AD-A 012 939

NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Md. 20034

ANALYSIS OF THE SEABORNE MOBILE LOGISTIC SYSTEM (SMLS) MAINTENANCE SUBSYSTEM USING THE MAINTENANCE OPTIMIZATION MODEL, VERSION II

by
Michael Gray

Approved for public release; distribution unlimited

COMPUTATION AND MATHEMATICS DEPARTMENT
RESEARCH AND DEVELOPMENT REPORT

April 1975 Report 4399

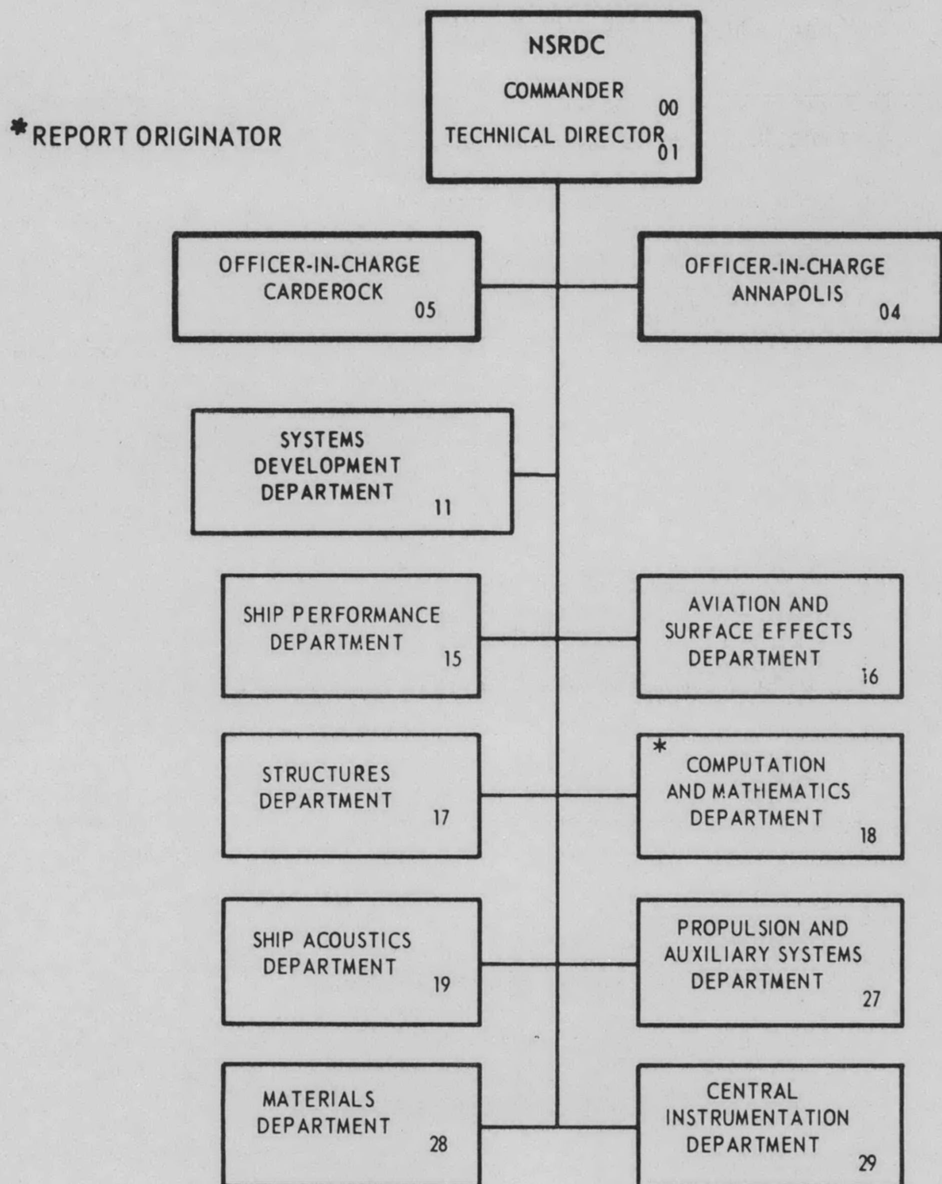
ANALYSIS OF THE SEABORNE MOBILE LOGISTIC SYSTEM (SMLS) MAINTENANCE SUBSYSTEM USING THE MAINTENANCE OPTIMIZATION MODEL, VERSION II
4399

The Naval Ship Research and Development Center is a U. S. Navy center for laboratory effort directed at achieving improved sea and air vehicles. It was formed in March 1967 by merging the David Taylor Model Basin at Carderock, Maryland with the Marine Engineering Laboratory at Annapolis, Maryland.

Naval Ship Research and Development Center

Bethesda, Md. 20034

MAJOR NSRDC ORGANIZATIONAL COMPONENTS



UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 4399	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Analysis of the Seaborne Mobile Logistic System (SMLS) Maintenance Subsystem Using the Maintenance Optimization Model, Version II		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Michael Gray		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Amphibious Warfare Group, Operations Research Div. Code 1865 Naval Ship Research and Development Center		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Task Area CF0189901 Element No. 6515M, Work Unit 1-1865-005
11. CONTROLLING OFFICE NAME AND ADDRESS Deputy Chief of Naval Operations (Surface Warfare) Assistant Chief of Staff (G-4) U.S. Marine Corps Washington, D.C.		12. REPORT DATE April 1975 13. NUMBER OF PAGES 118
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) SMLS Study Panel Development Center MCDEC Quantico, Va. 22134		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

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

18. SUPPLEMENTARY NOTES

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

Maintenance
Seaborne Mobile Logistic System
Logistics
Simulation
Monte Carlo
Repair
Failure
Echelon of Repair
Availability
Failure Generation
Queues

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

The Seaborne Mobile Logistic System (SMLS) defines operational procedures and allocation of resources for the logistic support of a Marine Corps Landing Force ashore from a seabase afloat. In evaluating the SMLS approach, ground maintenance of Marine Corps end items of an Amphibious Task Unit/Marine Amphibious Unit (ATU/MAU) and an Amphibious Task Group/Marine Amphibious Brigade (ATG/MAB) is considered independently because of its effects on requirements for amphibious shipping and large resources. A computer simulation model

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

of the maintenance system was developed to demonstrate the feasibility of, and to determine the requirements for, performing maintenance under SMLS. A user's guide to the model has been documented separately. Six scenarios were investigated with the model, two at the MAU level and four at the MAB level. The MAU results indicate that SMLS maintenance is both feasible and cost effective compared to the conventional system. Centralization of 2nd-echelon repair capability and the ability to perform 4th-echelon repair in the seabase are key factors. The MAB results indicate that currently maintenance ashore can be performed more effectively by the units than by Contact Team. The advantages of an Operational Readiness Float were also demonstrated. One MAB scenario, used to investigate the impact of an Expeditionary Airfield ashore on the ground maintenance capabilities of a MAB supported by SMLS showed that sufficient reserve capability exists to provide the necessary support.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

LIST OF FIGURES

Page

Page

LIST OF TABLES

SECTION 1
INTRODUCTION

Application of the concept of seabased support of amphibious operations to reduce the presence of US Forces ashore is being considered under the Seaborne Mobile Logistic Support (SMLS) Study. The seabase, which consists of amphibious ships, will provide the logistic support for a USMC landing force ashore during its mission. However, a new set of operational procedures will be required, different from those required for conventional support where logistic support is an integral part of the landing force ashore.

The Seaborne Mobile Logistic System (SMLS) consists of a set of operational procedures which extend logistics support from the seabase to the landing force ashore. The applicability of SMLS is postulated for low- and mid-intensity conflict levels supporting Marine Amphibious Unit (MAU) and Marine Amphibious Brigade (MAB) landing forces. Under SMLS, only a portion of the total force is deployed ashore; the remaining force stays aboard the seabase. The option always exists of deploying the entire force ashore and thus assuming a conventional operation.

SMLS is composed of maintenance, supply, and medical functions supported by transportation, communication, and coordination and control functions. The maintenance function was chosen for individual examination because of its large resource requirements and its effect on ship requirements. The maintenance simulation model described herein provides a tool for the examination and analysis of the performance of ground maintenance and the determination of required resources.

The purpose of the work described herein was to compare maintenance performed in the conventional manner with maintenance performed in two different ways under SMLS. The maintenance model described in this report was developed to determine maintenance requirements of MAU and MAB landing forces operating under six scenarios. The results were tabulated, graphed, and analyzed. The MAU results indicate that SMLS maintenance is both feasible and cost effective compared to the conventional system, and the MAB results indicate that maintenance ashore can be performed more effectively by the units than by Contact Teams (maintenance personnel detached from the seabase).

SECTION 2

APPROACHES TO DEVELOPMENT OF OPERATIONAL CONCEPTS

A number of methods can be used to assist in the design and development of operational concepts:

- Computer Simulation Models
- Operational Exercises
- Wargames

Computer models are the most efficient method for use in the early stages of system development because they make it possible to generate and examine a large number of alternative designs quickly and relatively inexpensively. Three computer models which examine SMLS ground maintenance have been developed by NSRDC. The SMLS Systems Model[1] considers maintenance as it interacts with all the other functions of SMLS. The maintenance Optimization Model, Version I[2], examines the maintenance subsystem by itself. Updates and changes (Section 3) were made to Version I to produce Version II[3] of the Maintenance Optimization Model, which is described in this report.

Amphibious operational exercises which utilize actual ships, aircraft, and troops have been used as practice sessions to maintain readiness of US Naval Amphibious Forces. These exercises, which resemble actual wartime conditions, are excellent vehicles for implementing new concepts.

---

[1] Hubai, P. et al., "Computer Simulation Model for the Seaborne Mobile Logistic System (SMLS) at the Amphibious Task Unit/Marine Amphibious Unit (ATU/MAU) Level, Part 1 - Model Description," NSRDC Report 4114, December 1974.

[2] Marcus, C.Y. and M. Gray, "Seaborne Mobile Logistic System (SMLS) Maintenance Optimization Model User's Manual," NSRDC Report 4115, August 1973.

[3] Van Eseltine, C.A., "Seaborne Mobile Logistic System (SMLS) Maintenance Optimization Model, Version II - User's Manual," NSRDC Report 4381, March 1974.

They allow testing, observation, and evaluation of operations and procedures of SMLS, many of which have been developed using the computer models already mentioned. One recent exercise was Operation Phiblex 5-72[4] which tested use of SMLS with a Marine Amphibious Unit (MAU) landing. Unfortunately, inadequate system design and poor weather conditions rendered observations from Phiblex 5-72 inconclusive. Also, because the SMLS concept had not been fully developed at that time, the test was premature and did not produce adequate feedback for refining SMLS. Even so, if adequate preparation of the system is accomplished and weather conditions good, valuable results can be obtained from such an exercise.

Wargames can also be used to test logistics concepts. Insights into system design can be obtained without resorting to expensive operational testing. Sea Log II[5], a logistic wargame, was carried out at the Naval War College in January 1973 to test SMLS.

For the development of the SMLS concept, emphasis has been on simulation computer models. One used extensively is Version II of the Maintenance Optimization Model which is described in the following sections.

---

[4]"Post Exercise Seaborne Mobile Logistic System Evaluation Report, Phiblex 5-72," Enclosure to COMPHIBGRUEASTPAC ltr FF8-3:01:mm, 3120, ser:010, 22 December 1972.

[5]Fuller, J.J., and C.A. Van Eseltine, "Sea Log II, A Logistic War Game Employing the Seaborne Mobile Logistic System (SMLS) Concept at the Amphibious Task Group/Marine Amphibious Brigade (ATG/MAB) Force Level," NSRDC Report 4136, January 1974.

SECTION 2

APPROACHES TO DEVELOPMENT OF OPERATIONAL CONCEPTS

A number of methods can be used to assist in the design and development of operational concepts:

- Computer Simulation Models
- Operational Exercises
- Wargames

Computer models are the most efficient method for use in the early stages of system development because they make it possible to generate and examine a large number of alternative designs quickly and relatively inexpensively. Three computer models which examine SMLS ground maintenance have been developed by NSRDC. The SMLS Systems Model[1] considers maintenance as it interacts with all the other functions of SMLS. The maintenance Optimization Model, Version I[2], examines the maintenance subsystem by itself. Updates and changes (Section 3) were made to Version I to produce Version II[3] of the Maintenance Optimization Model, which is described in this report.

Amphibious operational exercises which utilize actual ships, aircraft, and troops have been used as practice sessions to maintain readiness of US Naval Amphibious Forces. These exercises, which resemble actual wartime conditions, are excellent vehicles for implementing new concepts.

---

[1]Hubai, P. et al., "Computer Simulation Model for the Seaborne Mobile Logistic System (SMLS) at the Amphibious Task Unit/Marine Amphibious Unit (ATU/MAU) Level, Part 1 - Model Description," NSRDC Report 4114, December 1974.

[2]Marcus, C.Y. and M. Gray, "Seaborne Mobile Logistic System (SMLS) Maintenance Optimization Model User's Manual," NSRDC Report 4115, August 1973.

[3]Van Eseltine, C.A., "Seaborne Mobile Logistic System (SMLS) Maintenance Optimization Model, Version II - User's Manual," NSRDC Report 4381, March 1974.

They allow testing, observation, and evaluation of operations and procedures of SMLS, many of which have been developed using the computer models already mentioned. One recent exercise was Operation Phiblex 5-72[4] which tested use of SMLS with a Marine Amphibious Unit (MAU) landing. Unfortunately, inadequate system design and poor weather conditions rendered observations from Phiblex 5-72 inconclusive. Also, because the SMLS concept had not been fully developed at that time, the test was premature and did not produce adequate feedback for refining SMLS. Even so, if adequate preparation of the system is accomplished and weather conditions good, valuable results can be obtained from such an exercise.

Wargames can also be used to test logistics concepts. Insights into system design can be obtained without resorting to expensive operational testing. Sea Log II[5], a logistic wargame, was carried out at the Naval War College in January 1973 to test SMLS.

For the development of the SMLS concept, emphasis has been on simulation computer models. One used extensively is Version II of the Maintenance Optimization Model which is described in the following sections.

---

[4]"Post Exercise Seaborne Mobile Logistic System Evaluation Report, Phiblex 5-72," Enclosure to COMPHIBGRUEASTPAC ltr FF8-3:01:mm, 3120, ser:010, 22 December 1972.

[5]Fuller, J.J., and C.A. Van Eseltine, "Sea Log II, A Logistic War Game Employing the Seaborne Mobile Logistic System (SMLS) Concept at the Amphibious Task Group/Marine Amphibious Brigade (ATG/MAB) Force Level," NSRDC Report 4136, January 1974.

SECTION 3

EVOLUTION OF THE SMLS MAINTENANCE OPTIMIZATION MODEL

Version I of the Maintenance Optimization Model was developed in FY 72 to examine a MAU size landing force. A number of computer runs were made and analyzed and the results reported.[6,7] On the basis of insight gained in the MAU analysis, various aspects of the model were revised to more accurately describe actual maintenance operations. The new version of the model, referred to as Version II, simulates end item failures, repairs, repair parts distributions, and transportation; by use of Monte Carlo methods, queuing theory, and application of reliability and maintainability theory. Results from the model are described in this report and in the ATU/MAU and ATG/MAB Analysis volumes.[8]

The following modifications to Version I were incorporated into Version II:

- Contact teams (maintenance specialists) are brought ashore at 0600 and work until 1800 hours
- Contact Teams (CT) do not initiate new work after 1700 hours
- The decision as to whether to replace a failed item is based on projected downtime
- Repair parts may be required for failed items, depending on an input probability distribution

---

[6] Gray, M., "Development of the Seaborne Mobile Logistic System (SMLS) Maintenance Optimization Model, Version I", NSRDC Report 4116, October 1973.

[7] Seaborne Mobile Logistic System, Second Interim Report for Refined ATU/MAU and Interim ATG/MAB, Enclosure (1) of CNO (OP-323)/CMC (A04R-b15-2) ltr of 11 October 1973.

[8] Seaborne Mobile Logistics System (SMLS) Study, Volume II Amphibious Task Unit/Marine Amphibious Unit (ATU/MAU) Analysis and Volume III Amphibious Task Group/Marine Amphibious Brigade (ATG/MAB) Analysis, Enclosures (2) and (3) of MCDEC ltr D050-4/FDMJr:jmw of 18 July 1974.

- Repair parts may be located either at the seabase or outside the seabase
- Transportation times include administrative delays, waits for transportation, and message transmission times as determined by the Systems Model
- End items are operational either during daylight, i.e., 0600-1800 hr, or 24 hours a day, depending on type

The change which produced the greatest effect in maintenance operations was the introduction of a process for generation of repair parts requirements. As will be shown, a failed item spends more time waiting for repair parts than in waiting for maintenance or being repaired.

Version II was developed to accommodate a MAB size landing force. However, analysis of a MAU size force was also carried out with the Version II simulation model to observe the differences in MAU and MAB maintenance requirements using the same model.

SECTION 4

CONVENTIONAL AND SMLS MAINTENANCE CONCEPTS

4.1 CONVENTIONAL VS SMLS MAINTENANCE

Maintenance as presently performed in the Marine Corps will be referred to as conventional. Under this system, maintenance required by the landing force is provided by units which are an integral part of the organization positioned ashore. Under SMLS, most of the maintenance support for the landing force remains at the seabase. The support is still part of the landing force organization, even though it is separated from the force ashore.

4.2 ECHELONS OF MAINTENANCE

The performance of maintenance under SMLS differs from that performed in the conventional organization, not only in location of the maintenance activity but also in the level of support provided. The categories used by the USMC to describe maintenance requirements are given in Table 1.

