINT  CHR$ (27)"E"
Y1$ = "(EMREM LOWER BOUND TOO HIGH.)":Y2$ = "(EMREM UPPER BOUND TOO
LOW.)"
NC$ = "  NOTE: #PERS. INVARIANT TO USAGE RATE, AAPMH FACTOR RANGE LI
MITS AFTER ROUNDING.":FT$ = "  (SEE NOTE.)
S1$ = "NOTE: EMREM PREDICTED ":S2$ = " RELEVANT MOS GROUPS THAN "
F1$ = "FRMT,$3;":F2$ = "FRMT,X10,S,2,0;":F3$ = "FRMT,X10,S,2,0;":F4$
 = "FRMT,$15;"
F5$ = "FRMT,X7,S,0,0;": PRINT  CHR$ (12)
 PRINT : PRINT : PRINT  SPC( 6)"*************************************
***************************"
 PRINT  SPC( 6)"* EMREM MAINTENANCE & SUPPORT MANHOUR REQUIREMENTS E
STIMATES *"
 PRINT  SPC( 6)"************************************************
**********"
 PRINT  CHR$ (27)"E"
 PRINT : PRINT : PRINT : PRINT  SPC( 28)SY$" APPLICATION": PRINT : PRINT
: PRINT
 PRINT  SPC( 28)"AMMH"
 PRINT  SPC( 16)"MOS" SPC( 5)"LOW" SPC( 5)"HIGH" SPC( 6)"BASELINE SY
S."
 FOR K = 1 TO NO
 PRINT  SPC( 16): & PRNT,MS$(K),F1$: & PRNT,H1(K),F2$: & PRNT,H2(K),
F3$: & PRNT,B$(K),F4$: PRINT  SPC( 3): PRINT
 NEXT K
 FOR I = 1 TO 8: PRINT : NEXT
 PRINT  SPC( 35)"SCENARIO": PRINT  SPC( 16)"ESTIMATE" SPC( 6)"AAPMH"
 SPC( 4)"USAGE RATE ("U$")"
 PRINT  SPC( 18)"LOW" SPC( 10)F(2) SPC( 8)M1
 PRINT  SPC( 17)"HIGH" SPC( 10)F(1) SPC( 8)M2
 PRINT : PRINT : PRINT  SPC( 16)"ORG. UNIT SIZE = "N" "SY$"'S."
 FOR I = 1 TO 14: PRINT : NEXT : PRINT  SPC( 45)"DATE: "D$
 PRINT  SPC( 45)"PURPOSE: "PP$
 REM
 PR# 1: PRINT  CHR$ (9)"80N": PRINT  CHR$ (12)
 PRINT : PRINT
 PRINT  SPC( 4)"**************************************************
************"
```

```
 PRINT  SPC( 4)"*****************************************************
************"
 PRINT  SPC( 4)"* EMREM MAINTENANCE & SUPPORT PERSONNEL REQUIREMENTS
 ESTIMATES *"
 PRINT  SPC( 4)"*****************************************************
************"
 PRINT : PRINT : PRINT  SPC( 30)SY$" APPLICATION": PRINT : PRINT : PRINT

 PRINT  SPC( 18)"MOS" SPC( 4)"LOW" SPC( 3)"HIGH" SPC( 6)"BASELINE"
 FOR I = 1 TO NO
 PRINT  SPC( 18): & PRNT,MS$(I),F1$: & PRNT,P1(2,I),F5$: & PRNT,P2(1
,I),F5$: & PRNT,B$(I),F4$: PRINT  SPC( 3): PRINT
 NEXT I
 FOR I = 1 TO 8: PRINT : NEXT
 PRINT  SPC( 35)"SCENARIO": PRINT  SPC( 16)"ESTIMATE" SPC( 6)"AAPMH"
 SPC( 4)"USAGE RATE ("U$")"
 PRINT  SPC( 18)"LOW" SPC( 10)F(2) SPC( 8)M1
 PRINT  SPC( 17)"HIGH" SPC( 10)F(1) SPC( 8)M2
 PRINT : PRINT : PRINT  SPC( 16)"ORG. UNIT SIZE = "N" "SY$"'S."
 FOR I = 1 TO 14: PRINT : NEXT : PRINT  SPC( 45)"DATE: "D$
 PRINT  SPC( 45)"PURPOSE: "PP$
 PRINT
 SPEED= 100: PRINT : PRINT : PRINT : PRINT "IF YOU WOULD LIKE TO HAV
E A COMPARISON REPORT, ENTER 1.": SPEED= 255
 GET U: IF U = 1 THEN  GOTO 4400
 GOTO 4990
 REM   COMPARISON REPORT PRINT STATEMENTS (OPTIONAL)
 PR# 1: PRINT  CHR$ (12): PR# 1
 PRINT  CHR$ (9)"80N"
 PRINT  SPC( 22)"*** COMPARISON SUMMARY ***"
 PRINT : PRINT : PRINT  SPC( 26)SY$" APPLICATION": PRINT  SPC( 26)"B
ENCHMARK DATA SOURCE: "CS$
 PRINT : PRINT : PRINT
 IF NO > N1 THEN  PRINT S1$"MORE"S2$;: PRINT CS$"."
 IF NO < N1 THEN  PRINT S1$"FEWER"S2$;: PRINT CS$"."
 PRINT : PRINT
 PRINT "  MOS GROUP" SPC( 12)CS$" VALUE IN EMREM INTERVAL?"
 PRINT
 FOR J = 1 TO N1
 PRINT  SPC( 6)C1$(J) SPC( 24)LL$(J);
 IF CV(J) = 1 THEN  PRINT "  "Y1$
 IF CV(J) = 2 THEN  PRINT "  "Y2$
 IF CV(J) <  =  > 1 AND CV(J) <  =  > 2 THEN  PRINT " ": PRINT
 NEXT J
 PRINT  CHR$ (12)
 RETURN
```