The Marine Corps subdivides the three broad categories of maintenance (organizational, intermediate, and depot) into five echelons. Organizational maintenance is subdivided into 1st- and 2nd-echelon maintenance. First-echelon maintenance is characterized by proper care of the end item and is performed by the item user or operator. Second-echelon maintenance is characterized as minor repair and is performed by maintenance specialists, as is all higher echelon maintenance. Field or intermediate maintenance is subdivided into 3rd-echelon maintenance, characterized as component and assembly replacement; and 4th-echelon maintenance, characterized as component repair. Fourth-echelon maintenance utilizes a wider assortment of tools, test equipment, and repair parts than 3rd-echelon maintenance. Finally, depot maintenance is referred to as 5th-echelon maintenance and includes overhaul, rebuilding, etc.

The maintenance model considers only 2nd- through 4th-echelon maintenance. Since 1st-echelon maintenance is accomplished by the equipment operator and items of equipment usually are not inoperative due to a

TABLE 1 - DEFINITION OF ECHELONS OF MAINTENANCE

Level	Echelons	Maintenance and Distribution of Work
Organizational	First	Proper care of equipment; performed by equipment user, wearer, or operator
	Second	Characterized as minor repair; performed by school-trained organization personnel.
Field	Third	Characterized as component and assembly replacement. Piece-part replacement performed within limitations imposed by tools, test equipment, and repair parts authorized. Technical assistance to lower echelons included.
	Fourth	Characterized as component repair. Activities authorized a wider assortment of tools, test equipment, and repair parts than third-echelon activities. Technical assistance to lower echelons also provided.
Depot	Fifth	Highest echelon, characterized as industrial maintenance. Consists of overhaul, rebuild, fabrication, and manufacture. Provision of technical assistance to lower echelons included.

Source: Seaborne Mobile Logistic System, Second Interim Report for Refined ATU/MAU and Interim ATG/MAB, Enclosure (1) of CNO(OP-323)/CMC(A04R-b15-2) ltr of 11 October 1973.

requirement for 1st-echelon maintenance, it is not considered. Because 5th-echelon maintenance requires extensive facilities, tools, technicians, and repair parts, it cannot normally be performed in the seabase or the field. In the model, any item requiring 5th-echelon maintenance is either stored or evacuated to a rebuild facility.

A major use of the model has been the examination of the two different methods by which 2nd- and limited 3rd-echelon maintenance can be performed ashore; i.e., by contact teams (CT) or by the using unit.

CT's are composed of maintenance specialists who repair failed items ashore. They are mobile, usually having a jeep at their disposal, and move from item to item during the day. When CT's are used, the landing force ashore has no other maintenance capability (except 1st-echelon). Second and limited third echelons of maintenance are sufficiently simple so that they can be performed by CT's ashore; the remaining 3rd-and the 4th-echelons of maintenance are performed by maintenance shops in the seabase.

On the other hand, units of the Landing Force may be assigned the ability to perform 2nd-echelon and limited 3rd-echelon maintenance. Repair requiring a capability not found in the units ashore is performed at the seabase to determine optimal SMLS configurations.

The model was used to investigate and compare the operations and resources required of SMLS using both CT and unit maintenance procedures.

4.3 COMMODITY CLASSFICATION

All Marine Corps end items in the landing force are categorized in the Table of Authorized Material.[9] For the SMLS Maintenance Model, further division into eight subcommodity classes was required. The classes used are:

- Communication/Electronics - Radio
- Communication/Electronics - Teletype
- Engineer

---

[9]Table of Authorized Material (TAM), Rev 1, USMC, NAVMC 1017, 20 April 1970.

- Motor Transport
- Ordnance - Artillery
- Ordnance - Infantry Weapons
- Ordnance - Amphibious Vehicles
- Ordnance - Tank

Items in each subcommodity group are repaired independently of the others. At the seabase, eight separate maintenance shops, one for each subcommodity, are set up. Furthermore, different CT's are assigned to each subcommodity and they repair only items belonging to the subcommodity to which they are assigned. Similarly, when units are assigned maintenance capability it is by subcommodity. Each unit can have a maintenance capability of up to eight subcommodities (although highly unlikely), depending on the types of items in the units. Since maintenance personnel and operations are independent for all subcommodities, i.e., no interactions between subcommodities occur, maintenance requirements can be determined separately for each subcommodity. The total force requirement is then the total of the requirements generated by all the individual subcommodities.

4.4 LANDING FORCE ORGANIZATION

A MAU or MAB consists of a number of units, such as battalions, companies, batteries, etc., each of which is assigned a number of end items. When item repair is required, the unit to which the item belongs will repair the item if it has the capability. If the unit does not have the capability, a CT will be requested. If the CT cannot repair the item, the item will be evacuated to the seabase. If a replacement is required and is available from the ORF or from a non-deployed unit, it will be transported to the unit, which then assumes ownership of the replacement item. The ORF or non-deployed unit from which the replacement item originated will then own the failed item.

Under SMLS, the total MAB is considered as made up of three separate components: the operational end items in the force ashore, the ORF, located at the seabase, which consists of replacement items for selected end items; and the items held by the non-deployed units (NDU) at the seabase.

These units can be deployed if the mission requires conventional operation. Under SMLS the non-deployed units are not required ashore, but provide a reserve capability.

SECTION 5

MODEL DESCRIPTION

5.1 OPERATION

Failures, repairs, and transportation events are generated in the model to simulate actual maintenance operations during a mission. The model uses event-store procedures and Monte Carlo methods as described by Marcus[2] to simulate replications of the specified mission. For each replication or simulated mission, output quantities are calculated and stored. The final values of the output quantities are obtained by averaging the output values of a number of simulated missions.

5.2 INPUT AND OUTPUT

The model utilizes input from punch cards describing

a) The maintenance system (e.g., number of CT's available maximum permissible queue lengths, echelons of repair),

b) The Landing Force organization (end items by number and type), and

c) The mission scenario (e.g., mission duration, transportation times, end item usage factors).

The model also accesses a permanent file for such end item characteristics as mean-time-between-failures (MTBF), mean-time-to-repair (MTTR), weight, and cube.

The model output includes the (1) availability of end items; i.e., the percentage of mission time that end items are operational, and (2) the downtime, i.e.; total time that items are not operational after failure (The downtime comprises repair times, transportation times, and delay times), (3) end items failures, and (4) downtime per failure. Further output includes queue characteristics, CT and seabase shop utilization, discard rates, and percentages of items not operational because of maintenance or supply delays. Utilization of CT's represents the percentage of the total mission time they are repairing and diagnosing items, or being transported. Utilization of seabase shop spaces represents the percentage of time they are used for diagnosing and repairing items.

Availability, downtime, and utilization are considered measures of effectiveness (MOE) of the maintenance system. They are used to measure the performance of the maintenance system and the end items of the Landing Force and to characterize and compare alternate maintenance configurations.

5.3 MISSION SCENARIOS

Scenario characteristics are required as inputs to the model. Operational procedures for the model for a MAU and MAB are identical. The force sizes and units are defined in the input solely by the number and type of end items entered into the model. Sections 8.1 and 9.3 contain a description of the scenarios. A more detailed description can be found in the ATU/MAU and ATG/MAB Analysis volumes[8].

SECTION 6
SYSTEM DESCRIPTION

This section covers only the major concepts utilized in the model logic flow which are needed to provide a basis for understanding the analytical results. Section 7 describes the flow in detail. Additional detail can be found in a report by Gray.[6] Figure 1 shows the simulation model logic. Each step in Figure 1 represents either a major decision or the generation of information, and is assigned a step number by which it is referred to subsequently.

6.1 OVERVIEW

End item failures ashore are simulated (step 1) and then categorized as either urgent or routine (2). As specified in the input, an assignment is made that the item is either to be repaired at the seabase, by a CT, or by a unit ashore (3). To compensate for administrative and communication delays, delay times are added (4) to the transportation time. The transportation time (5) is the time required to send a CT between points ashore, or to evacuate items to the seabase and to send replacements from the seabase. Additional delays such as time spent in queues, awaiting resources, or waiting for daylight are generated internally.

The decision on whether to replace a failed item is based on the projected downtime (6). If the item is to be replaced, a replacement item is requisitioned either from the ORF or from a non-deployed unit (7) and then transported ashore.

A failed item that is to be repaired is placed in the appropriate queue, either the CT, unit, or seabase queue (8). Items to be repaired as the seabase are queued by priority (9). A repair time is generated to simulate item repair (10). During repair, parts may be required (11). After repair the item returns ashore if not repaired there or replaced and the failure cycle repeats.

Each box in Figure 1 is discussed in detail in the following paragraphs.

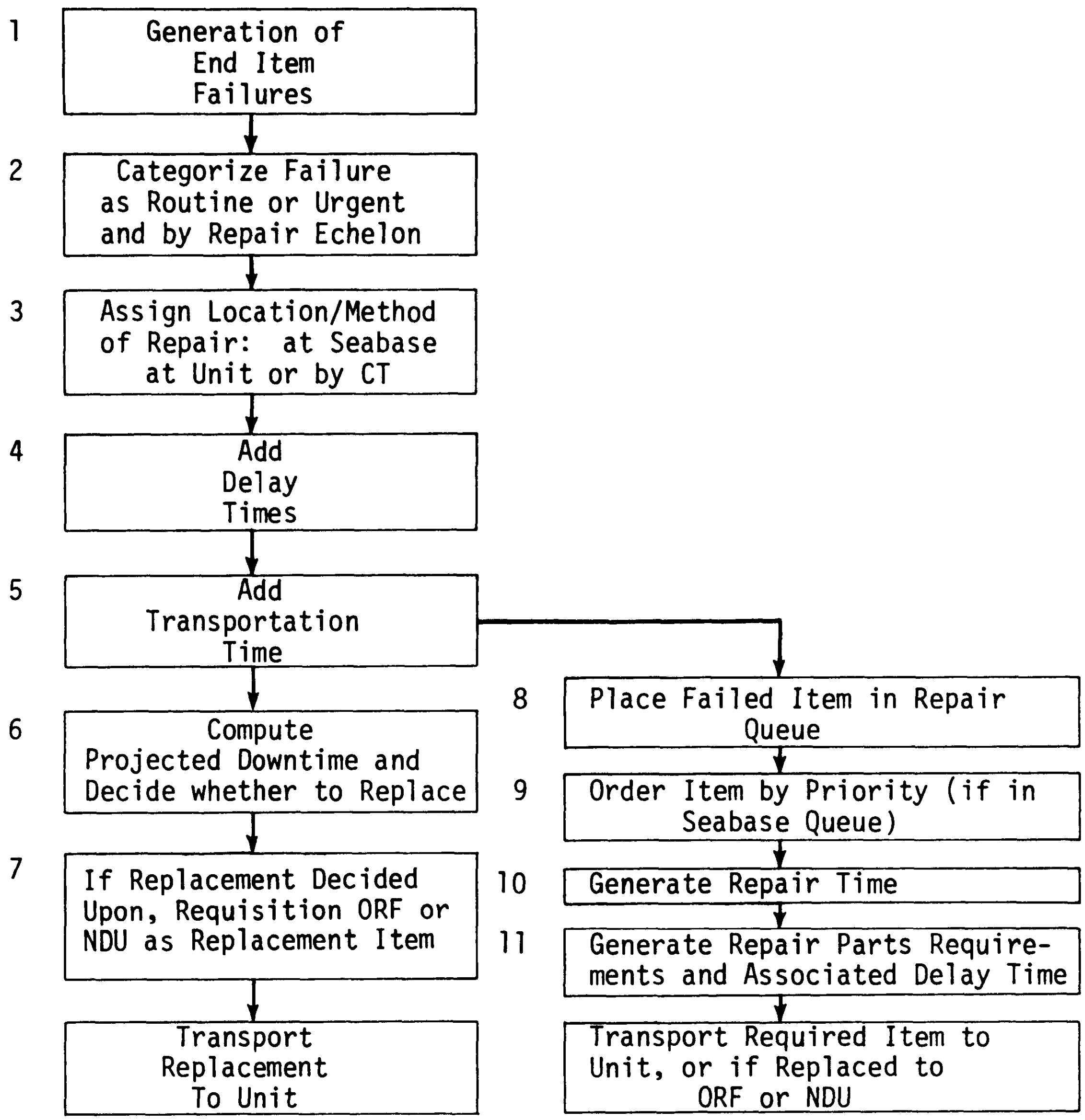


Figure 1 - Overall Maintenance Flow

6.2 GENERATION OF END ITEM FAILURES (STEP 1)

End item failures are generated by an inverted form of the reliability formula

$$R = EXP \left(\frac{-Ut}{24 \times MTBF}\right)$$

where R is the reliability*(values range from 0 to 1).

t is the time

MTBF is the mean-time-between-failures for a given end item

U is a usage factor (number of hours the item is operational each day)

If the reliability is assigned a value RN, a random number (generated from a uniform distribution from 0 to 1), then t may be interpreted as TTF, a specific time to failure. Solving for TTF gives

$$TTF = -\frac{24(MTBF)}{U} \ln RN$$

Each time a failure is simulated, the TTF for that item is calculated as shown. The process is described in greater detail by Marcus.[2]

6.3 TYPE OF FAILURE (STEP 2)

Each item is designated in the input as requiring either urgent or routine response upon failure, based on its combat essentiality. When an item fails, an echelon of repair, either 2nd, 3rd, 4th, 5th, or an instruction to discard, is also generated. The highest echelon of repair available at the seabase is specified in the input; this level may be no higher than 4th-echelon. Items with 5th-echelon maintenance requirements and those to be discarded are considered inoperable for the remainder of the mission.

*Reliability is defined as the probability that a system will perform satisfactorily; i.e., without failing for a given period of time.

6.4 LOCATION OF REPAIR (STEP 3)

A failed item, unless it requires 5th-echelon maintenance or is beyond repair, will be repaired either at the seabase or ashore (i.e., repaired ashore by CT or unit, depending on which is specified). Determination of the location of repair is based on the echelon of repair required (2) and whether or not a replacement is to be provided.

6.4.1 Seabase Repair

A centralized maintenance capability aboard ships of the seabase is inherent in SMLS. This capability is provided by portable shops in the form of Marine Corps maintenance vans, which are set up in the ships to perform up to 4th-echelon repair on USMC end items. These shops are distinct from the permanent shops on the ship which are used primarily for ship-related maintenance. If the entire force must be deployed, these vans can be quickly mobilized to accompany the force. The possibility of the need for rapid deployment requirements makes reliance in SMLS on permanent shipboard shops impractical.

Maintenance shop capability (i.e., number of shop spaces) is equated to the maximum number of items that can be repaired in the shop at one time. The required overall throughput repair capability for each subcommodity is a function of the number of failures and the repair times of all end items belonging to each subcommodity. Throughput capabilities of shops for each of the eight subcommodities are determined by running the model. Results indicate that one maintenance ship is necessary to provide the required capability in shop spaces for a MAU and two ships for a MAB.

The seabase shops operate 24 hours a day, but since there is no transportation at night, failed items come aboard only during daylight hours. Therefore, a lower shop utilization can be expected during the night. After the seabase repairs an item, the item will be (a) sent back to its unit if it had not been previously replaced, (b) sent to the ORF or non-deployed unit if it had been replaced and no requirement exists ashore, or (c) sent to a different unit which requires a replacement but for which none was available at the time of failure. If the seabase cannot repair the item, it is stored for subsequent evacuation for repair at the depot level.

6.4.2 CT Repair

CT's are maintenance specialists who are detached from the seabase maintenance shops to repair items ashore. They are transported ashore in the morning and back to the seabase at the end of the day. Transporting all CT's ashore for the entire day instead of on an "as required" basis was determined to be a more feasible policy through analysis of the Systems Model results. It was found that individual transportation of CT's placed too much of a strain on the transportation system (i.e., required too high a helicopter utilization).

CT's work between the daytime hours of 0600 to 1800. Items that fail at night, i.e., between 1800 and 0600 hours, are not repaired at that time but are placed in the CT queue. They wait until daytime to be examined.

When an item fails, there is a probability (currently set at 80%) that CT diagnosis is required. In such a case, a CT is transported to the item and determines whether it can repair the item (i.e., if the failure requires no more than 2nd- or limited 3rd-echelon repair) or whether the item must be evacuated to the seabase. The causes of the remaining failures (i.e., 20%) are considered relatively obvious, so that the item user can diagnose the failure and then request a CT if one is required for repair. CT's will repair end items after diagnosis unless

- repair parts outside the seabase are required,
- a replacement is decided upon (based on the item's projected downtime), or
- the echelon of repair required is beyond the capability of the CT.

When repair parts arrive ashore from the seabase, a CT will be reassigned to repair the item if one is not already assigned.

6.4.3 Unit Repair

The model has the capability to examine retention of 2nd- and limited 3rd-echelon repair capability with the units, as opposed to assigning that capability to CT's.

When an item fails and requires 2nd- or limited 3rd-echelon repair, a unit will perform the repair if it has the appropriate maintenance capability. A unit can perform maintenance between 0600 and 1800 hours. Failures occurring during 1800 and 0600 hours will be placed in the unit repair queue to be examined later. The comparison of CT and unit maintenance procedures will be used to establish optimal SMLS maintenance configurations.

6.5 DELAY TIME (STEP 4)

Requests for maintenance encounter various delays, such as:

- Communications
- Administrative
- Equipment preparation
- Equipment evacuation

Delay times were generated by the SMLS Simulation Model for use in the Maintenance Model.

6.6 TRANSPORTATION TIMES (STEP 5)

Transportation events include the movement of end items from the seabase to the shore and back and the movement of CT's from one point ashore to another. (Since CT's are transported ashore in the morning and returned to the ship each evening, this transportation time is not considered to add to equipment downtime.)

6.7 COMPUTATION OF DOWNTIME (STEP 6)

6.7.1 Characteristics of Downtime

The downtime for an item during the mission represents the total time the item is not operating. When an item fails, it is necessary to project its downtime which consists of

- transportation time
- communication time
- repair time
- queueing time
- time waiting for parts

The downtime cannot be computed precisely when an item fails because all relevant events have not yet been generated. The predicted downtime is used as a criterion for replacing a failed item. It is compared to an input criterion to determine whether the item is to be replaced.

Downtime is projected for

- items to be repaired at the seabase
- items to be repaired by CT or unit during the daytime, whether the failure occurred during the day or during the night

For each of these situations, a maintenance space will either be available or unavailable at a given time, and the associated queue will be either occupied or empty. Thus, in projecting the downtime each situation can be categorized as follows:

- Category A - Queue empty, space available
- Category B - Queue empty, space unavailable
- Category C - Queue occupied, space unavailable
- Category D - Queue occupied, space available

Equations used for calculating downtime are shown in Table 2. Derivations of these equations and definitions of terms are given in Sections 6.7.2 through 6.7.4.

6.7.2 Seabase Repair Downtime

For categories A, B, and C at the seabase (Table 2) the term "queue" means the total number of end items in the seabase queue ashore and those in the queue located at the seabase. If the queue is empty (no items waiting for repair) and repair space is available (Category A), then

TABLE 2 - DOWNTIME PROJECTION FORMULAS

Queues	Empty		Occupied	
Category	A	B	C	D
Location of Repair \ Personnel and/or space	Available	Unavailable	Unavailable	Available
Seabase	$RT_{FI} + 2T + C$	$RT_a = \frac{RT_{FI}}{NS}$ $RT_{FI} + RT_a + 2T + C$	$RT_b = \frac{\underline{\Sigma RT \text{ items in queue}}/NQ}{NS}$ $RT_{FI} + [NQ]RT_b + 2T + C$	Only shore queue can be occupied. Afloat queue must be empty if personnel or space available. If NS>NQ, Cat.D≡Cat.A NS=NQ, Cat.D≡Cat.B NQ>NS, Cat.D≡Cat.C
CT or Unit (Daytime Failure)	$2RT_{FI} + KT_s$	RT_a as above $2RT_{FI}+2RT_a+KT_s$	RT_b as above $2RT_{FI}+2[NQ]RT_b+KT_s$	Not possible
CT or Unit (Nighttime Failure)	$2RT_{FI} + KT_s + 6$	RT_a as above $2RT_{FI}+2RT_a+KT_s+6$	RT_b as above $2RT_{FI}+2[NQ]RT_b+KT_s+6$	If NS>NQ, Cat.D≡Cat.A NS=NQ, Cat.D≡Cat.B NQ>NS, Cat.D≡Cat.C

$C = \begin{cases} 6, \text{ day failure} \\ 12, \text{ night failure} \end{cases}$

$K = \begin{cases} 0, \text{ for unit repair} \\ 1, \text{ for CT repair} \end{cases}$

RT, Repair Time
RT_{FI}, Repair time of failed item (See Section 6.11)
T, Transportation time ship-to-shore
T_s, Transportation time shore-to-shore
NQ, Number of items in the particular queue
NS, Number of repair resources: either repair spaces at the seabase or number of contact teams

downtime, $DT = RT_{FI} + 2T + C$. RF_{FI} is the repair time of the failed item, 2T represents one trip to the seabase and one from the seabase, and C is 6 hours for day failures and 12 hours for night failures. The factor C adjusts the downtime for items failing or being repaired at night, when no transportation is available, and for other delays. If the queue is empty but repair space is unavailable (Cat. B), $DT = RT_{FI} + RT_a + 2T + C$, differing from (Cat. A) by the term $RT_a = \frac{RT_{FI}}{NS}$, where NS is the number of repair spaces at the seabase. This term approximates the time the item waits for a space to become available. If the queue is occupied and space is unavailable (Cat. C), then $DT = RT_{FI} + RT_b(NQ) + 2T + C$, where

$$RT_b = \frac{\Sigma RT \text{ items in queue}/NQ}{NS} .$$

The numerator of RT_b, $\frac{\Sigma RT}{NQ}$ gives an average repair time for the queued items. Dividing by NS gives the average wait for repair for the first item in the queue, i.e., RT_a. Since there are NQ items in the queue, there is a total expected wait expressed by NQ x RT_b. Category D, where the queue ashore is occupied and (seabase) personnel are available, can only exist at night (transportation is not available). The shore queue builds up while the seabase repair process continues to decrease the length of the queue afloat. The projected DT formulas for CT and unit repair with nighttime failures will be covered in paragraph 6.7.4.

6.7.3 Downtime for CT and Unit Repair (Daytime Failures)

Categories A, B, and C apply to CT or unit repair of items failing during the day. Category D is not possible during the day. The same formulas are used for the CT and unit, since repair capabilities of both are available for 12 hours a day. Repair by CT differs from repair by unit in the transportation factor K. For unit repair K is zero; no transportation is required. For CT repair K is one, one trip required. Categories A, B, and C for the CT and unit are of the same form as for the seabase case, but with a factor of 2 applied to the repair times. This factor is used to compensate for the fact that the CT and unit perform repair during only half of the day.

6.7.4 Downtime for CT and Unit Repair (Nighttime Failures)

The downtime computations for nighttime failures of items in Categories A, B, and C are of the same form as for the corresponding daytime failure categories, except for the additional six hour term which represents an average wait until daylight. However, the downtime computation for items in Category D will depend on the values of NS and NQ. Category D will change to either Category A, B, or C in the morning, depending on NS and NQ. The downtime formula for the category changed to in the morning will be used for the item originally in Category D during the night. If, at night, NS > NQ, i.e., more repair resources are available than there are items in the queue, then in the morning this situation will shift to Category A. The queue will be emptied and some repair resources will remain available. If NS = NQ, in the morning all the queued items will be repaired, and Category B will be reached. The queue will be empty and resources will be unavailable. Last, if NQ > NS, more items are waiting than can be repaired. In the morning this condition will result in Category C, resources unavailable.

Category D, seabase repair of items failing during the night, uses the same rationale as CT and unit repair of items failing during the night. Thus the items in the seabase queue ashore must wait until morning for transportation to the seabase and cannot be repaired during the night.

The length of the projected downtime determines whether a replacement will be requested. Two criteria are input to the model, one for routine and one for urgent response. If the item requires only routine response and the projected downtime is less than 36 hours, no replacement is requested. If the item requires urgent response and the projected downtime is less than 24 hours, no replacement is sent. If either criterion is exceeded, replacements are sent if available.

6.8 REPLACEMENT OF FAILED ITEMS FROM THE OPERATIONAL READINESS FLOAT (ORF) OR NON-DEPLOYED UNITS (STEP 7)

Most of the replacements come from the ORF, which is the inventory of selected replacement items located at the seabase. ORF levels are dependent on end item type, criticality, cost, weight, volume, and usage factor.

When an item is replaced ashore, the unit registers a smaller down-time than if a replacement were not sent. When an item is replaced, an exchange is made; the unit owns the replacement item and the failed item is then owned by the ORF. Consequently, after the failed item is repaired, it is sent to the ORF. The unit will not necessarily get its original item back.

A reserve replacement capability is provided through selective use of items in the non-deployed units (NDU) at the seabase. In the model, about 10% of the items in the NDU are designated as available as replacements should the need arise. These NDU items are treated in the same way as are the ORF items. When an item fails and a replacement from the NDU is issued, the replacement item belongs to the unit which owned the original failed item. After the original failed item is repaired, it will be sent to the non-deployed unit from which the replacement came.

6.9 QUEUES (STEP 8)

When all capabilities are being utilized, queues are established as required at the seabase, ashore for items awaiting transportation to the seabase, at units were maintenance is provided, and ashore for items to be repaired by CT's. Since different repair facilities are organized for each subcommodity and there is no sharing of repair personnel among different subcommodities, each such facility will have a separate queue associated with it. Up to three different echelons of repair (2nd, 3rd, and 4th) can be represented in each queue.

6.9.1 Seabase Queue

Two queues are associated with the seabase, one ashore and one at the seabase. Since there is limited space for queuing items at the seabase, a queue will be established ashore for items unable to wait at the seabase. When a vacancy exists at the seabase queue during the day, the first item in the queue ashore will be transported to the seabase queue. However, since transportation is not available for items that fail at night, they will be queued ashore even if the seabase queue afloat is not full.

6.9.2 CT Queue

If CT's are not available, items requiring repair will enter a queue established ashore. The items in the CT queue will not be physically positioned in the queue, but ordered chronologically by failure time. Thus, CT's will be transported to items and will attempt to repair them in the order in which they fail.

6.9.3 Queue Representation in Multi-Ship Configurations

The model is used to simulate operations of both MAU- and MAB-size forces. One maintenance ship with eight separate shops and queues is assumed sufficient to support a MAU. Two such ships are required for the MAB. However, the model assumes repair is provided by only one ship. Rather than change the model, it was assumed that one ship would be utilized by the MAB, but the number of ship shops and the queue limitations were doubled to simulate the capacity provided by two ships.

6.10 PRIORITY (STEP 9)

A priority scheme with four levels is used to decrease the downtime of failed items which are to be repaired in the seabase. Priorities are assigned to items only while they are waiting in the seabase queue. The items in the queue are ordered by priority. The higher the priority of the item, the shorter is the wait in the queue. The four priorities starting with the highest are:

> Priority 1 - assigned to failed items, not replaced, for which the requirement is urgent.

- Priority 2 - assigned to failed items, not replaced, for which the requirement is routine.
- Priority 3 - assigned to failed items that have been replaced and, after repair, will be used to restock the inventory, which has dropped to zero.
- Priority 4 - failed items which have not yet been assigned a higher priority or which will be used to restock the inventory which has not dropped to zero.

Priorities 1 and 2 are assigned to items which are repaired without being replaced. Downtime is registered at the unit until the item is sent back after repairs. Thus, by minimizing the item's wait in the queue, the downtime is also minimized. Priority 3 is assigned to items that have been replaced but where the remaining level of the ORF for that item is zero. The priority then minimizes the wait for repair of the item destined for the ORF (the failed item was replaced). Priority 4 is assigned to all items which do not qualify for a higher priority.

6.11 REPAIR TIME (STEP 10)

To simulate repair of an item, a repair time is generated by the following algorithm:

$$TTR = - MTTR \ln(RN)$$

where TTR is the time to repair

MTTR is the mean time to repair

RN is a random number generated from a uniform distribution from 0 to 1.

The derivation of this algorithm is similar to the derivation of the algorithm for TTF in Section 6.1.

An item which fails and is to be repaired will be transported to its location of repair, and a repair time will be generated using the above algorithm for time to repair (TTR). TTR represents only the time actually spent in repairing the item, and does not include delays, queuing times or transportation times.

6.12 REPAIR PARTS (STEP 11)

Maintenance cannot be simulated without taking into account the supply subsystem. A major interaction between maintenance and supply is caused by repair parts requirements of failed items. When items fail, repair parts may be required to complete the repairs, and if so the parts must be requested. The seabase has an inventory of repair parts, but any parts not available there must be requested from outside the seabase.

A probability specified in the input is used with a random number generator (see Section 7, Step 15) to determine whether repair parts are required upon item failure. If the parts exist in the seabase, they can be transported from the seabase during daytime. Parts not available in the seabase will be transported from outside the seabase, taking from 10 to 25 days, depending on the location of the parts and the mode of transportation (see Section 7, Step 54).

If the parts exist at the seabase and the item is repaired at the seabase, the parts are assumed to be in the vicinity and repair is not interrupted. If the repair is performed at the unit or by CT, item repair will be discontinued until parts arrive from the seabase.

During CT or unit repair, if parts required do not exist at the seabase, the failed item will be evacuated to the seabase. A replacement will be sent automatically if available because the downtime will exceed either criterion mentioned in Section 6.9. Items waiting for parts at the seabase are not ordered in any fashion. Once repair parts arrive at the seabase the appropriate item is placed at the front of the queue ahead of items not yet examined for parts.

SECTION 7
DETAILED MODEL LOGIC FLOW

In the following flow diagram (Figure 2) all decision boxes are numbered and are referred to in the text by number. Trapezoidal boxes indicate that the flow is to be transferred to the segment of flow headed by the box with the same title.

At the beginning of the simulation t = 0 (mission start), a time to failure for each end item ashore is generated using the exponential distribution as described in Section 6.3. The items are examined in the order of their failure times. The item with the earliest failure time is examined first and so on for all items in one commodity class through all four classes. The logic presented in the flow charts is followed for each end item in the Landing Force in the order of occurrence of failure. An echelon of repair is then generated through entry into a uniform random distribution and if that echelon of repair capability is available (for the appropriate commodity class) either at the unit or seabase, the item can be repaired. The failure distribution includes provisions for discarding items either because they are beyond repair or because repair is not economical.

The flow begins when an end item fails ashore. A probability of 80% is specified that an item will require a CT diagnosis before repair. If a CT is required for diagnosis (1), and the failure occurs during the day (i.e., between the hours of 0600 and 1800) (2), and if there is sufficient time to transport a CT to the item (minimum of 1 hour before 1800)(3), and a CT is available (4), the CT will be transported to the failed item. If any of these conditions is not satisfied, the failed item is added to the CT queue. If a CT is not required for diagnosis (probability of 20%) (1), the item user will diagnose. If an item is beyond repair (probability of 1%) (5), it will be discarded. If the repair echelon is not available (probability of 1%) in the ATF (6), the item will be stored. In either case, the flow segment REPLACEMENT is entered to obtain a replacement item. If the repair echelon is available