```
REM    ****** ESTIMATE INPUT DATA ******
DATA   M1 TANK,MILES/YR,7
DATA   31,1000,131.8,M60A3,FY82 AMIM
DATA   41,1000,.001,MBT-70,P/CR
DATA   44,1000,.001,M60A3,FY82 AMIM
DATA   45,1000,275.92,M60A1,AR 570-2
DATA   54,1000,25,M60A1,AR 570-2
DATA   63,1000,879.99,MBT-70,P/CR
DATA   76,1000,4.6,M60A3,FY82 AMIM
REM    *********************************
```

```
REM    ****** ESTIMATE INPUT DATA ******
DATA   M1 TANK,MILES/YR,7
DATA   31,1000,78.3,M60A3,FY82 AMIM
DATA   41,1000,134.5,MBT-70,P/CR
DATA   44,1000,15,M60A3,FY82 AMIM
DATA   45,1000,293.16,M60A1,AR 570-2
DATA   54,1000,8,M60A1,AR 570-2
DATA   63,1000,721.18,MBT-70,P/CR
DATA   76,1000,.001,M60A3,FY82 AMIM
REM    *********************************
```

```
REM    ****** ESTIMATE INPUT DATA ******
DATA   M1 TANK,MILES/YR,7
DATA   31,1000,42,M60A3,FY82 AMIM
DATA   41,1000,95.5,MBT-70,P/CR
DATA   44,1000,9,M60A3,FY82 AMIM
DATA   45,1000,198.32,M60A1,AR 570-2
DATA   54,1000,17,M60A1,AR 570-2
DATA   63,1000,378.83,MBT-70,P/CR
DATA   76,1000,.001,M60A3,FY82 AMIM
REM    *********************************
```

**** EMREM ****

RECORD KEEPING INFORMATION

TODAY'S DATE (MO/DA/YR)?11/30/83

PURPOSE:
1 ORG ECHELON RUN
2 DS ECHELON RUN
3 GS ECHELON RUN

YOUR CHOICE?

M1 TANK-RELATED PARAMETER INPUT SECTION

ENTER UPPER AND LOWER BOUNDS FOR
M1 TANK USAGE RATE.

LOWER BOUND = ?800
UPPER BOUND = ?1200

****

ENTER UPPER AND LOWER BOUNDS FOR
AAPMH FACTOR.

LOWER BOUND = ?2250
UPPER BOUND = ?2750

ENTER ANTICIPATED NO. OF M1 TANKS
PER ORGANIZATIONAL UNIT.?58

```
*****************************************************************
* EMREM MAINTENANCE & SUPPORT MANHOUR REQUIREMENTS ESTIMATES *
*****************************************************************
```

M1 TANK APPLICATION

	AMMH		
MOS	LOW	HIGH	BASELINE SYS.
31	6115.52	9173.28	M60A3
41	.0	.0	MBT-70
44	.0	.0	M60A3
45	12802.69	19204.03	M60A1
54	1160.00	1740.00	M60A1
63	40831.54	61247.30	MBT-70
76	213.44	320.16	M60A3

	SCENARIO	
ESTIMATE	AAPMH	USAGE RATE (MILES/YR)
LOW	2750	800
HIGH	2250	1200

ORG. UNIT SIZE = 58 M1 TANK'S.

DATE: 12/01/83
PURPOSE: ORG ECHELON RUN

```
*****************************************************************
* EMREM MAINTENANCE & SUPPORT PERSONNEL REQUIREMENTS ESTIMATES *
*****************************************************************
```

M1 TANK APPLICATION

MOS	LOW	HIGH	BASELINE
31	3	4	M60A3
41	0	0	MBT-70
44	0	0	M60A3
45	5	8	M60A1
54	1	1	M60A1
63	14	27	MBT-70
76	0	1	M60A3

	SCENARIO	
ESTIMATE	AAPMH	USAGE RATE (MILES/YR)
LOW	2750	800
HIGH	2250	1200

ORG. UNIT SIZE = 58 M1 TANK'S.

DATE: 12/01/83
PURPOSE: ORG ECHELON RUN

IF YOU WOULD LIKE TO HAVE A COMPARISON REPORT, ENTER 1.

```
*****************************************************************
* EMREM MAINTENANCE & SUPPORT MANHOUR REQUIREMENTS ESTIMATES *
*****************************************************************
```

M1 TANK APPLICATION

MOS	AMMH LOW	AMMH HIGH	BASELINE SYS.
31	3633.12	5449.68	M60A3
41	6240.80	9361.20	MBT-70
44	696.00	1044.00	M60A3
45	13602.62	20403.94	M60A1
54	371.20	556.80	M60A1
63	33462.75	50194.13	MBT-70
76	.0	.0	M60A3

SCENARIO

ESTIMATE	AAPMH	USAGE RATE (MILES/YR)
LOW	2970	800
HIGH	2430	1200

ORG. UNIT SIZE = 58 M1 TANK'S.

DATE: 12/01/83
PURPOSE: DS ECHELON RUN