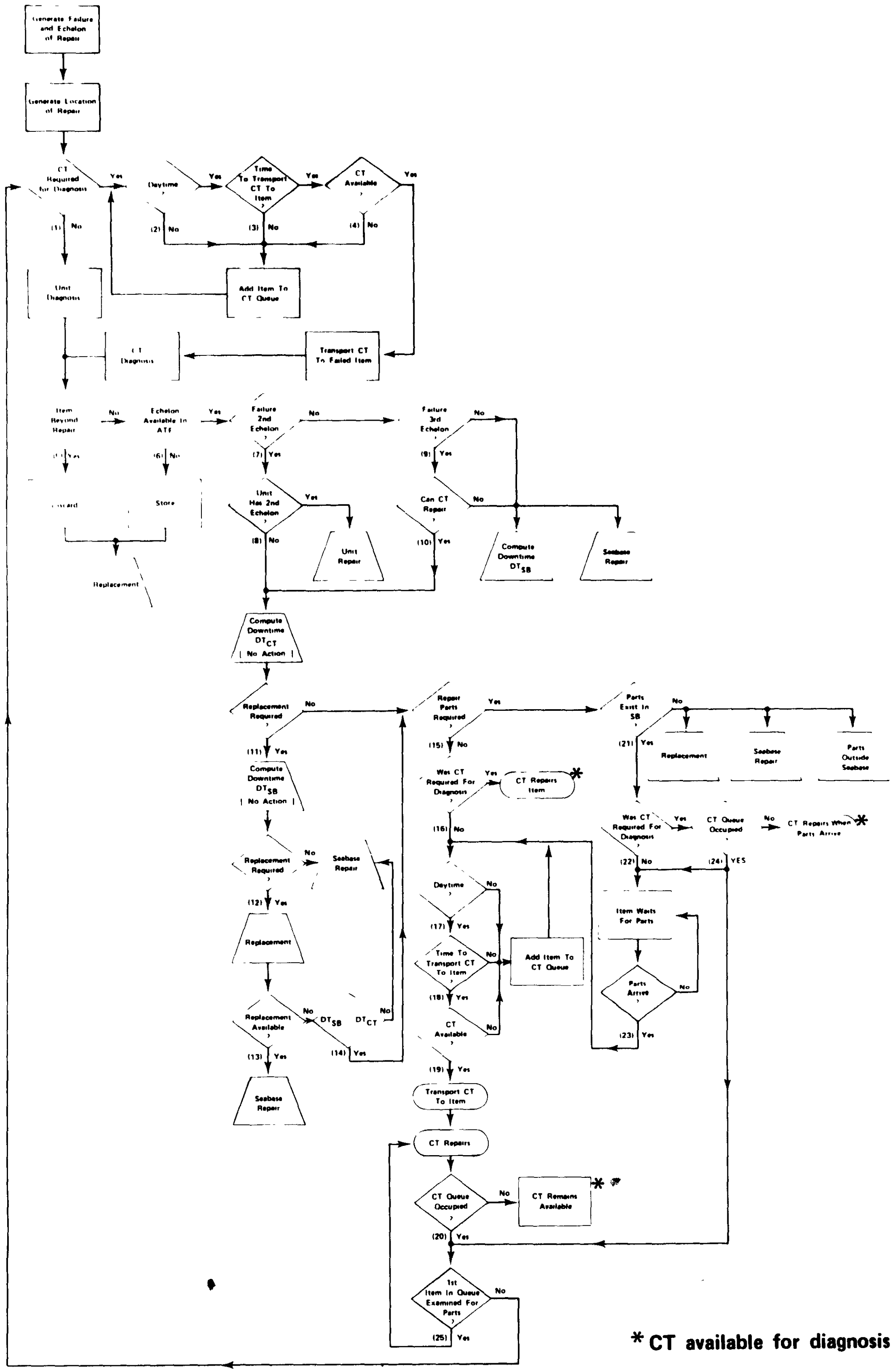


Figure 2 - Maintenance Model Logic Flow

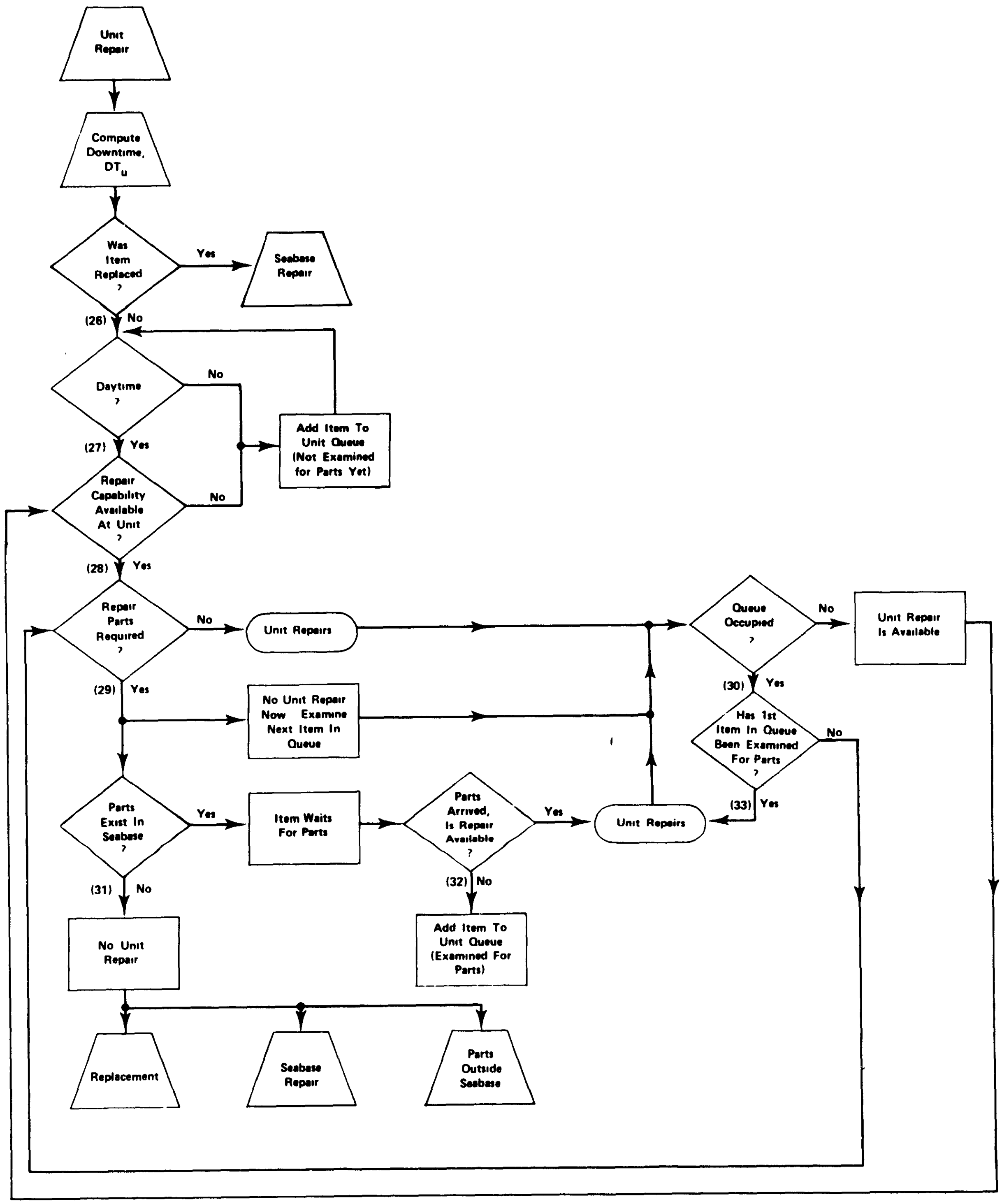
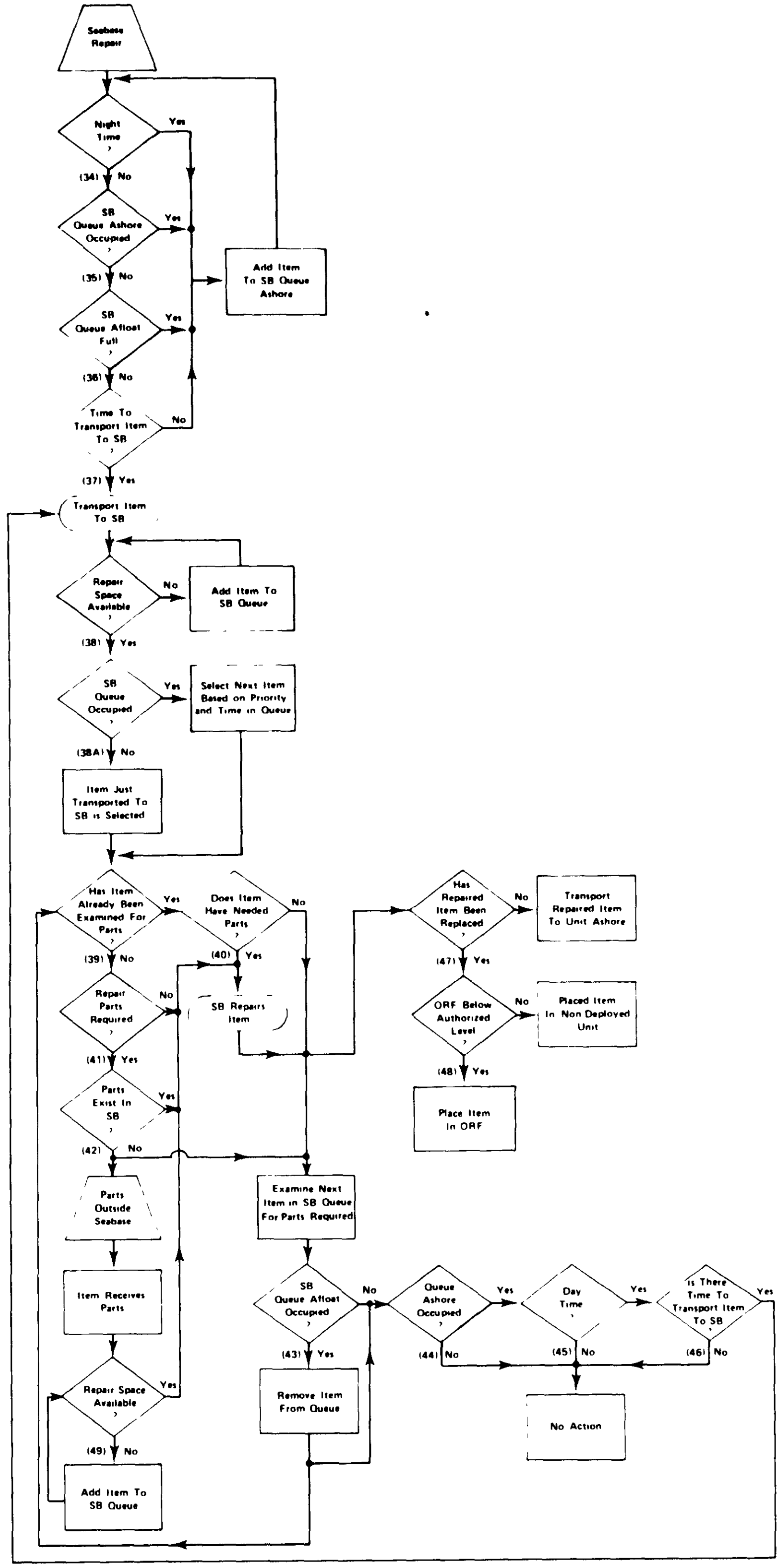
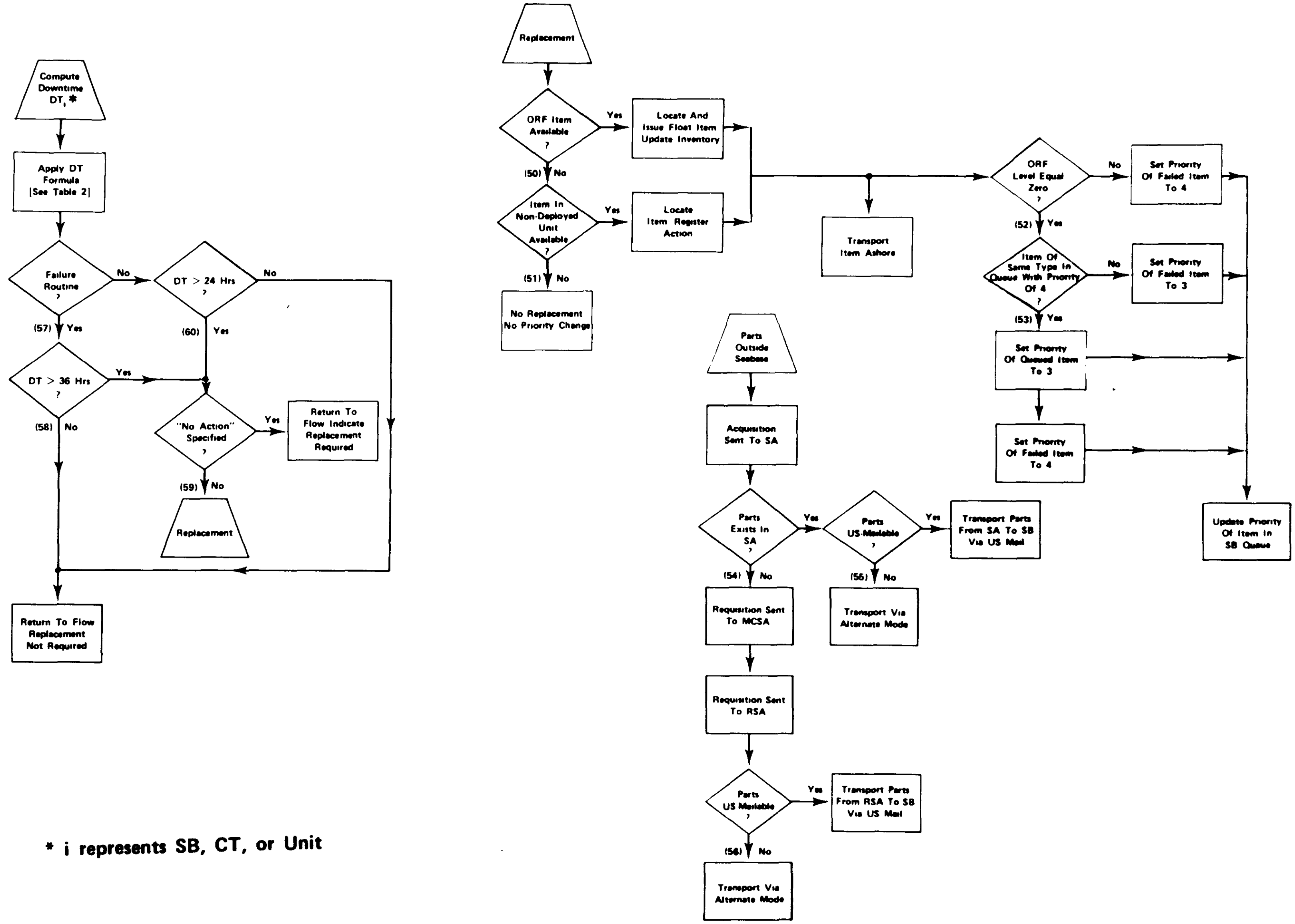


Figure 2 - (Cont'd)



NOTE: Items are selected after box 49 on the same basis as indicated in box 38A.

Figure 2 - (Cont'd)



* i represents SB, CT, or Unit

Figure 2 - (Cont'd)

in the ATF (6), and the failure requires only 2nd-echelon repair (57% probability) (7), and the appropriate unit has a 2nd-echelon capability (8), the flow segment UNIT REPAIR is entered. If 3rd-echelon repair is required (probability of 36%) (9), and the CT cannot repair the item (10), the flow segment COMPUTE DOWNTIME, DT_{SB} is entered to determine whether a replacement is required. Flow segment SEABASE REPAIR is also entered. If 3rd-echelon repair is not sufficient (9), then 4th-echelon repair is required (probability of 5%) and the flow enters COMPUTE DOWNTIME, DT_{SB}, and SEABASE REPAIR.

If decision (8) is "no" or decision (10) is "yes," the flow enters COMPUTE DOWNTIME, DT_{CT}, to determine whether the projected downtime is sufficient to require a replacement. For the Engineer, Motor Transport, and Ordnance Commodity Classes, the probability that a CT can repair is 100% for 2nd-echelon and 15% for 3rd-echelon maintenance. For Communications-Electronics, the probability that a CT can repair is 40% for 3rd-echelon maintenance. If a replacement is required (11), the flow enters COMPUTE DOWNTIME, DT_{SB} to determine whether the projected downtime for seabase repair would also be great enough to require a replacement. If a replacement is not required (12), based on the seabase projected downtime criterion, the flow enters SEABASE REPAIR. If a replacement is required (12), the flow enters REPLACEMENT. If a replacement is available (13), the flow enters SEABASE REPAIR and the failed item is repaired at the seabase. If a replacement is not available (13) and the downtime projected for repair at the seabase, DT_{SB}, is less than the downtime projected for repair by CT, DT_{CT} (14), the flow enters SEABASE REPAIR. If DT_{SB} is greater than or equal to DT_{CT}, a CT will repair and the flow goes to decision (15).

If a replacement is not required (11), and parts are not required (probability of 40%) (15), and if a CT is required for diagnosis (16), the CT will repair the item. If a CT is not required for diagnosis and it is daytime (17), and if there is sufficient transportation time available (18), and a CT is available (19), the CT will be transported to repair the item. If a "no" results from either (17), (18), or (19), the CT will not repair at this time, and the item will be added to the CT queue. After the CT repairs an item, the queue is examined (20). If it is not occupied, the CT remains available; otherwise the first item in the queue will be examined if it has not already been examined (25) and the flow repeats at (1). If the item has been examined and has any needed parts (25), the CT will repair the item and the flow repeats at (20). Items that have been examined and require parts are not queued until the parts arrive.

If parts were required (probability of 60%) (15) and they existed in the seabase (probability of 80%) (21), and if a CT was not required for diagnosis (22), the item waits for its parts. When they arrive (23), a CT is required and the flow repeats at (17). If a CT was required for diagnosis (22) and the queue is not occupied (24) (no items waiting), the CT will remain until the parts arrive and repair the item. If the queue is occupied (24), it is examined (25) to determine the next item for the CT to repair and the flow repeats. In addition, the failed item waits for parts and the flow repeats at (23). If parts are to be obtained from outside the seabase (probability of 20%) (21), the flow goes to SEABASE REPAIR, REPLACEMENT, and PARTS OUTSIDE SEABASE. Since the downtime of items requiring parts from outside the seabase will always be greater than the specified criterion, a replacement is required.

If the unit has 2nd-echelon repair capability (8), the flow enters UNIT REPAIR. The projected downtime for repair at the unit is computed by the flow segment COMPUTE DOWNTIME, DT_U. If the item is to be replaced (26), the flow enters SEABASE REPAIR. If the downtime criterion is not exceeded, or it is exceeded but a replacement is not available (26), and if it is daytime (27) and resources are available at the unit (28), the unit will repair. If either (27) or (28) is "no," the item will be placed in the unit queue. When resources are available at the unit (28), and repair parts are not required (29), the unit will repair. After repair, if the unit queue is not occupied (30), the unit's repair resources remain available. If the unit queue is occupied (30) and the first item in the queue has been examined to see if repair parts are required (33), the unit repairs that item and the flow repeats at (30). If the first item in the queue has not been examined for parts requirements (33), the flow repeats at (29).

If repair parts are required (29), the unit will not repair at this time. The queue is examined and the flow repeats at (30). If parts exist in the seabase (31), the item waits at the unit for parts. If resources are available at the unit when the parts arrive (32), the unit repairs and the flow repeats at (30). If personnel are not available (32), the item with its parts is added to the front of the queue. When parts do not exist in the seabase (31), flow enters SEABASE REPAIR, REPLACEMENT, and PARTS OUTSIDE SEABASE.

If the failure occurs during nighttime; i.e., between 1800 and 0600 hours (34), items destined for seabase repair are placed in the queue ashore. If it is daytime (34) and the queue ashore is not occupied (35), and if the seabase queue is not full (36), the item will be transported to the seabase if there is sufficient time (37); i.e., if it is not later than 1400 hrs. However, if the seabase queue ashore is occupied, the item is placed in that queue (35). Occupancy of this queue during the day indicates the seabase queue afloat is full. If the seabase queue ashore is empty (35) but the queue at the seabase is full (36), the item is placed in the queue ashore. If the seabase queue has vacancies but there is insufficient time for transportation before dark (37), the item is placed in the seabase queue ashore. After the item is transported to the seabase and if a repair space is not available (38), the item is added to the repair queue at the seabase. If a space exists (38) and the seabase queue is occupied (38A), an item will be selected from the queue based on priority and time in queue. If the seabase queue is not occupied (38A), the item just transported to the seabase is selected to be repaired. If the item has already been examined to see if repair parts are needed (39) and has any needed parts (40), the item will be repaired. If the item does not yet have its parts (40), the next item in the queue will be examined. If the item has not been examined before (39) and repair parts are not required (41), the item will be repaired. If the item needs parts (41) and if the parts exist in the seabase (42), the item will be repaired. If repair parts are required from outside the seabase (42), the flow enters PARTS OUTSIDE SEABASE. Since this leaves a vacant repair space, the next item in the queue will be examined. If the seabase queue is occupied (43), the first item will be removed, and the flow repeats at (39). If the seabase queue is not occupied and if the queue ashore is also not occupied (44), or if it is not daytime (45), or if there is insufficient time for transportation (46), then no action will be taken. If (44), (45), and (46) are "yes," the item is transported from the queue ashore to the seabase queue.

After an item that was replaced (47) is repaired at the seabase, if the ORF levels are not below that authorized (48), the repaired item is placed in the non-deployed unit from which the replacement was removed. If the ORF level is below that authorized (48), the item is placed in the ORF. If the item was not replaced (47), the repaired item is transported ashore.

When parts ordered from outside the seabase are received, and when a repair space becomes available (49), the item will be repaired. If space is not available (49), the item will be added to the repair queue at the seabase.