```
*****************************************************************
* EMREM MAINTENANCE & SUPPORT PERSONNEL REQUIREMENTS ESTIMATES *
*****************************************************************
```

M1 TANK APPLICATION

MOS	LOW	HIGH	BASELINE
31	2	3	M60A3
41	2	4	MBT-70
44	1	1	M60A3
45	5	8	M60A1
54	1	1	M60A1
63	11	20	MBT-70
76	0	0	M60A3

ESTIMATE	SCENARIO AAPMH	USAGE RATE (MILES/YR)
LOW	2970	800
HIGH	2430	1200

ORG. UNIT SIZE = 58 M1 TANK'S.

DATE: 12/01/83
PURPOSE: DS ECHELON RUN

IF YOU WOULD LIKE TO HAVE A COMPARISON REPORT, ENTER 1.

****
* EMREM MAINTENANCE & SUPPORT MANHOUR REQUIREMENTS ESTIMATES *
****

M1 TANK APPLICATION

MOS	AMMH LOW	AMMH HIGH	BASELINE SYS.
31	1948.80	2923.20	M60A3
41	4431.20	6646.80	MBT-70
44	417.60	626.40	M60A3
45	9202.05	13803.07	M60A1
54	788.80	1183.20	M60A1
63	17577.71	26366.57	MBT-70
76	.0	.0	M60A3

SCENARIO

ESTIMATE	AAPMH	USAGE RATE (MILES/YR)
LOW	3410	800
HIGH	2790	1200

ORG. UNIT SIZE = 58 M1 TANK'S.

DATE: 12/01/83
PURPOSE: GS ECHELON RUN

****
* EMREM MAINTENANCE & SUPPORT PERSONNEL REQUIREMENTS ESTIMATES *
****

M1 TANK APPLICATION

MOS	LOW	HIGH	BASELINE
31	1	1	M60A3
41	2	3	MBT-70
44	1	1	M60A3
45	3	5	M60A1
54	1	1	M60A1
63	5	9	MBT-70
76	0	0	M60A3

		SCENARIO
ESTIMATE	AAPMH	USAGE RATE (MILES/YR)
LOW	3410	800
HIGH	2790	1200

ORG. UNIT SIZE = 58 M1 TANK'S.

DATE: 12/01/83
PURPOSE: GS ECHELON RUN

IF YOU WOULD LIKE TO HAVE A COMPARISON REPORT, ENTER 1.

****
* EMREM MAINTENANCE & SUPPORT MANHOUR REQUIREMENTS ESTIMATES *
****

M1 TANK APPLICATION

	AMMH		
MOS	LOW	HIGH	BASELINE SYS.
31	11697.44	17546.16	M60A3
41	10672.00	16008.00	MBT-70
44	1113.60	1670.40	M60A3
45	35607.36	53411.04	M60A1
54	2320.00	3480.00	M60A1
63	91872.00	137808.00	MBT-70
76	213.44	320.16	M60A3

		SCENARIO
ESTIMATE	AAPMH	USAGE RATE (MILES/YR)
LOW	3410	800
HIGH	2250	1200

ORG. UNIT SIZE = 58 M1 TANK'S.

DATE: 12/01/83

```
*****************************************************************
* EMREM MAINTENANCE & SUPPORT PERSONNEL REQUIREMENTS ESTIMATES *
*****************************************************************
```

M1 TANK APPLICATION

MOS	LOW	HIGH	BASELINE
31	4	8	M60A3
41	3	7	MBT-70
44	1	1	M60A3
45	10	23	M60A1
54	1	2	M60A1
63	26	61	MBT-70
76	0	1	M60A3

	SCENARIO	
ESTIMATE	AAPMH	USAGE RATE (MILES/YR)
LOW	3410	800
HIGH	2250	1200

ORG. UNIT SIZE = 58 M1 TANK'S.

DATE: 12/01/83

IF YOU WOULD LIKE TO HAVE A COMPARISON REPORT, ENTER 1.

*** COMPARISON SUMMARY ***

M1 TANK APPLICATION
BENCHMARK DATA SOURCE: FY82 AMIM (M1)

NOTE: EMREM PREDICTED MORE RELEVANT MOS GROUPS THAN FY82 AMIM (M1).

MOS GROUP	FY82 AMIM (M1) VALUE IN EMREM INTERVAL?
31	NO (EMREM UPPER BOUND TOO LOW.)
41	NO (EMREM LOWER BOUND TOO HIGH.)
44	YES
45	YES
63	NO (EMREM LOWER BOUND TOO HIGH.)

```
REM   *********    EMREM PROGRAM    *********
PRINT  CHR$ (4)"BRUN AMPER INTERPRETER"
TEXT : HOME
REM   INITIALIZATION STATEMENTS
A = 0:B = 0:C = 0:D = 0:E = 0:F = 0:G = 0:H = 0:I = 0:J = 0:K = 0:L = 0:
   M = 0:N = 0:
P = 0:Q = 0:R = 0:S = 0:T = 0:U = 0:V = 0:W = 0:X = 0:Y = 0:Z = 0
REM
REM    DIMENSION STATEMENTS
REM
 DIM C1(30),C2(30),A1(30),A2(30),A3(30),A4(30),LL$(30),CV(30)
 DIM H1(30),H2(30),P1(10,30),P2(10,30)
 DIM MS(30),MI(30),MH(30),B$(30),S$(30)
 REM
 REM   READ & DATA STATEMENTS
 REM
 READ SY$,NO
 FOR I = 1 TO NO: READ MS(I),MI(I),MH(I),B$(I),S$(I): NEXT
 REM
 REM    *** ESTIMATE INPUT DATA ***
 DATA  M1 TANK,7
 DATA  63,1,1.98,MBT-70,P/CR
 DATA  41,1,.23,MBT-70,P/CR
 DATA  31,1000,282.13,M60A3,AMIM
 DATA  44,1000,26.8,M60A3,AMIM
 DATA  45,1000,767.4,M60A1,AR 570-2
 DATA  54,1000,50,M60A1,AR 570-2
 DATA  76,1000,5.15,M60A3,AMIM
 REM    ****************************
 REM
 READ CS$,MLS,N1
 FOR J = 1 TO N1: READ C1(J),C2(J): NEXT
 REM
 REM    ***** COMPARISON DATA *****
 DATA  FY 82 AMIM,1000,5
 DATA  63,1243.3
 DATA  41,84.0
 DATA  31,305.16
 DATA  44,24.0
 DATA  45,890.0
 REM    ****************************
 REM
  REM   PROMPT USER FOR SCENARIO INPUT
  GOSUB 1000
  REM   CALCULATE MANPOWER REQUIREMENTS
  GOSUB 2000
  REM   COMPARE ESTIMATES WITH ACTUALS
  GOSUB 3000
  REM   GENERATE OUTPUT REPORT
  GOSUB 4000
  END
```

```
REM   PARAMETER INPUT SUBROUTINE
ER$ = "ERROR -- LOWER WAS => UPPER"
 HOME : PRINT : PRINT : INVERSE : PRINT SY$"-RELATED PARAMETER INPUT
SECTION": NORMAL
 PRINT : PRINT : SPEED= 180: PRINT "ENTER UPPER AND LOWER BOUNDS FOR"
: PRINT SY$" USAGE RATE. "
 PRINT : PRINT "LOWER BOUND = ";: INPUT M1: PRINT "UPPER BOUND = ";: INPUT
M2: PRINT : PRINT
 IF M2 > M1 GOTO 1060
 SPEED= 10: PRINT : PRINT : PRINT ER$"   ": HOME : GOTO 1020
 PRINT  SPC( 5)"********************************" SPC( 5)
 PRINT : PRINT : SPEED= 180: PRINT "ENTER UPPER AND LOWER BOUNDS FOR"
: PRINT "AAMMH FACTOR. "
 PRINT : PRINT "LOWER BOUND = ";: INPUT F(1): PRINT "UPPER BOUND = ";
: INPUT F(2): PRINT : PRINT
 IF F(2) > F(1) GOTO 1110
 PRINT : PRINT : SPEED= 10: PRINT ER$: HOME : GOTO 1070
 REM
 HOME : PRINT : PRINT : PRINT : PRINT : PRINT : PRINT "ENTER ANTICIPA
TED NO. OF "SY$"S": PRINT "PER ORGANIZATIONAL UNIT.";: INPUT N
 SPEED= 35: HOME : PRINT : PRINT : PRINT : PRINT : PRINT : PRINT : PRINT
: PRINT : INVERSE : PRINT " --- NOW CALCULATING REQUIREMENTS. --- ": NORMAL
 RETURN
```

```
 REM    CALCULATION SUBROUTINE
 REM   CALCULATE TOTAL MANHOUR REQUIREMENTS FOR ORG UNIT
 FOR J = 1 TO NO
H1(J) = N * (M1 / MI(J)) * MH(J)
H2(J) = N * (M2 / MI(J)) * MH(J)
 NEXT
 REM   CHECK FOR EXCESSIVE WORKLOAD DUE TO DOWNWARD ROUNDING
 FOR I = 1 TO 2: FOR K = 1 TO NO
 IF (H1(K) / F(I) -  INT (H1(K) / F(I))) / ( INT (H1(K) / F(I)) + .00
01) > .1 GOTO 2080
P1(I,K) =  INT (H1(K) / F(I)): GOTO 2090
P1(I,K) =  INT (H1(K) / F(I)) + 1
 IF (H2(K) / F(I) -  INT (H2(K) / F(I))) / ( INT (H2(K) / F(I)) + .00
01) > .1 GOTO 2110
P2(I,K) =  INT (H2(K) / F(I)): GOTO 2120
P2(I,K) =  INT (H2(K) / F(I)) + 1
 NEXT K: NEXT I
 REM   CHECK FOR DIMINUTIVE WORKLOAD
 FOR I = 1 TO 2: FOR K = 1 TO NO
 IF H1(K) / P1(I,K) < .1 * F(I) THEN P1(I,K) = P1(I,K) - 1
 IF H2(K) / P2(I,K) < .1 * F(I) THEN P2(I,K) = P2(I,K) - 1
 NEXT K: NEXT I
 RETURN
```

```
 REM    COMPARISON SUBROUTINE
 REM   TOTAL COMPARISON MANHOUR REQUIREMENTS DATA OVER MOS GROUPS
 FOR J = 1 TO N1:T = T + C2(J): NEXT
 REM   ASSIGN WORKLOAD PROPORTIONS TO COMPARISON MOS GROUPS
 FOR I = 1 TO N1:A1(I) = C2(I) / T: NEXT
 REM   FIND MIDPOINTS OF EMREM MANHOUR ESTIMATE INTERVALS
 FOR J = 1 TO NO:A2(J) = (H1(J) + H2(J)) / (2 * N): NEXT
 REM   CALCULATE ACCURACY FACTOR
 REM   DETERMINE WHETHER ESTIMATE INTERVALS CONTAIN BENCHMARK DATA
 FOR I = 1 TO N1
X = X + 1
 IF X = NO + 1 THEN A3(I) = A1(I):LL$(I) = "EMREM DID NOT ANTICIPATE
THIS MOS GROUP.":CV(I) = 3: GOTO 3400
 IF C1(I) = MS(X) THEN  GOTO 3380
 GOTO 3330
A3(I) = A1(I) * ( ABS (A2(X) - C2(I)))
 IF C2(I) =  > (H1(X) / N) AND C2(I) =  < (H2(X) / N) THEN LL$(I) = "
YES": GOTO 3400
LL$(I) = "NO": IF C2(I) < H1(X) / N THEN CV(I) = 1: GOTO 3400
CV(I) = 2
 NEXT I
 FOR I = 1 TO N1:VL = VL + 100 * A3(I): NEXT
 RETURN
```