When a replacement is required, the flow enters REPLACEMENT. If an ORF item is available (50), it is located, issued, and transported ashore. If an ORF item is not available (50) but replacement from a non-deployed unit is possible (51), the item is sent ashore. If neither source has a replacement, no action is taken. If, after an item has been issued, the ORF level is non-zero (52), the priority of the failed item is set to 4 in the queue. If the ORF level becomes zero (52) and there is an item of the same type in the queue with a priority of 4 (53), the priority of the queued item becomes 3 and the failed item receives a priority of 4. If there is no similar item in the queue with a priority of 4 (53), the failed item receives a priority of 3.

When repair parts are required from outside the seabase, the flow enters PARTS OUTSIDE SEABASE. If the parts exist in the Stock Account (SA) (probability of 70%) (54) and if they are US-mailable (probability of 80%) (55), they are sent to the seabase, taking 10 days. If the parts are non-US-mailable (probability of 20%) (55), they are transported by other means, taking 20 days. If the parts do not exist in the associated stock account (SA) (probability of 30%) (54), the requisition is sent to the Marine Corps Supply Activity (MCSA) and then to the Remote Storage Activity (RSA) from which the parts are sent. If the parts are US-mailable (56), they are sent that way, taking 15 days; if not, they are sent by other means, taking 25 days.

To predict the downtime (as described in Section 6.7) in order to determine whether a replacement is required, the flow enters COMPUTE DOWNTIME, DT_i (where i stands for seabase, CT, or unit). The downtime is computed by one of a set of formulas described in Table 2. If the failure is routine (57) and DT is less than 36 hours (58), no replacement is required. If DT is greater than 36 hours (58), unless the "no action" branch has been specified (59), the flow enters REPLACEMENT. If "no action" has been specified (59), then a return to the flow is made indicating that a replacement is required. If the failure is not routine (i.e., urgent) (57) and if DT is less than 24 hours (60), no replacement is required. If DT is greater than 24 hours (60), flow goes to (59).

SECTION 8
MAU ANALYSIS

8.1 CONVENTIONAL VS. SMLS SUPPORT

The entire MAU is loaded aboard ships of the ATF during the embarkation phase of an amphibious operation and then is transported to the AOA during the movement phase. Up to the start of the assault phase, the type of logistic support utilized; i.e., whether it is SMLS or conventional, does not affect the operation. In the assault phase of a conventional operation, the entire MAU is disembarked from the ATF and deployed ashore. Maintenance support is an integral part of the MAU ashore. In an SMLS operation, most if not all of the maintenance support is retained aboard ships of the ATF while the remaining portion of the MAU is deployed ashore, and the ships of the ATF form a seabase providing maintenance support (and other logistics functions) to the deployed MAU. Table 3 summarizes the differences in the two systems.

Since the SMLS maintenance support in terms of personnel, repair parts, and maintenance equipment is located aboard ships, the MAU has a reduced maintenance capability when it disembarks. Consequently, the MAU deployed ashore, when supported by SMLS, is smaller than a MAU supported conventionally. Whether or not SMLS is utilized during a mission, the total MAU is loaded during the embarkation phase, since the capability must always exist to convert from SMLS to conventional support.

A MAU was especially configured along present day Marine Corps organization lines for use in this study. The table of organization (T/O) and the table of equipment (T/E) are such that within the conventional MAU organization personnel and equipment can be identified which are to be deployed ashore as the Landing Force when the MAU is supported by SMLS. The remaining personnel and equipment of the conventional MAU are retained at the seabase. Therefore, forces of two sizes can be examined: (1) The total MAU ashore (conventional) and (2) the SMLS force; i.e., a portion of the total MAU. Both forces have the same size ORF from which to draw replacement end items.

TABLE 3 - COMPARISON OF SMLS AND CONVENTIONAL MAU MAINTENANCE PROCEDURES

AMPHIBIOUS OPERATION PHASE	SMLS	CONVENTIONAL
Embarkation	MAU Personnel, supplies, and equipment loaded on ships	
	Additional space may be required aboard ships for operation of non-deployed maintenance support and non-deployed units.	
Movement	Transport embarked force to AOA	
Assault	Disembark portion of MAU and deploy ashore. [Reduced force because of minimal logistics support ashore]	Disembark entire MAU and deploy ashore.
Support	Ships in ATF form seabase to provide logistic support to deployed forces ashore during mission.	ATF may or may not leave area depending on mission. Logistics support provided by forces ashore.

The following terms are used in discussing the alternative approaches.

Total Force - Total MAU embarked; the same for SMLS and conventional logistic support.

Deployed Force - That part of the MAU which is deployed ashore to perform the mission. In conventional operations, the total MAU is deployed.

Non-Deployed Force - That part of the MAU which remains at the seabase, relevant to SMLS only. (Includes shop and CT personnel and the non-deployed units (NDU)).

ORF - Operational Readiness Float used in both SMLS and conventional operations. In SMLS, the ORF is located at the seabase; in the conventional approach, it is positioned ashore as part of the total force.

Two scenarios[8] were used in the comparison of conventional vs. SMLS support. Scenario I is a relatively intense, short-duration (10-day) operation with the battalion headquarters, four infantry companies, headquarters and service support company, and an artillery battery deployed ashore. Scenario II is a crisis-deterrence/counterinsurgency operation of longer duration (90 day) with the battalion headquarters, three infantry companies, and limited combat support deployed ashore.

8.2 MAINTENANCE CAPABILITY

SMLS - The maintenance support at the seabase consists of overflow 2nd-echelon repair capability (repair that cannot be accomplished ashore), all 3rd-echelon capability, and a limited 4th-echelon maintenance capability. Limited 4th-echelon maintenance is simulated in the model by assigning a probability of 50% that 4th echelon repair can be performed at the seabase. Items which require 4th-echelon maintenance, and which cannot be repaired, are stored for subsequent action. Ashore, CT's can perform 2nd- and limited 3rd-echelon maintenance.

Conventional - The conventional MAU locates a 2nd-echelon maintenance capability at the units for most commodity classes and overflow 2nd- and all 3rd-echelon capability at the Logistic Support Unit (LSU). No 4th-echelon capability is available. Equipment requiring 4th-echelon repair is stored or evacuated.

8.3 MEASURES OF EFFECTIVENESS

In this analysis, the measure of equipment readiness used is the end item availability, the probability that at a given time an item or a group of items is operational. In SMLS, the availability of items in the deployed forces measures the equipment readiness of only those items which have been deployed ashore. The availability of items in the total force measures the equipment readiness of (1) the items deployed ahsore, (2) the items in the non-deployed forces, and (3) the items in the ORF. However, the non-deployed items are not being operated, and are thus not liable to fail. It is assumed at the beginning of an operation that when required, these non-deployed items will all be available. In the conventional organization where there are no non-deployed forces, only the availability of items in the total forces (including the ORF) is considered. Normally the greater the utilization of ORF items, the lower will be the availability of the ORF items.

The average daily failure rate per 100 items (ADFR) is also used to indicate system performance. For items in each commodity or subcommodity class ADFR is defined as follows:

$$\frac{100 \text{ X } NF}{ML \text{ X } NI}$$

where

ML is the mission length in days

NF is the total number of failures for each commodity or subcommodity class during the mission, and

NI is the number of items in each subcommodity class.

The failure rate is computed for each subcommodity class. The higher the failure rate, the more failures will occur during the mission. The

ADFR is a function of the frequency of failures and of the level of equipment utilization. The ADFR will vary among items because of the different reliabilities. A third quantity used to display performance is the downtime expressed both in total hours and in hours/failure.

8.4 EQUIPMENT READINESS RESULTS FOR SCENARIOS I AND II

Figure 3 illustrates that for the two scenarios the Radio, Artillery, and Infantry Weapons subcommodity class end items have the lowest ADFR's. Tank and AMTRAC (LVT) end items (Scenario I only) have the highest failure rates and Teletype, Engineer, and Motor Transport end items lie between the two extremes. Figures 4 through 9 are graphs of availability versus mission duration in days for all subcommodities. Figure 10 presents availability results for end items in all subcommodities.

8.4.1 Discussion of Scenario I Results

Of all the classes in the MAU, LVT's and Tanks show the greatest descrease in availability as illustrated in Figure 8, where the LVT and Tank curves are shown to drop to below 90% in 10 days. The next worst performance is exhibited by the Engineer equipment whose availability is graphed in Figure 6. However, this availability curve does not decrease as rapidly as either the LVT or Tank curve.

The average downtime per failure (DT/F)* is plotted in Figure 11 for the various subcommodity classes. For Scenario I, the DT/F ashore is highest for LVT and Tank items because no ORF items of these subcommodity classes are embarked and the average repair time is longer than for other subcommodities. The high DT/F is also due to the low reliability of the equipment. The high failure rates and lack of ORF items combine to produce a 13% decrease in availability for Tank and LVT items over a 10-day period. However, even if a group of equipments has a low reliability, as in the case of Tank or LVT items, the DT/F can be decreased through the addition of ORF items.

*DT/F is defined as the total hours of downtime registered for all items of a given subcommodity, divided by the total number of failures experienced by items of that subcommodity during the mission.

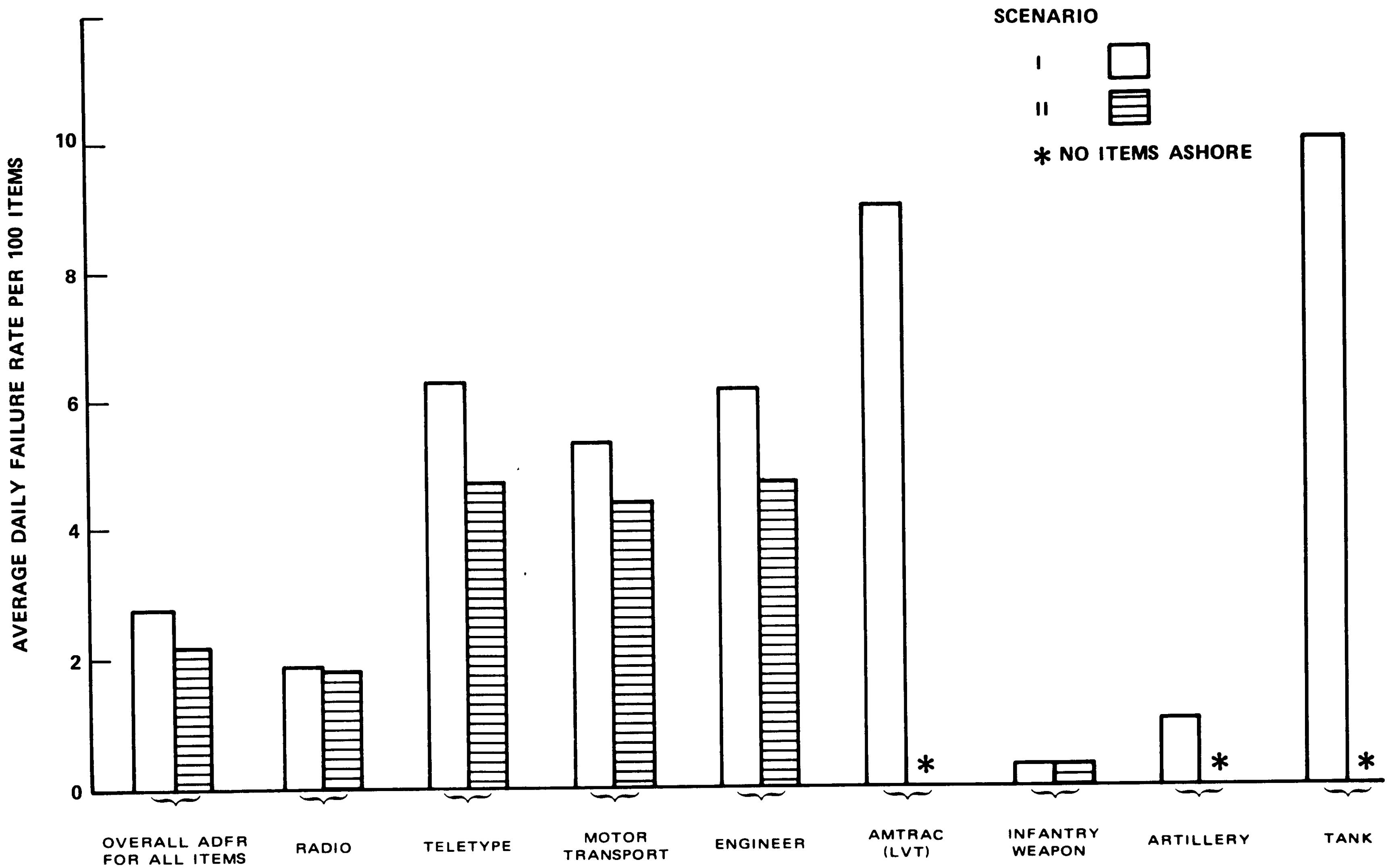


Figure 3 - Average Daily Failure Rate (ADFR) per 100 Items - MAU Scenarios I and II