```
 REM    REPORT WRITING SUBROUTINE
 PR# 1
 PRINT  CHR$ (9)"80N"
Y1$ = "(EMREM LOWER BOUND TOO HIGH.)":Y2$ = "(EMREM UPPER BOUND TOO L
OW.)"
NC$ = "#PERS. INSENSITIVE TO USAGE RATE, AAMMH FACTOR RANGE LIMITS.":
FT$ = "  (SEE NOTE.)"
HD$ = "MOS     AMMH    #PERS.    BASELINE SYS."
S1$ = "NOTE: EMREM PREDICTED ":S2$ = " RELEVANT MOS GROUPS THAN "
F1$ = "FRMT,X3,S,0,0;":F2$ = "FRMT,X10,S,2,0;":F3$ = "FRMT,X7,S,0,0;"
:F4$ = "FRMT,$15;"
 PRINT  CHR$ (12)
 HOME : INVERSE : PRINT : PRINT : PRINT  SPC( 5)"*******  EMREM RESULT
S  *******" SPC( 5): NORMAL
 PRINT : PRINT  SPC( 10)SY$" APPLICATION" SPC( 6)
 PRINT : PRINT
 FOR Q = 1 TO 2
 PRINT  SPC( 6)"CASE "Q" RESULTS:"
 PRINT  SPC( 6)"USAGE RATE = "M1" MILES/YR.": PRINT  SPC( 6)"AAMMH FA
CTOR = "F(Q)".": PRINT : PRINT
 PRINT HD$
 FOR K = 1 TO NO
 & PRNT,MS(K),F1$: & PRNT,H1(K),F2$: & PRNT,P1(Q,K),F3$: & PRNT,B$(K)
,F4$: PRINT  SPC( 3): PRINT
 NEXT K
 PRINT : PRINT : PRINT "HIT ANY NUMERIC KEY FOR NEXT OUTPUT PAGE.": PRI
: GET C: PRINT  CHR$ (12)
 PR# 1: PRINT  CHR$ (9)"80N": PRINT  CHR$ (12): NEXT Q
 REM
 FOR Q = 3 TO 4
 PRINT  SPC( 6)"CASE "Q" RESULTS:"
 PRINT  SPC( 6)"USAGE RATE = "M2" MILES/YR.": PRINT  SPC( 6)"AAMMH FA
CTOR = "F(Q - 2)".": PRINT : PRINT
 PRINT : PRINT
 PRINT HD$
 FOR K = 1 TO NO
 & PRNT,MS(K),F1$: & PRNT,H2(K),F2$: & PRNT,P2(Q - 2,K),F3$: & PRNT,B
$(K),F4$: PRINT  SPC( 3): PRINT
 NEXT K
 PRINT : PRINT : PRINT "HIT ANY NUMERIC KEY FOR NEXT OUTPUT PAGE.": PRI
: GET C: PRINT  CHR$ (12)
 PR# 1: PRINT  CHR$ (9)"80N": PRINT  CHR$ (12): NEXT Q
 PRINT  SPC( 16)"*** PERSONNEL REQUIREMENTS SUMMARY ***"
 PRINT : PRINT : PRINT  SPC( 24)SY$" APPLICATION": PRINT  SPC( 24)"OR
G. UNIT SIZE = "N" "SY$"S."
 PRINT : PRINT : PRINT : PRINT : PRINT  SPC( 2)"MOS GROUP" SPC( 3)"**
********** RESULT *************"
 PRINT : FOR I = 1 TO NO
 PRINT  SPC( 6)MS(I) SPC( 6);
 IF P1(2,I) = P2(1,I) THEN  GOTO 4245
 PRINT "#PERS. RANGES BETWEEN "P1(2,I)" AND "P2(1,I)".": GOTO 4260
 PRINT "#PERS. = "P1(2,I)".  "FT$
 NEXT I
 PRINT : PRINT : PRINT : PRINT : PRINT : PRINT  SPC( 2)"NOTE: "NC$
 SPEED= 100: PRINT : PRINT : PRINT : PRINT "IF YOU WOULD LIKE TO HAVE
 A COMPARISON REPORT, ENTER 1.": SPEED= 255
 GET U: IF U = 1 THEN  GOTO 4400
 GOTO 4990
```

```
REM   COMPARISON REPORT PRINT STATEMENTS (OPTIONAL)
PR# 1: PRINT  CHR$ (12): PR# 1
PRINT  CHR$ (9)"80N": PRINT : PRINT
PRINT  SPC( 22)"*** COMPARISON SUMMARY ***"
PRINT : PRINT : PRINT  SPC( 26)SY$" APPLICATION": PRINT  SPC( 26)"BE
NCHMARK DATA SOURCE: "CS$
PRINT : PRINT : PRINT
IF NO > N1 THEN  PRINT S1$"MORE"S2$;: PRINT CS$"."
IF NO < N1 THEN  PRINT S1$"FEWER"S2$;: PRINT CS$"."
PRINT : PRINT
PRINT "  MOS GROUP" SPC( 12)CS$" VALUE IN EMREM INTERVAL?"
PRINT
FOR J = 1 TO N1
PRINT  SPC( 6)C1(J) SPC( 24)LL$(J);
IF CV(J) = 1 THEN  PRINT "  "Y1$
IF CV(J) = 2 THEN  PRINT "  "Y2$
IF CV(J) <  =  > 1 AND CV(J) <  =  > 2 THEN  PRINT " ": PRINT
NEXT J
PRINT  CHR$ (12)
RETURN
```

```
RUN

M1 TANK-RELATED PARAMETER INPUT SECTION

ENTER UPPER AND LOWER BOUNDS FOR
M1 TANK USAGE RATE.

LOWER BOUND = ?800
UPPER BOUND = ?1200

     ******************************

ENTER UPPER AND LOWER BOUNDS FOR
AAMMH FACTOR.