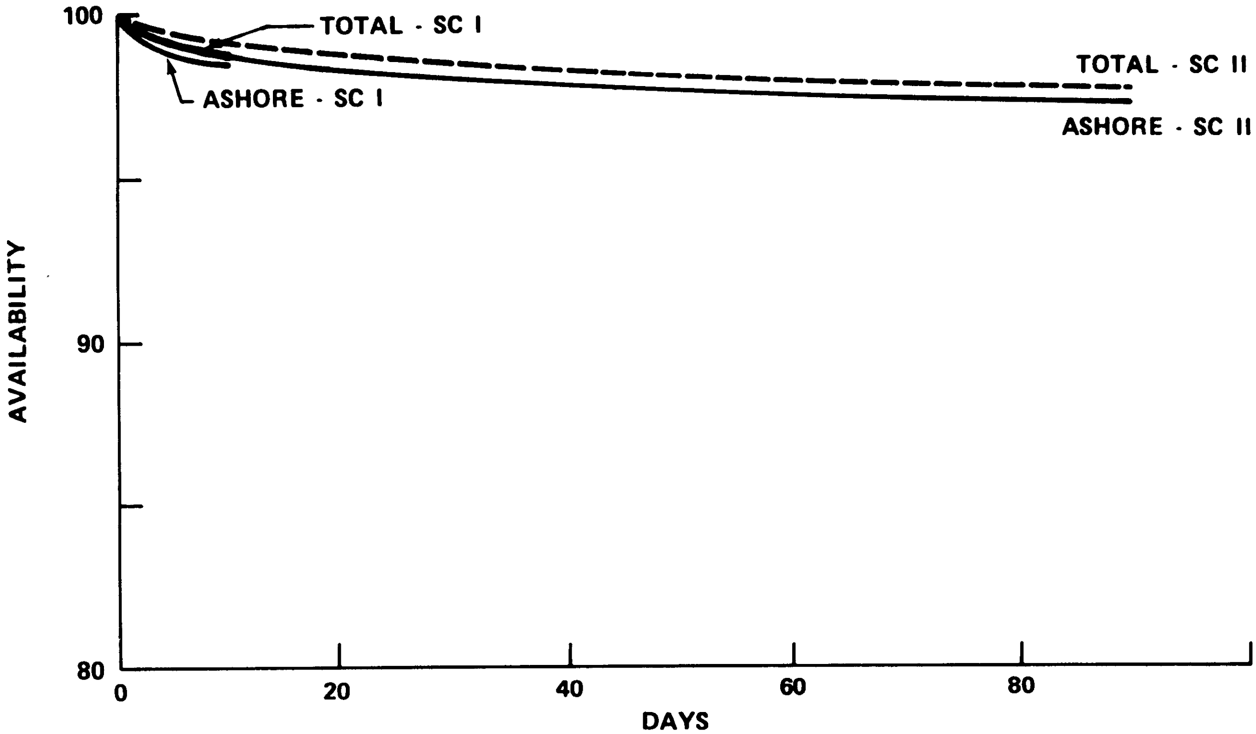


Figure 4 - Radio Equipment Availability - MAU Scenarios I and II

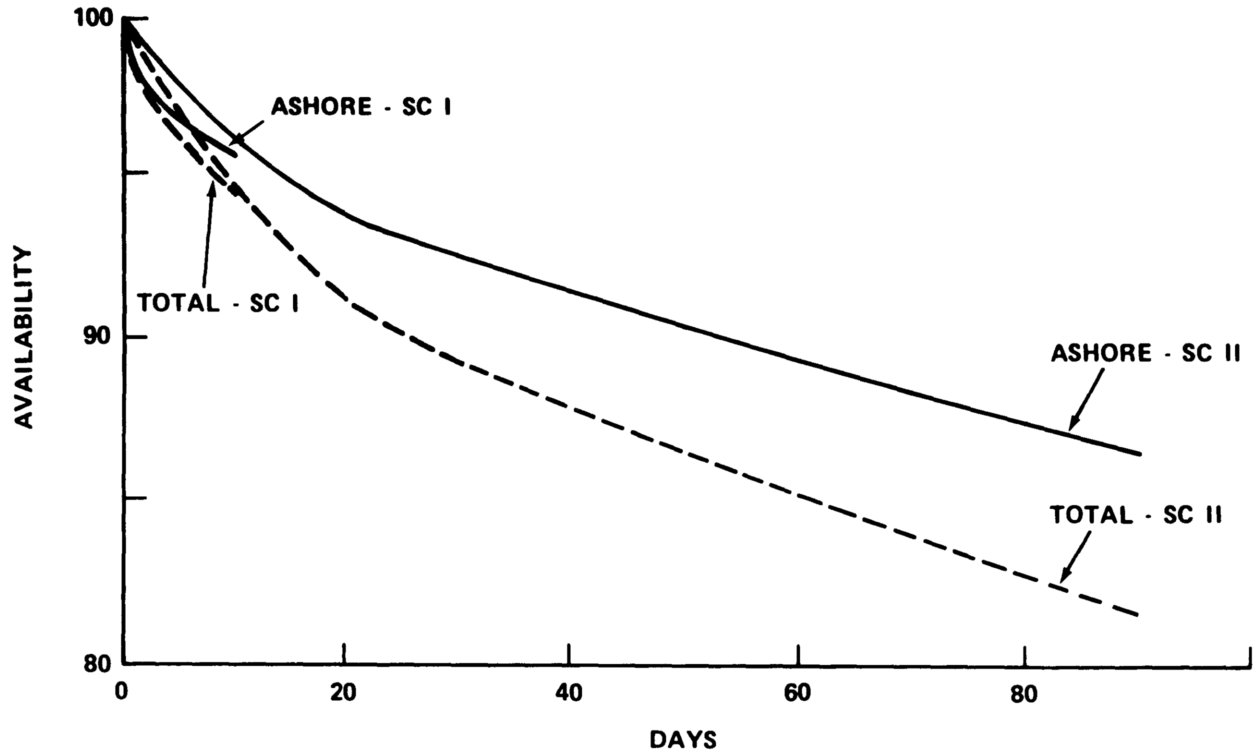


Figure 5 - Teletype Equipment Availability - MAU Scenarios I and II

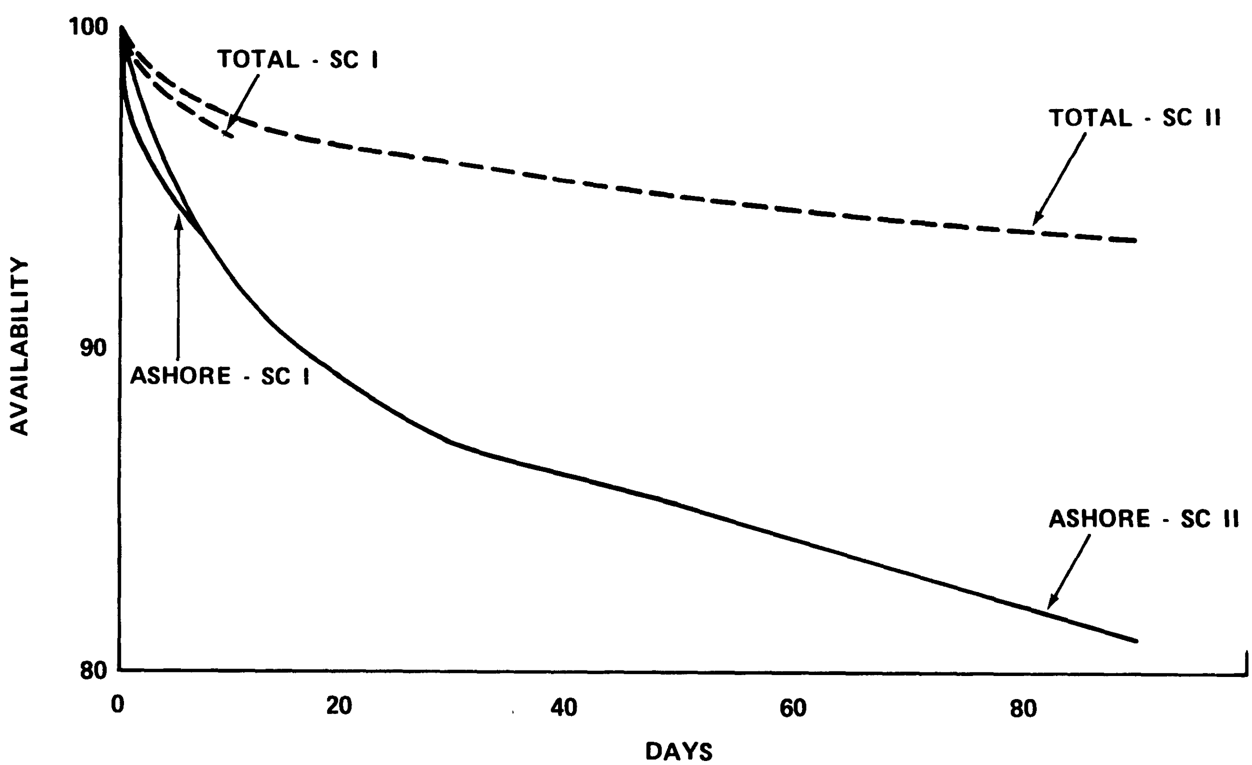


Figure 6 - Engineer Equipment Availability - MAU Scenarios I and II

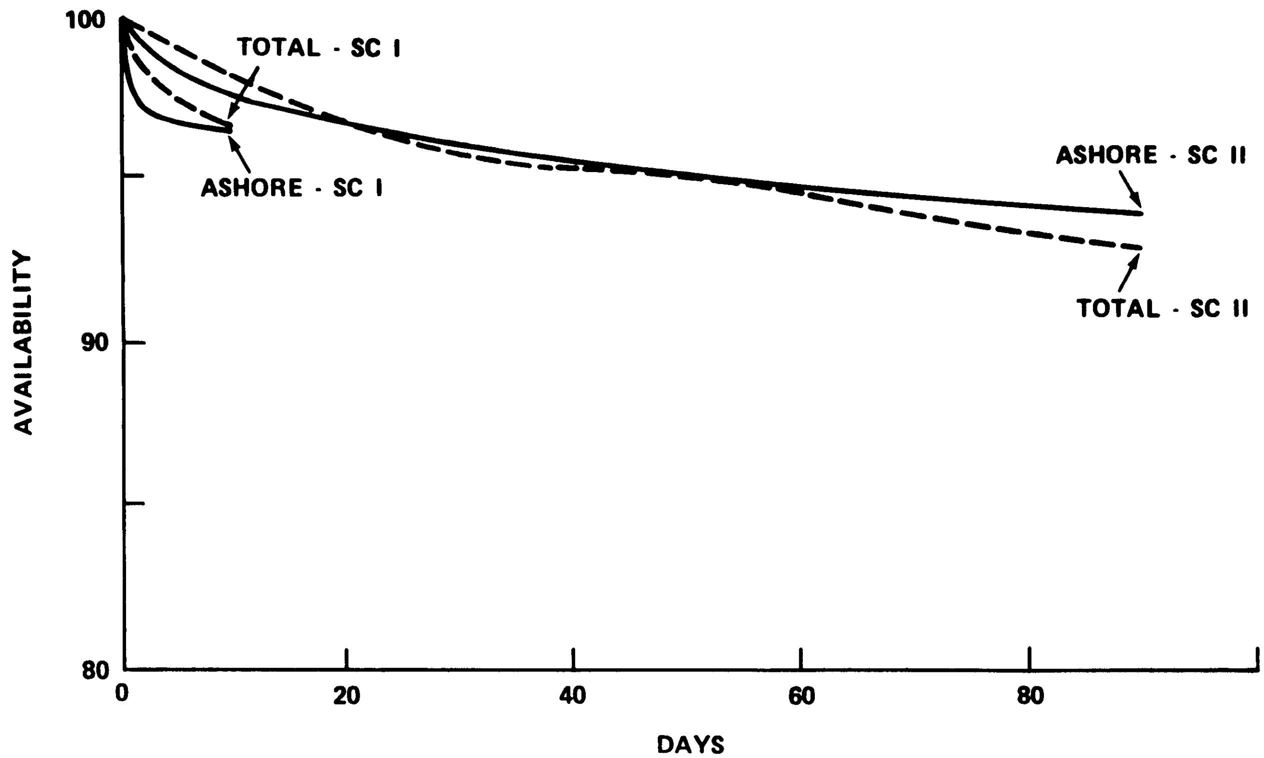


Figure 7 - Motor Transport Equipment Availability - MAU Scenarios I and II

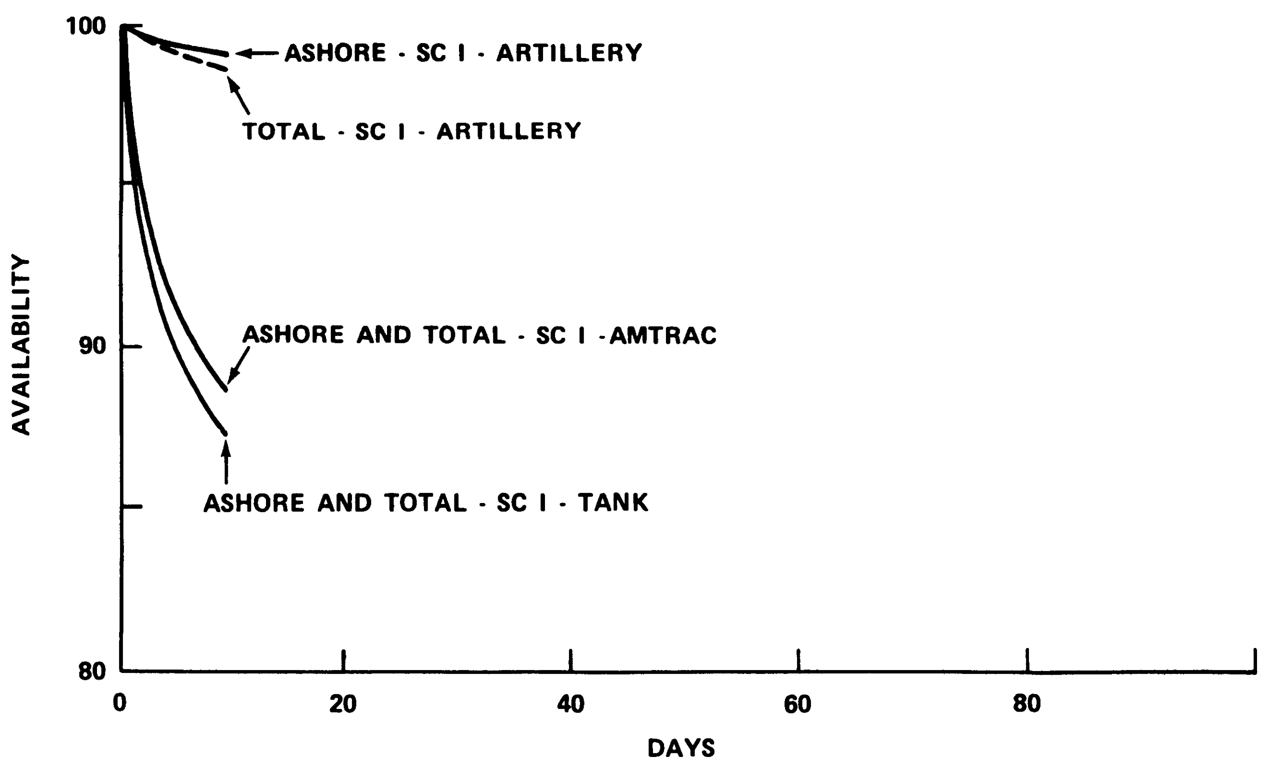


Figure 8 - Artillery, AMTRAC, and Tank Equipment Availability - MAU Scenario I

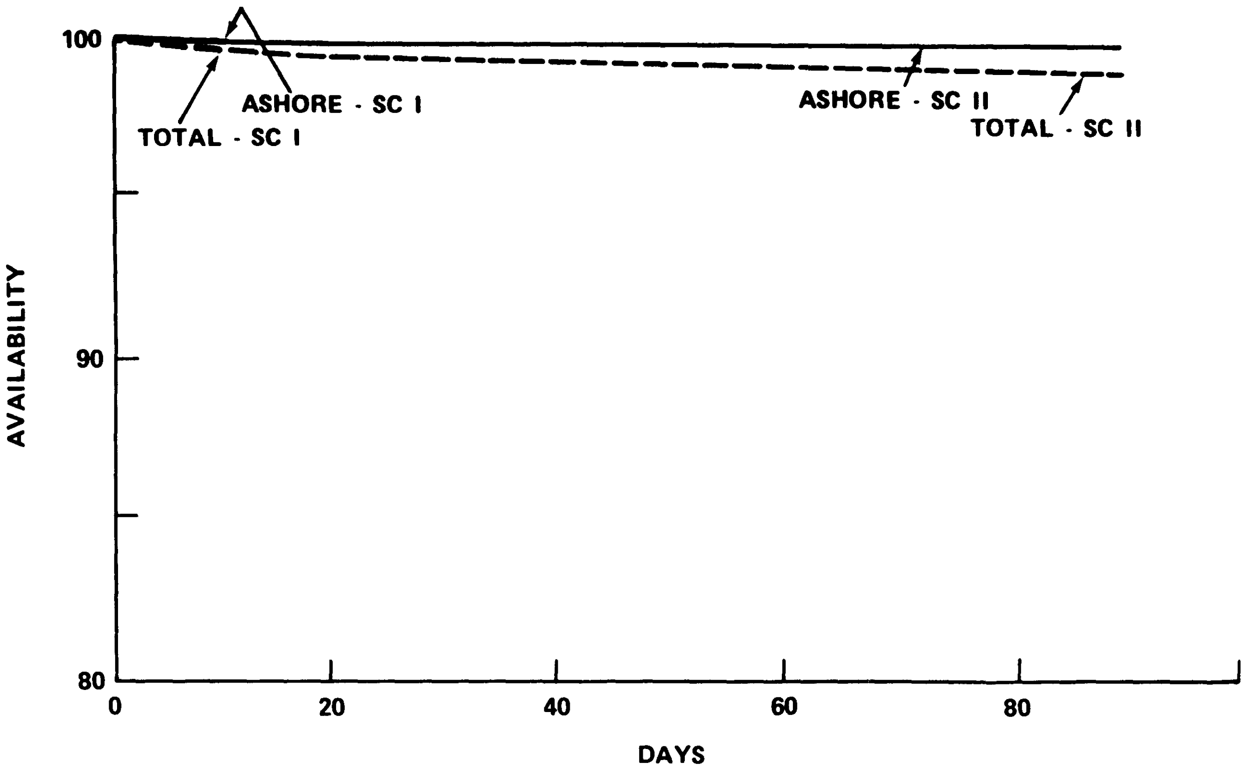


Figure 9 - Infantry Weapon Availability - MAU Scenarios I and II

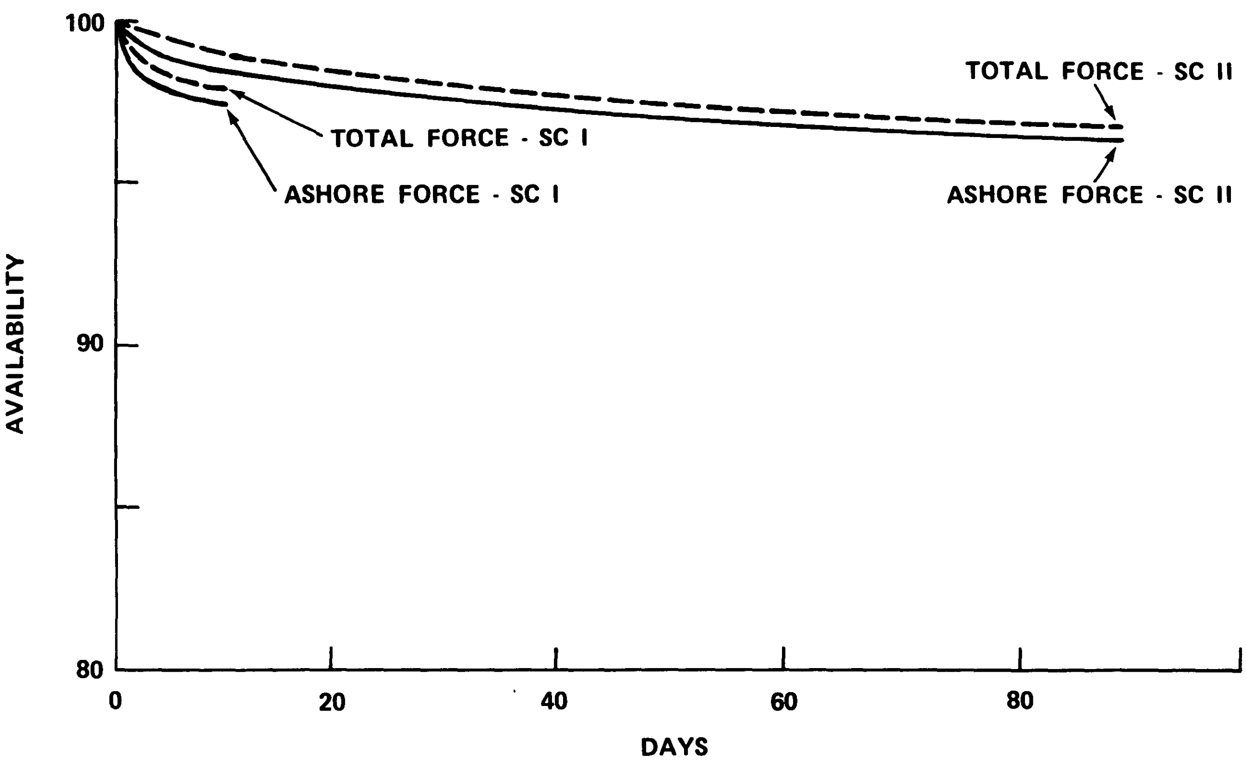


Figure 10 - Overall Ground Equipment Availability - MAU Scenarios I and II

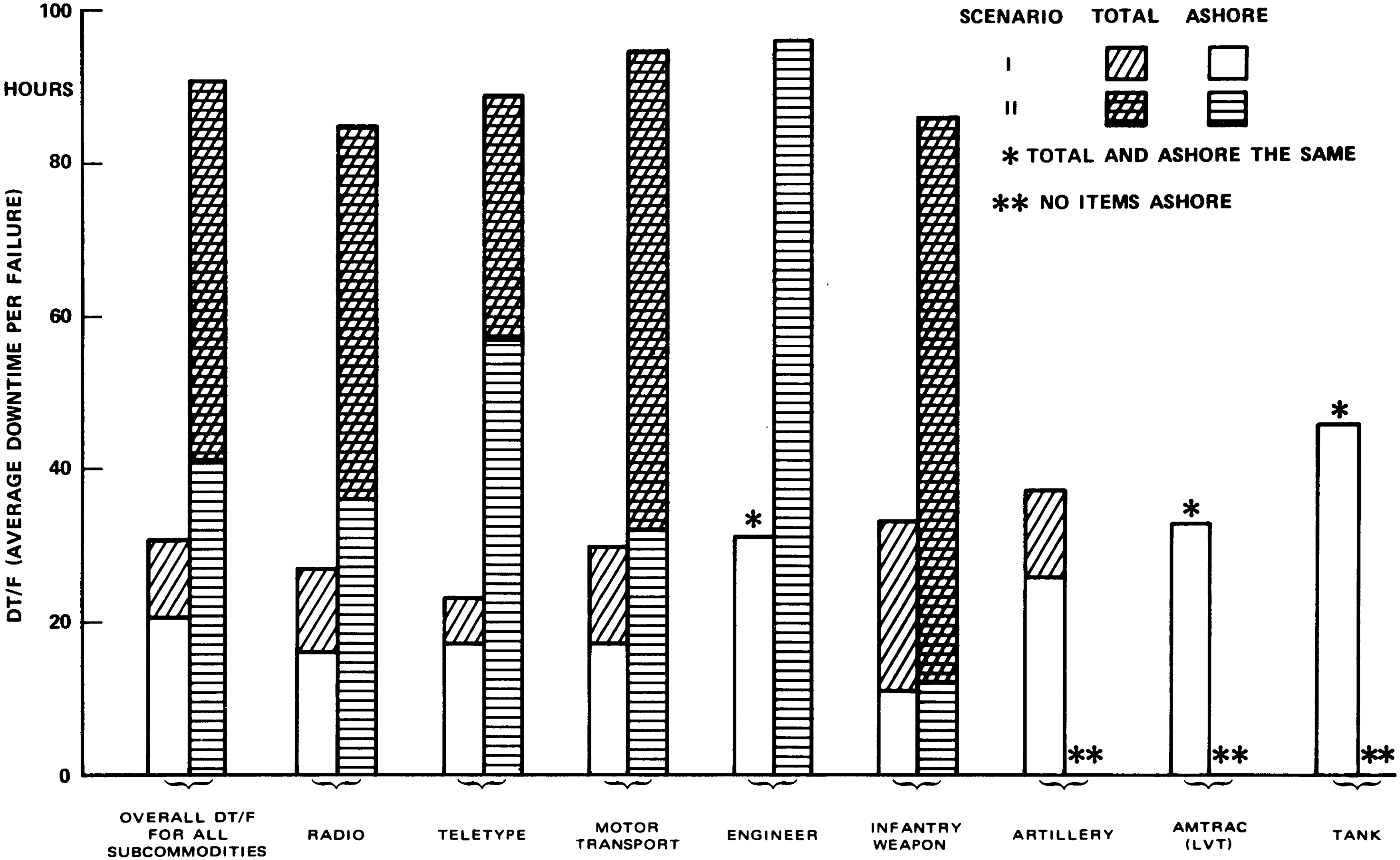


Figure 11 - Average Equipment Downtime per Failure (DT/F) - MAU Scenarios I and II

Artillery items have a DT/F of 37 hours for the total force and a DT/F of 26 hours for the ashore force. Since all items are deployed, the only difference between the numbers of items in the total and ashore forces is one ORF item. The existence of this one replacement item permits a transfer of registered downtime from the ashore force to the total force, which decreases the DT/F by 35%. LVT items, for example, are all deployed, and the total and ashore DT/F for this subcommodity class are the same because there are no ORF items. The other subcommodity classes which have ORF items (except Engineer) have lower ashore DT/F than total DT/F, indicating the effect of the ORF items on DT/F and availability. The higher the number of ORF items, the lower is the ashore DT/F when compared to the total. Radio, Motor Transport, and Infantry items, which have high ORF levels, have an average DT/F ashore of 16.4 hours, lower by 26% than the overall average of 21.4 hours. The average total DT/F for these three subcommodities is 30.1 hours, only 3% below the overall average of 31.1 hours. Therefore, the utilization of ORF items increases the ashore-force availability markedly, but has a minimal effect on the total force availability.

8.4.2 Discussion of Scenario II Results

No Artillery items, LVT's, and Tanks are deployed ashore in this scenario and consequently are not considered in the analysis. There are 235 items ashore in Scenario II, compared to 315 for Scenario I. Utilization and failure rates are identical to those used in the analysis of Scenario I. The effect of utilization of ORF items is more evident in the DT/F values in this scenario than in Scenario I. Greater DT values are experienced than in Scenario I because the longer mission duration (90 days) requires that more repair parts be requested from outside the sea-base and causes more items to be discarded. The DT/F for just Motor Transport, Radio, and Infantry items, is 33 hours for the ashore force and 90 hours for the total force. For all subcommodities these figures are 41 and 91 respectively. The presence of ORF items in these three subcommodities accounts for their downtime being 20% lower than the downtime for all subcommodities. This indicates the advantage of ORF items in decreasing DT/F in a mission of 90 days with a SMLS configured force.

8.4.3 Comparison of Scenarios I and II

Scenario II had 459 failures over 90 days or an average of 51 failures for a 10-day period; Scenario I had 87 failures over a 10-day period. The average numbers of failures per day for items of each commodity class are illustrated in Figure 12. The overall DT/F ashore for all end items for Scenario II is twice that for Scenario I; and the overall DT/F for the total force for Scenario II is 3 times that of Scenario I, as indicated in Figure 11. This comparison stresses the effect that delays awaiting repair parts and the discarding of items (that have not been replaced) have on downtime. To decrease the DT/F it is necessary to (1) carry more repair parts in the seabase, thus reducing the rate at which repair parts are ordered outside the seabase, and (2) carry more ORF items for high-failure subcommodities in the seabase. Both of these actions carry penalties by increasing costs and increasing space requirements.

Finally, availability of the items of the total MAU, shown in Figure 10, suffer relatively little decrease over 90 days. The presence of a large number of items with high availability offsets the effect of fewer items with low availability. Therefore, the total force on the whole has the appearance of high availability, even though some items of various subcommodity classes have much lower availabilities than the average. These items have much greater impact on the performance of the mission (as shown by ashore force availability curves) than the curves in Figure 10 would indicate.

8.5 COMPARISON OF SMLS AND CONVENTIONAL MAU'S

There are two differences between the SMLS and the conventional MAU. First, limited 4th-echelon repair can be performed at the seabase under SMLS. Only up to 3rd-echelon repair can be performed ashore in the conventional MAU. Second, in SMLS the time to transport failed items to the seabase from the shore is two hours. In the conventional MAU the time to transport failed items to the maintenance facility ashore; i.e., Logistic Support Area/Beach Support Area (LSA/BSA) is one hour. ORF levels are the same for both MAU'S.

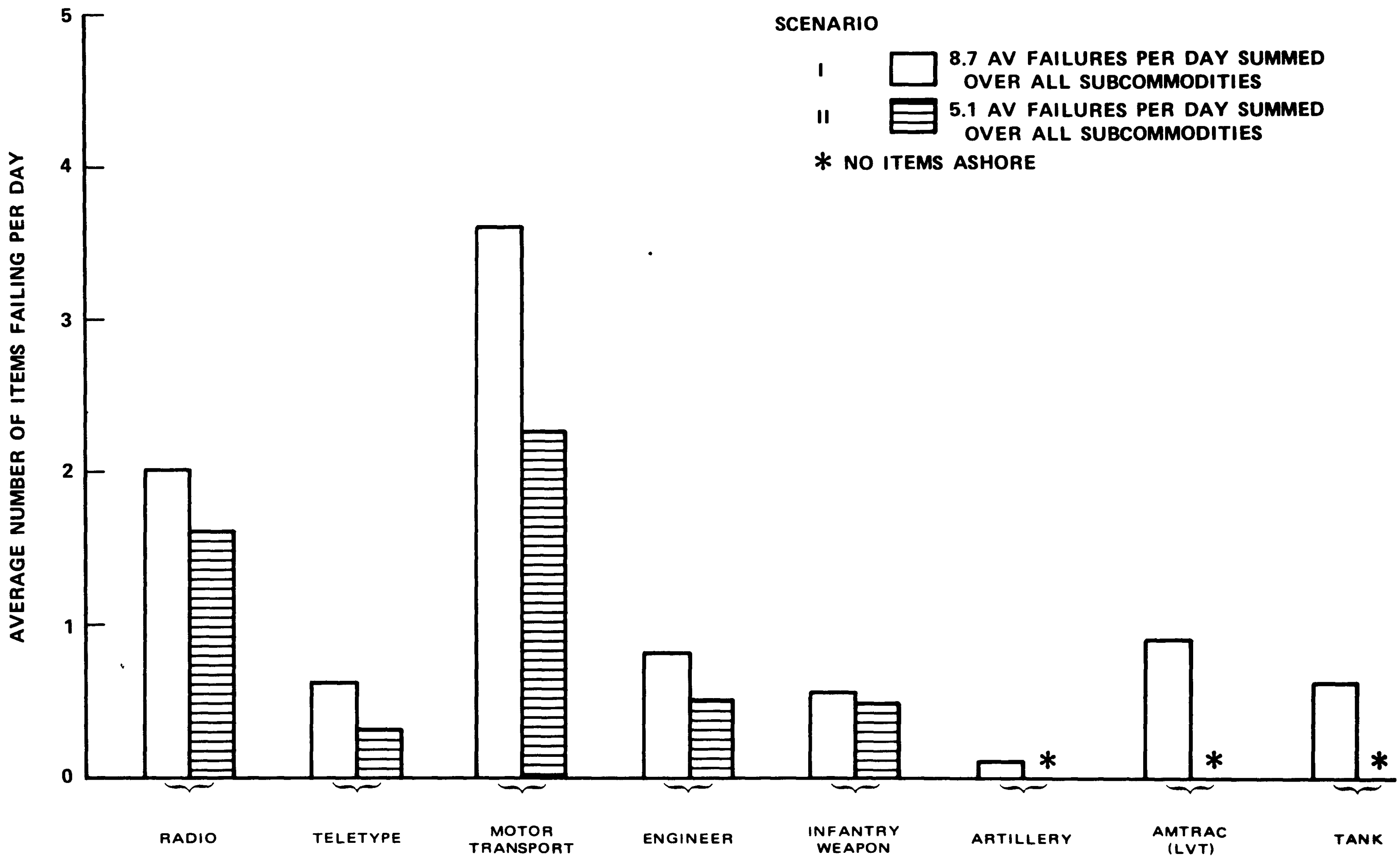


Figure 12 - Average Number of Equipment Failures per Day - MAU Scenarios I and II

8.5.1 Scenario I Availability

The difference in availability in 10 days between SMLS and conventional maintenance performance was so small (1%) for all subcommodities that plots of the conventional MAU data are not presented in this report. This result shows that from the standpoint of availability there is little reason to choose one approach over the other in a Scenario of this type.

8.5.2 Scenario II Availability

Availability of equipment maintained by SMLS, for both total and ashore forces, is compared with conventional force equipment availability in Figure 13. Because of the large number of non-deployed equipment items (294 out of 555), item availability for the total SMLS force is always greater than item availability for the ashore SMLS force. Availability for the conventional force is always less than that for the SMLS force. Generally, SMLS-maintained end items have a higher availability than those maintained by conventional means, 2% higher at 10 days and 8% higher at 90 days. The longer SMLS operates, the higher is the availability of its equipment compared to the availability of the conventional MAU, because the entire MAU is not deployed ashore in SMLS. Thus, because the entire MAU is ashore in a conventional operation, much more equipment is utilized for logistics and administrative functions than is required for the SMLS MAU. As a result, the larger equipment requirements and higher utilization tend to contribute to lower availability in the conventional MAU. In addition, the conventional MAU has no 4th-echelon maintenance capability whereas SMLS has limited 4th-echelon capability. Thus, since 4th-echelon repairs are not accomplished in a conventional organization, availability decreases compared to an SMLS organization.

The overall conventional force item availability at 90 days is 0.89, for 529 deployed items and 26 ORF items; or a total of 555 items. At 90 days the total SMLS availability is 0.965 for 235 deployed items, 294 non-deployed items, and 26 ORF items; or a total of 555 items. Consequently, for the same mission requirements the SMLS approach, with the same total force as for the conventional MAU, but with only 42% of the

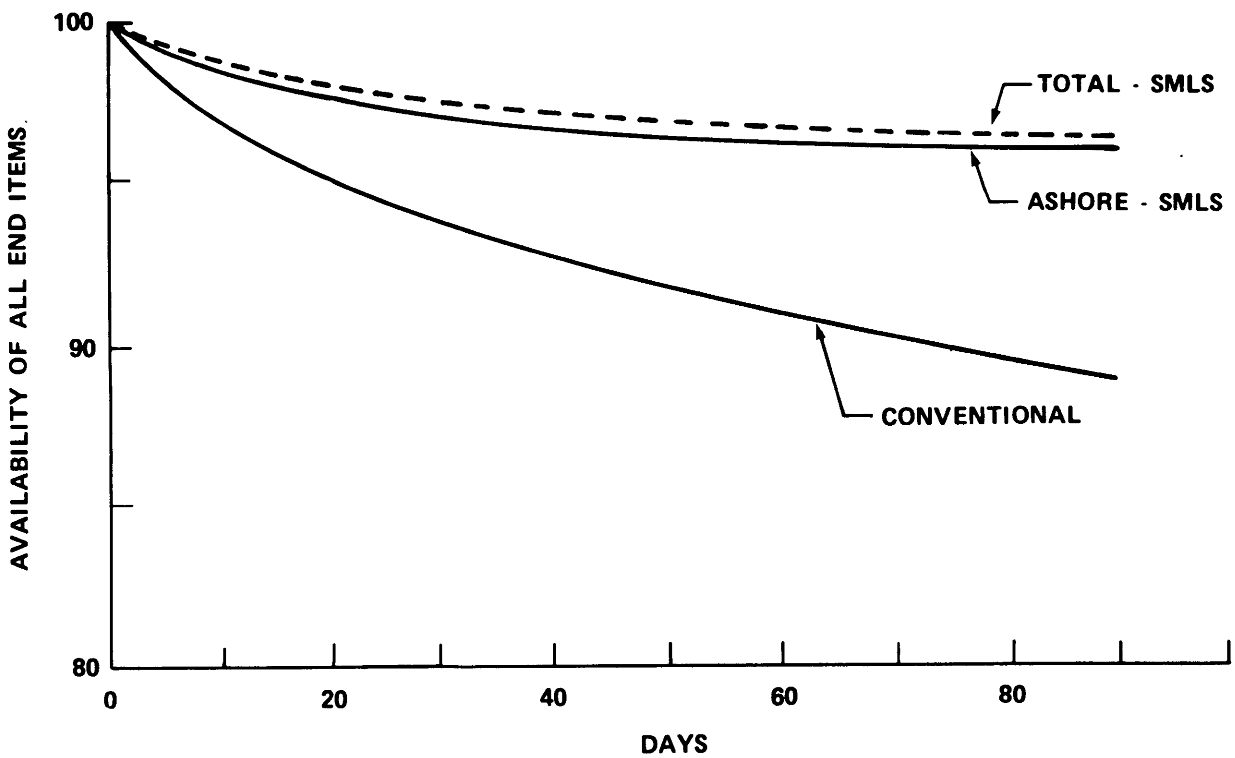


Figure 13 - Availability of Landing Force Equipment Maintained by SMLS vs Conventional MAU Capability - Scenario II

items deployed, has an 8% higher availability at 90 days. The availability of equipment supported by SMLS decreases 3.5% and that supported conventionally by 11.0% in 90 days. Thus conventional force availability decreases three times as much as does SMLS-supported equipment availability.

8.5.3 Comparison of Averaged Downtime Per Failure

(DT/F) comparisons are given in Figure 14 for both scenarios.

Scenario 1 - At 10 days, equipment availability in the conventional organization is less than the availability of SMLS-supported equipment because of high item utilization and lack of 4th-echelon maintenance capability. However, this fact does not affect the DT/F. The conventional maintenance organization has a 2% lower average DT/F than the corresponding value for the SMLS total force even though its availability is lower. In the conventional organization, overflow 2nd- and 3rd-echelon repair and the ORF are located at the LSA/BSA. In SMLS, overflow 2nd- and 3rd- and limited 4th-echelon maintenance and the ORF are located at the seabase. Because maintenance shops are at sea, it is evident that the SMLS organization requires more time to transport items for repair than a conventional organization.

Scenario II - For this scenario, Artillery, LVT, and Tank subcommodities are not required ashore in SMLS, so there is no contribution from these items to the downtime. However, these items are included in the conventional organization since all equipment is ashore. In Scenario II, the DT/F is clearly greater for the conventional organization. For the 90-day mission, total item DT/F under conventional support is 2.8 times the DT/F for items ashore under SMLS but only 1.3 times that for the total force DT/F under SMLS. This behavior indicates that, for a mission duration of up to 90 days, the performance of the conventional maintenance organization is not as good as that of SMLS.