LOWER BOUND = ?2200
UPPER BOUND = ?2800




ENTER ANTICIPATED NO. OF M1 TANKS
PER ORGANIZATIONAL UNIT.?58




 --- NOW CALCULATING REQUIREMENTS. ---
```

****** EMREM RESULTS ******
M1 TANK APPLICATION

CASE 1 RESULTS:
USAGE RATE = 800 MILES/YR.
AAMMH FACTOR = 2200.

MOS	AMMH	#PERS.	BASELINE SYS.
63	91872.00	41	MBT-70
41	10672.00	5	MBT-70
31	13090.83	6	M60A3
44	1243.52	1	M60A3
45	35607.36	16	M60A1
54	2320.00	1	M60A1
76	238.96	1	M60A3

HIT ANY NUMERIC KEY FOR NEXT OUTPUT PAGE.

CASE 2 RESULTS:
USAGE RATE = 800 MILES/YR.
AAMMH FACTOR = 2800.

MOS	AMMH	#PERS.	BASELINE SYS.
63	91872.00	32	MBT-70
41	10672.00	4	MBT-70
31	13090.83	5	M60A3
44	1243.52	1	M60A3
45	35607.36	12	M60A1
54	2320.00	1	M60A1
76	238.96	0	M60A3

HIT ANY NUMERIC KEY FOR NEXT OUTPUT PAGE.

CASE 3 RESULTS:
USAGE RATE = 1200 MILES/YR.
AAMMH FACTOR = 2200.

MOS	AMMH	#PERS.	BASELINE SYS.
63	137808.00	62	MBT-70
41	16008.00	7	MBT-70
31	19636.25	9	M60A3
44	1865.28	1	M60A3
45	53411.04	24	M60A1
54	3480.00	2	M60A1
76	358.44	1	M60A3

HIT ANY NUMERIC KEY FOR NEXT OUTPUT PAGE.

CASE 4 RESULTS:
USAGE RATE = 1200 MILES/YR.
AAMMH FACTOR = 2800.

MOS	AMMH	#PERS.	BASELINE SYS.
63	137808.00	49	MBT-70
41	16008.00	6	MBT-70
31	19636.25	7	M60A3
44	1865.28	1	M60A3
45	53411.04	19	M60A1
54	3480.00	2	M60A1
76	358.44	1	M60A3

HIT ANY NUMERIC KEY FOR NEXT OUTPUT PAGE.

*** PERSONNEL REQUIREMENTS SUMMARY ***

M1 TANK APPLICATION
ORG. UNIT SIZE = 58 M1 TANKS.

MOS GROUP	************* RESULT *************
63	#PERS. RANGES BETWEEN 32 AND 62.
41	#PERS. RANGES BETWEEN 4 AND 7.
31	#PERS. RANGES BETWEEN 5 AND 9.
44	#PERS. = 1. (SEE NOTE.)
45	#PERS. RANGES BETWEEN 12 AND 24.
54	#PERS. RANGES BETWEEN 1 AND 2.
76	#PERS. RANGES BETWEEN Ø AND 1.

NOTE: #PERS. INSENSITIVE TO USAGE RATE, AAMMH FACTOR RANGE LIMITS.

IF YOU WOULD LIKE TO HAVE A COMPARISON REPORT, ENTER 1.

*** COMPARISON SUMMARY ***

M1 TANK APPLICATION
BENCHMARK DATA SOURCE: FY 82 AMIM

NOTE: EMREM PREDICTED MORE RELEVANT MOS GROUPS THAN FY 82 AMIM.

MOS GROUP	FY 82 AMIM VALUE IN EMREM INTERVAL?
63	NO (EMREM LOWER BOUND TOO HIGH.)
41	NO (EMREM LOWER BOUND TOO HIGH.)
31	YES
44	YES
45	YES

APPENDIX D

OVERVIEW OF APTITUDE CLUSTER DEFINITIONS

This study has involved the development of methodologies for estimating the long-term supply of manpower and the demand for military enlisted manpower. In order to ultimately relate the projected manpower supply to the projected manpower demand, a mechanism for translating these estimates into common terms was necessary. This mechanism is the Aptitude Cluster. The Aptitude Cluster is intended, at an aggregate level, to represent those characteristics and capabilities identified as "necessary" for the performance of particular military jobs, by each of the Services. It reflects the common relationships (i.e., similarity of aptitude requirements based on combinations of subtests) of aptitude composites among the Services. As such, the Aptitude Cluster, as opposed to the aptitude composite, is non-Service specific. The cluster represents the common characteristics shared by several composites.

Given the ability to relate Services' aptitude composites to each other and to represent them at a more aggregate level, it is possible to translate weapon system-specific manpower requirements to the related Aptitude Cluster. In this translation, the distinctions which are made at the Service level among occupations are blurred, so that those occupations which use the same "types" of people are collectively represented as a single "type" of requirement. Conceivably, within the Services as well as among the Services, competition occurs for "types" of people to support specific occupational requirements.

The Aptitude Clusters can also be applied to the manpower supply projections as a mechanism for tailoring, or characterizing, the projected population. This is necessary in order to add another dimension to the population, the distribution of those capabilities which the population may have and which the Services need in their apprentices. In this use, the Aptitude Clusters are used in conjunction with historic ASVAB scoring data to show the overall distribution of aptitudes in the projected population.

Given the aggregate nature of the Aptitude Clusters, it was necessary to identify the characteristics common among the Services' composites. The distribution and variety of subtest combinations clearly indicated that the subtest level of detail was not a functional level at which to identify common characteristics. Initial examination and review for discussion of the content of the subtests indicated that it was possible to group the subtests. This grouping is based on the similarity of the knowledge groups the subtests are addressing. There are two studies which have statistically analyzed these relationships.[1/]

Four groups of subtests were used:

- Math, composed of Arithmetic Reasoning (AR) and Math Knowledge (MK);
- Speed, composed of Numerical Operations (NO) and Coding Speed (CS);

1/ Dr. Darrell Bock of the University of Chicago has studied these relationships using the 1980 "Profile of American Youth" data. The Army Research Institute analysis is documented in "Factor Structure of the Armed Services Vocational Aptitude Battery (ASVAB), Forms 8, 9 and 10: 1981 Army Applicant Sample."

- Verbal, composed of Paragraph Comprehension (PC), Word Knowledge (WK), and General Science (GS); and
- Technical, composed of Electronic Information (EI), Mechanical Comprehension (MC), and Automotive Shop (AS).

The relationships identified in the Profile of American Youth data were selected since they are based on the same data base used in developing MCR's manpower supply projections. The Services' aptitude composite/subtest combinations were arrayed according to these subtest groupings and are shown in Exhibit D-1.

As noted earlier, all four Services have three composites which are structurally composed of the same set of subtests and are, therefore, common to all. These are the General, Administrative/Clerical and Electronics composites. Using the subtest grouping approach, it can be seen, however, that there are additional cases of common characteristics. Since the subtests are grouped, these common relationships are based on the combination of subtests in a group. Therefore, although one composite may use one subtest in a group, and another composite may not use the first subtest but does use another subtest in the same group, the two composites are considered related. Based on this analysis of subtest selections by group, all of the composites have been related to each other and assigned to a cluster.

As discussed earlier, some analytical judgement has been used in defining and assigning the Navy composites. Analysis at the subtest level assigned a number of very skilled electronics

APTITUDE CLUSTER	SERVICE	APTITUDE COMPOSITE	ASVAB SUBTESTS									
			MATH		SPEED		VERBAL			TECHNICAL		
			AR	MK	NO	CS	PC	WK	GS	EI	MC	AS
General	Army	General Technical	X				X	X				
	Navy	General (Basic)	X				X	X				
	Navy	General (Electronics)	X	X					X			
	Marine Corps	General Technical	X				X	X				
	Air Force	General	X				X	X				
Administrative/ Clerical	Army	Clerical			X	X	X	X				
	Navy	Administrative			X	X	X	X				
	Marine Corps	Clerical			X	X	X	X				
	Air Force	Administrative			X	X	X	X				
Technical	Army	Electronics	X	X					X	X		
	Navy	Electronics	X	X					X	X		
	Marine Corps	Electronics	X	X					X	X		
	Air Force	Electronics	X	X					X	X		
	Army	General Maintenance		X					X	X		X
	Marine Corps	General Mechanical		X					X	X		X
	Army	Skilled Technical		X			X	X	X		X	
	Navy	Skilled Technical	X				X	X			X	
	Marine Corps	Field Artillery	X				X	X			X	
	Navy	Nuclear	X	X			X	X	X	X		X
Mechanical	Navy	Mechanical Technical					X	X			X	X
	Air Force	Mechanical							X		X	X
Mechanical Maintenance	Army	Mechanical Maintenance	X							X	X	X
	Marine Corps	Mechanical Maintenance	X							X	X	X
Combat	Army	Field Artillery	X	X		X					X	
	Army	Combat	X			X					X	X
Field	Army	Operators/Food			X		X	X			X	X
	Army	Surveillance/Communic.			X	X	X	X				X
	Marine Corps	Combat			X		X	X				X

Exhibit D-1. RELATIONSHIP OF APTITUDE COMPOSITES TO APTITUDE CLUSTERS occupations to the Navy Skilled Technical and Electronics composites, although structurally they were not quite compatible. Analysis according to subtest groups allowed for the splitting out of these occupations into a separate composite, called here General (Electronics).

In addition to combinations of subtests, aptitude composites are also defined by the minimum combined scores required to qualify for occupations (i.e., training) in the composite. Within the composite, individual occupations are assigned minimum required scores. In order to determine the proportion of the population qualifying in each aptitude composite, it was necessary to select criteria for this qualification. A minimum combined score was identified for each aptitude composite based on analysis of the occupation qualification scores used by each Service. (The list of apprentice occupations in each Service by Aptitude Cluster and minimum score is included in the MCR Report Aptitude Content of the Non-Prior Service Youth and Enlisted Apprentice Populations: 1982-2010, TR-8217-2, Appendix C.) In those cases where large differences exist in the minimum combined score requirements for groups of occupations in a composite, the composite was restructured for this analysis to reflect this. Thus, the Navy/General (Basic) and Navy/General (Electronics) composites belong to the same cluster, based on the analysis of their subtest requirements. However they are different composites, not only due to differences in subset combinations, but also due to the large differences in the score requirements. A single minimum combined score was determined, based on analysis of the overall bottom end of the score range, for each service composite in each cluster. These are shown in Exhibit D-2. These combinations of subtests and scores, expressed as individual composites and as cluster qualification scores, were used as the basis for refining the population projections of the non-prior service youth (17-21 years old) and the military enlisted apprentice populations.

In order to develop the aptitude composite and cluster qualification rates for the NPS youth and enlisted apprentice populations, the definitions of the composites and clusters were applied to three data bases. The Profile of American Youth study was used to represent NPS youth, also referred to here as the civilian population. The enlisted apprentice rates were developed from analysis of the FY81 and FY82 military accession data bases. The composite and cluster qualification definitions were applied to these data bases through a two-step process to produce the qualification rates used in the third part of the PROMANSA model.

In the first step, the test results in the three data bases were reviewed to determine if the individuals in the selected age groups met the minimum combined score requirements in each composite. Based on this analysis, composite qualification rates were developed for the NPS youth and enlisted apprentice populations.

In the second step, the Aptitude Cluster qualification rates were developed. Within each cluster, there may be more than one combination of subtests making up the various composites in the

Aptitude Cluster	Service	Aptitude Composite	Related ASVAB Subtests	Minimum Score*	Application Rules
General	Army	General Technical	AR PC WK	N/A	• Not Applicable to Classif.
	Navy	General (Basic)	AR PC WK	90	• 90 for Basic Ratings
	Navy	General (Elect.)	AR MK GS	200	• 200 for Gen. Elect. Ratings
	Marine Corps	General Technical	AR PC WK	92	• Combined Scores
	Air Force	General	AR PC WK	87	• Combined Scores
Administrative/ Clerical	Army	Clerical	NO CS PC WK	138	• Combined Scores
	Navy	Administrative	NO CS PC WK	149	• Combined Scores
	Marine Corps	Clerical	NO CS PC WK	131	• Combined Scores
	Air Force	Administrative	NO CS PC WK	142	• Combined Scores
Technical	Army	Electronics	AR MK GS EI	175	• Combined Score
	Navy	Electronics	AR MK GS EI	156/212	MK+GS+EI=156(+AR=212)
	Marine Corps	Electronics	AR MK GS EI	182	• Combined Scores
	Air Force	Electronics	AR MK GS EI	181	• Combined Scores
	Army	General Mtnce	MK GS EI AS	177	• Combined Scores
	Marine Corps	General Mech	MK GS EI AS	N/A	• Not Applicable to Classif.
	Army	Skilled Technical	MK PC WK GS MC	[illegible]	• Combined Scores
	Navy	Skilled Technical	AR PC WK MC	146	• Combined Score with Multiple Rating-Specific Variations
	Marine Corps	Field Artillery	AR PC WK MC	139	• Combined Scores
	Navy	Nuclear	AR PC WK GS MK EI AS		
			AR PC WK	115	• Must meet all of these qualifications
			AR 2MK GS	200	
			AR MK GS EI	156/218	MK+GS+EI=156(+AR=218)
			MK AS	94	
Mechanical	Air Force	Mechanical	GS MC AS	173	• Combined Scores
	Navy	Mechanical Tech.	PC WK MC AS	145	• Combined Scores
Mechanical Maintenance	Army	Mech. Mtnce	AR EI MC AS	179	• Combined Scores
	Marine Corps	Mech. Mtnce	AR EI MC AS	167	• Combined Scores
Combat	Army	Field Artillery	AR MK CS MC	177	• Combined Scores
	Army	Combat	AR CS MC AS	178	• Combined Scores
Field	Marine Corps	Combat	NO PC WK AS	131	• Combined Scores
	Army	Operators/Food	NO PC WK MC AS	180	• Combined Scores
	Army	Surveillance/Comm	NO CS PC WK AS	191	• Combined Scores

*Minimum Score=Sum of Standard Scores

Exhibit D-2. DEFINITIONS OF MCR APTITUDE CLUSTERS cluster. In order to determine the qualification rates for the seven clusters, it was necessary to determine if individuals qualified in any one of the different combinations of subtests included in the cluster. Seventeen unique subtest combinations were identified within the 26 composites. These 17 combinations were used to determine the cluster qualification rates. For example, in order to qualify for the Technical cluster, an individual could qualify in any one of six ways. The arrows in Exhibit D-2 show the 17 subtest combinations used to develop the Aptitude Cluster qualification rates.

APPENDIX E

WARTIME AND PEACETIME USAGE RATES FOR MAIN BATTLE TANKS: IMPLICATIONS FOR MANPOWER REQUIREMENTS

Two points of concern have been raised about the Army's Manpower Authorization Standards and Criteria (MACRIT). First, MACRIT estimates of manpower requirements are based on the use of a single value for the annual available productive manhour factor (AAPMH). The second point that concerns MACRIT manhour requirements values for main battle tanks (MBT) centers on assumed MBT usage rates. While both of these concerns will be addressed by the new MARC system, the use of older MACRIT studies required the consideration of these issues.

In this application of EMREM to the M1 MBT, the first point was accommodated through the use of a range of AAPMH values instead of a single value. The second point is more complex and deserves careful consideration. The total MACRIT manhour requirements for those MOSs involved with MBT maintenance in a wartime environment seem to be reasonable estimates. However, the MACRIT-assumed usage rate of 1,000 miles per year per tank does not appear to be representative of MBT usage in most wartime scenarios. A value of 3,000 miles per year is a more widely held value for an MBT wartime usage rate. This appendix examines the implications of this latter observation.

As mentioned, the MACRIT annual maintenance manhour requirements seem representative of MBT maintenance manhour requirements during wartime. However, the assumed usage rate is about one third what would be expected to prevail in the same environment. Thus, MACRIT manhour requirements per mile of MBT usage may, in fact, be inflated to three times their "true" value.

To examine the implications of this situation, the EMREM below depot level maintenance manpower requirements were recalculated with the input data modified so as to reflect the "corrected" MBT usage rate. Two values for usage rate for the new system were assumed:

- 1,000 miles per year, roughly representative of peace-time MBT utilization, and
- 3,000 miles per year, a wartime MBT usage rate.

The results of these calculations are presented in Exhibit E-1.

		"WARTIME" REQUIREMENTS		"PEACETIME" REQUIREMENTS	
		LOW	HIGH	LOW	HIGH
	USAGE	3000	3000	1000	1000
	AAPMH	2250	3410	2250	3410
MOS					
31		4	6	2	2
41		4	6	2	2
44		1	1	1	1
45		13	19	4	6
54		1	2	1	1
63		33	51	11	17
76		0	1	0	0

Exhibit E-1. WARTIME AND PEACTIME ESTIMATES OF BELOW DEPOT LEVEL MAINTENANCE MANPOWER REQUIREMENTS.

The results shown in Exhibit E-1 are consistent with prior intuition. The so-called peacetime personnel requirements for the 58 tank batallion are significantly less than the "wartime" requirements; for this illustration, the difference is primarily due to the wartime annual usage rate being three times the peacetime annual usage rate. Note, however, that the personnel requirements, for a given AAPMH factor, are not consistently three times greater during a wartime operating tempo. Rather, the differences in the personnel requirements estimates reflect a combination of differing usage rates and the results of the conventions adopted for rounding the personnel estimates to integer values.

These results are presented to illustrate the potential impact on manpower requirements of variations between operating tempos such as those that would likely occur when moving between wartime and peacetime scenarios. The assumptions imposed so as to obtain the above results are rather restrictive; a more rigorous investigation of the consequential change in peacetime manpower requirements of imposing a wartime operational scenario would require further investigation into at least two areas:

- productive manhour availability under peacetime and wartime scenarios (AAPMH values need not remain the same under both scenarios); and
- once again, the translation of a given usage rate parameter into factors by which to scale all personnel requirements (in order to reflect varying operating tempos).

Such studies would be useful for programming peacetime and (predicting) wartime weapon system personnel requirements throughout the weapon system life cycle.

APPENDIX F

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This report demonstrates the feasibility of implementing a manpower requirements estimation technique very early in the acquisition process. The methodology is briefly reviewed and is applied to estimate manpower requirements for the Army's M1 Main Battle Tank. For demonstration purposes, the application to the M1 was done with data available early in the M1's acquisition. The resulting estimates are analyzed and compared with the Army's current M1 manning requirements.

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