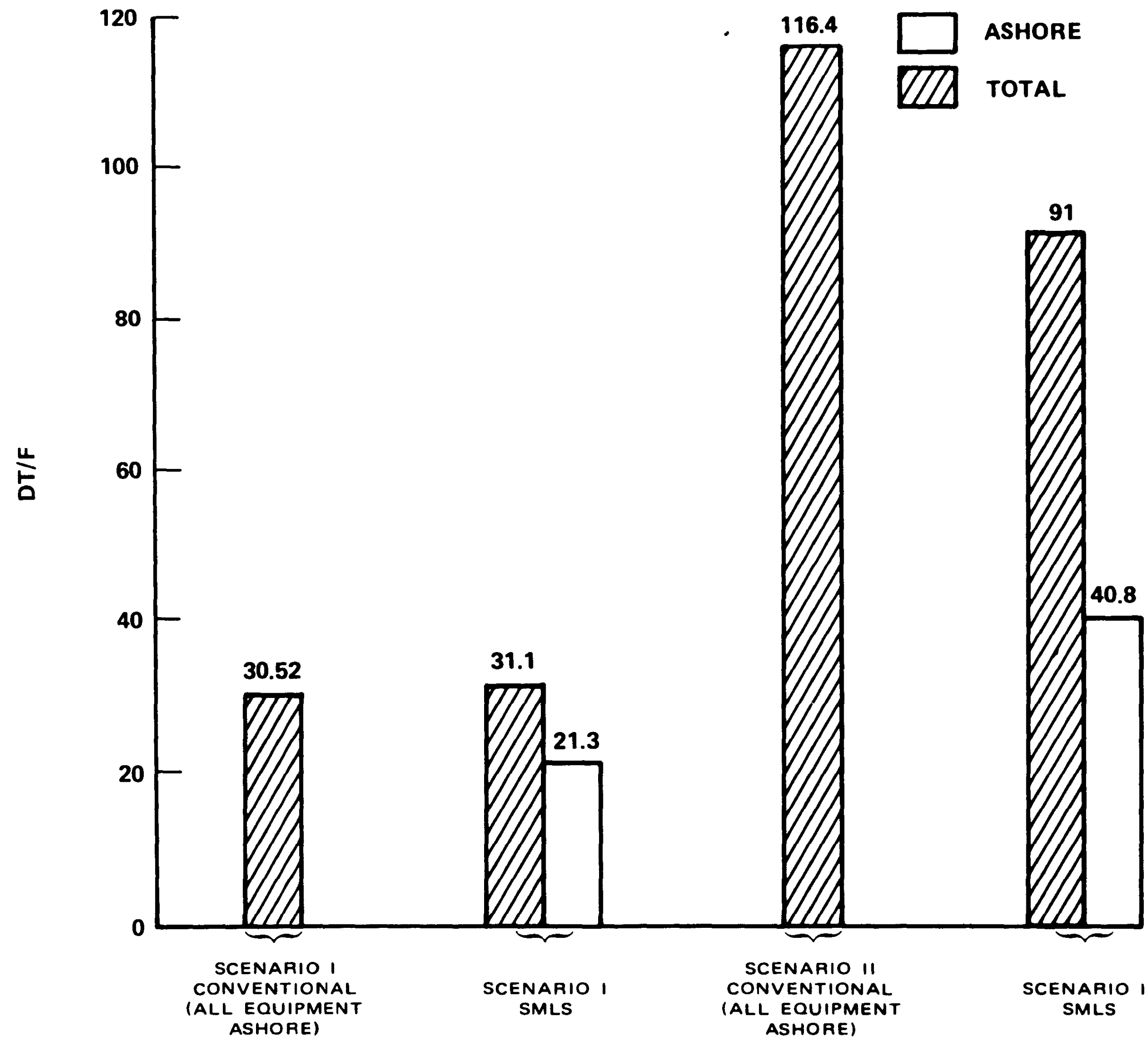


Figure 14 - Overall Equipment Downtime/Failure Comparison Between SMLS and Conventional MAU - Scenarios I and II

8.6 EFFECT OF THE OPERATIONAL READINESS FLOAT

8.6.1 Downtime

The total downtime (for all subcommodities) shown in Table 4, in Scenario I for the ashore force without an ORF* using SMLS is 2625 hours. With an ORF, the downtime of the ashore force is reduced by 32% to 1777 hours. For Scenario II, the total downtime for the ashore force without an ORF is 38,426 hours. With an ORF the downtime is reduced by 51% to 18,735 hours. Thus, the inclusion of an ORF has a marked effect on the downtime of the items of the ashore force.

Without an ORF, items that fail ashore are not replaced. Therefore, downtime is registered by the ashore force until the item is repaired ashore or evacuated and repaired at the seabase and returned ashore. When an ORF is present, the bulk of the downtime is registered (during repair) by the ORF which now owns the failed items. Because the number of operational items during the mission is similar with or without an ORF, an approximately equal number of item failures will occur, and downtime of the total force with an ORF will be similar to the downtime of the ashore force without an ORF, as can be seen in Table 4. The ORF then is a device for transferring the downtime of the ashore force to the ORF while the overall change in downtime (of the total force) is negligible.

8.6.2 Availability

Figure 15 shows a slight difference in availability with and without an ORF for Scenario I. However, in Scenario II the effect of the ORF is more pronounced. By 90 days there is a difference of 4% between the availability of the end items of the ashore force with and without an ORF. Specifically, by 90 days the ashore force with an ORF experiences a decrease of 3.7% in availability and the ashore force without an ORF experiences a decrease of 7.6%. These results indicate

---
* In this context, the ORF refers to all replacement items, i.e., both ORF and NDU items.

TABLE 4

EFFECTS OF UTILIZING AN ORF* ON DOWNTIME

Subcommodity	Number of Items in the ORF	Downtime for 10-Day Scenario			Downtime for 90-Day Scenario		
		Ashore Force w/o ORF	Ashore Force w/ ORF	Total Force w/ ORF	Ashore Force w/o ORF	Ashore Force w/ ORF	Total Force w/ ORF
Radio	19	583	333	586	12,699	5647	13,187
TTY	1	125	83	119	2761	1952	3029
Eng	0	244	244	244	4135	4135	4135
MT	13	1096	602	1097	17,021	6741	19,619
Art	1	38	27	37	--	--	--
LVT	0	301	301	301	--	--	--
Tank	0	154	154	154	--	--	--
Inf	8	84	33	94	1846	260	1808
Overall	42	2625	1777	2632	38,426	18,735	41,778

* In this context, the ORF refers to all replacement items, i.e., both ORF and NDU

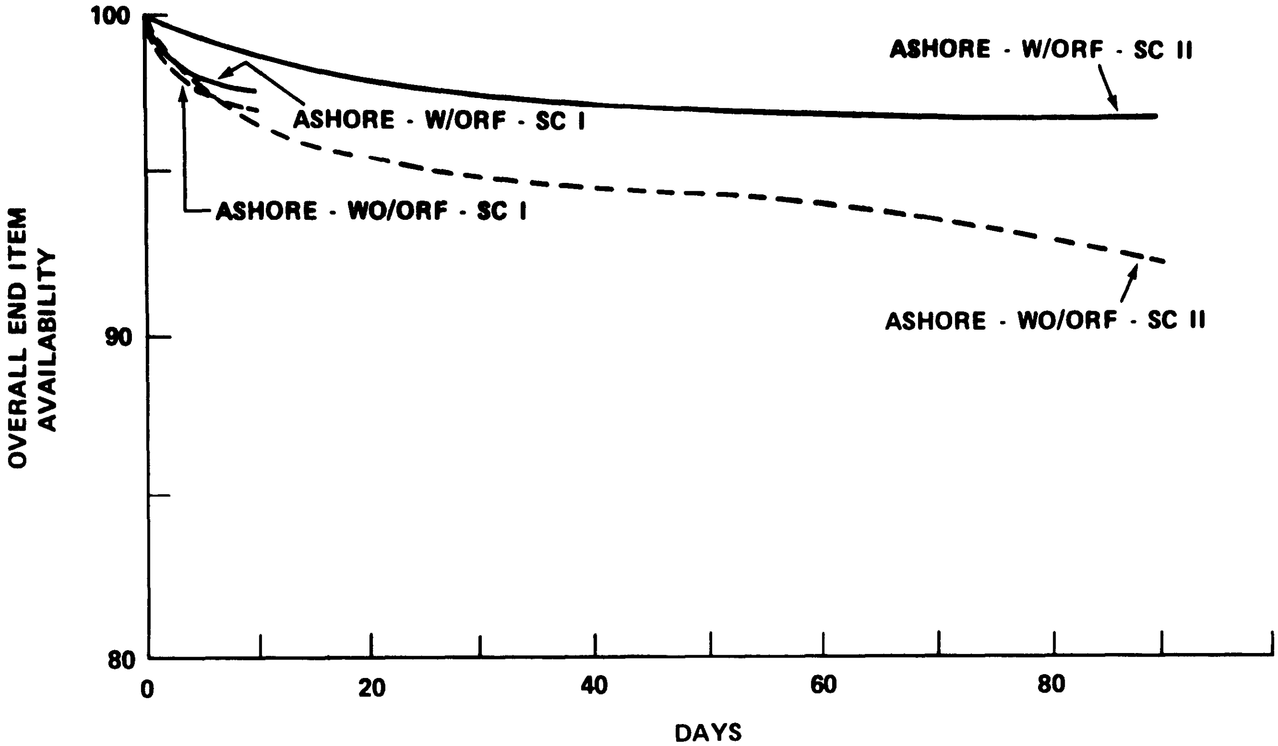


Figure 15 - Effects Using an ORF on Availability - MAU Scenarios I and II

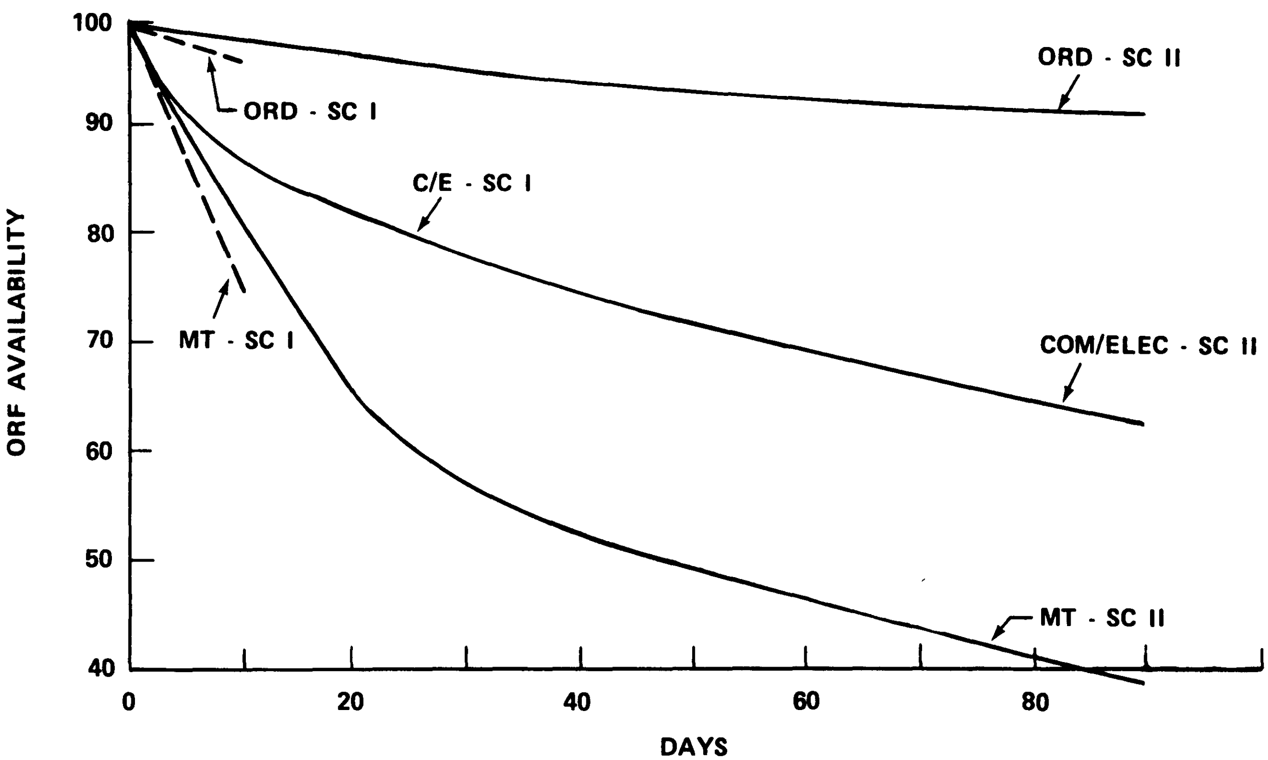


Figure 16 - Availability of ORF Items, SMLS Maintenance Support - MAU Scenarios I and II

the more prominent role the ORF plays in longer mission durations with respect to ashore force equipment availability.

The lower the ORF availability* the greater is the usage of the ORF items (larger number of replacement requirements). Figure 16 indicates the low availability and therefore high use of the Motor Transport and Com/Elec ORF's. The Ordnance ORF shows little usage. ORF utilization is also indicated by the ORF turnover percentages shown in Figure 17. Motor Transport and Radio items have turnover percentages** of 263% and 156%, indicating the high utilization of the ORF. The average turnover percentage for Scenario II is 150% compared to 23% for Scenario I. The ORF turnover percentage for Scenario II (90 days) is thus 6.5 times that of Scenario I (10 days).

8.7 CONTACT TEAM AND SEABASE UTILIZATION

In the SMLS MAU, 12 CT's were deployed in Scenario I and eight in Scenario II, and a total of 19 maintenance spaces were allocated at the seabase in both cases. Seabase shop utilization (defined in Section 5.2) for both scenarios was extremely low, with an average of about 1.5%, as shown in Figure 18. This result indicates that more than enough maintenance capability exists at the seabase. However, these utilization values do not include time required to perform various essential shop maintenance functions; e.g., repair of secondary repairable items/components, and periodic preventive maintenance services, because of the difficulty in obtaining appropriate data.

Average CT utilization, shown in Figure 19 was 9% for Scenario I and 8% for Scenario II. The 9% figure for Scenario I indicates that, on the average, the 12 CT's were either working or being transported 9% of the time. The 8% figure indicates that on the average, the 8 CT's in Scenario II were either working or being transported 8% of the time.

---

* ORF availability is the ratio of the total number of items available in the ORF at any given time to the total original number of items in the ORF.

**Defined as 100 times the ratio of the number of replacements from the ORF to the total original number of ORF items.

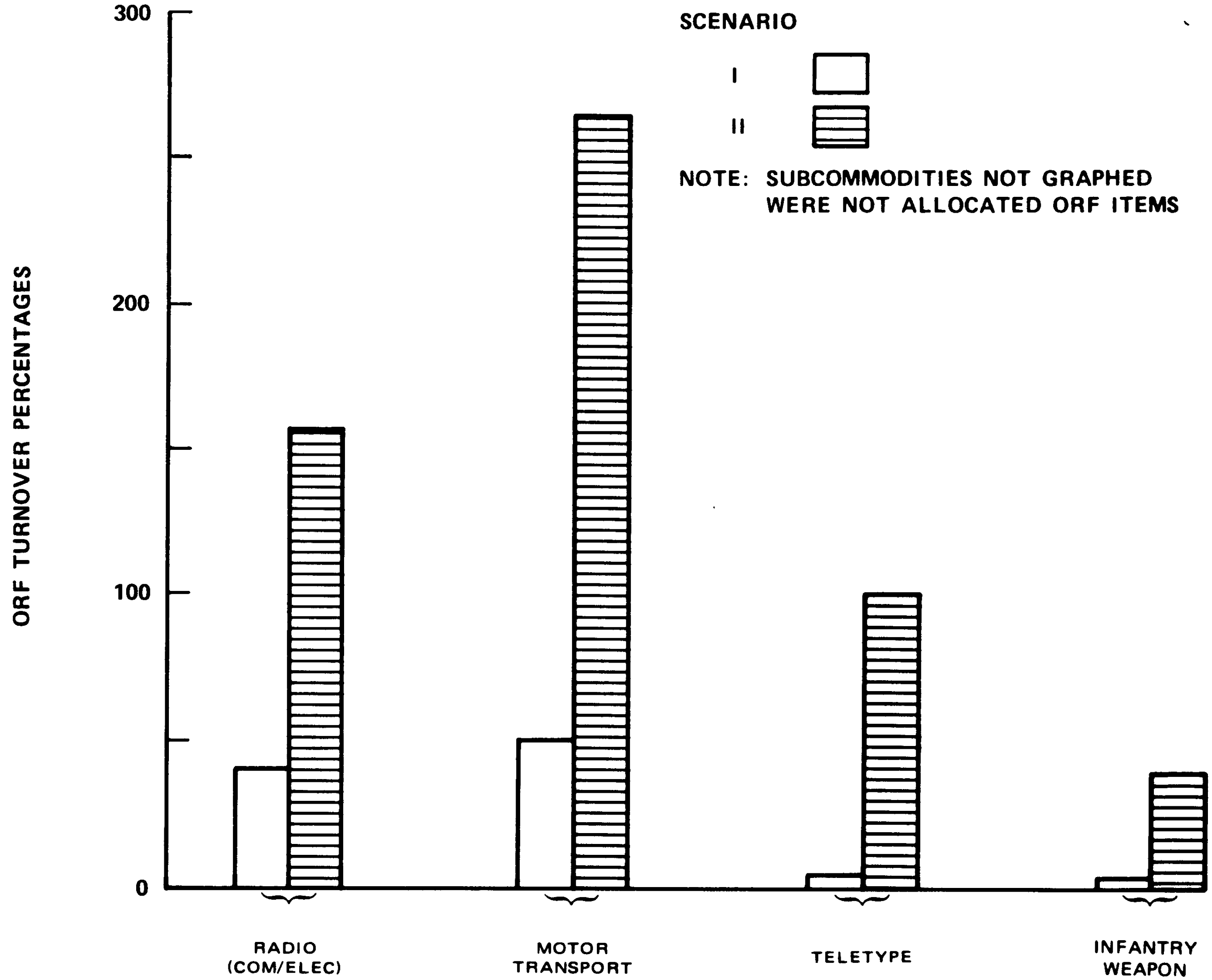


Figure 17 - Turnover Percentage of ORF Items - MAU Scenarios I and II

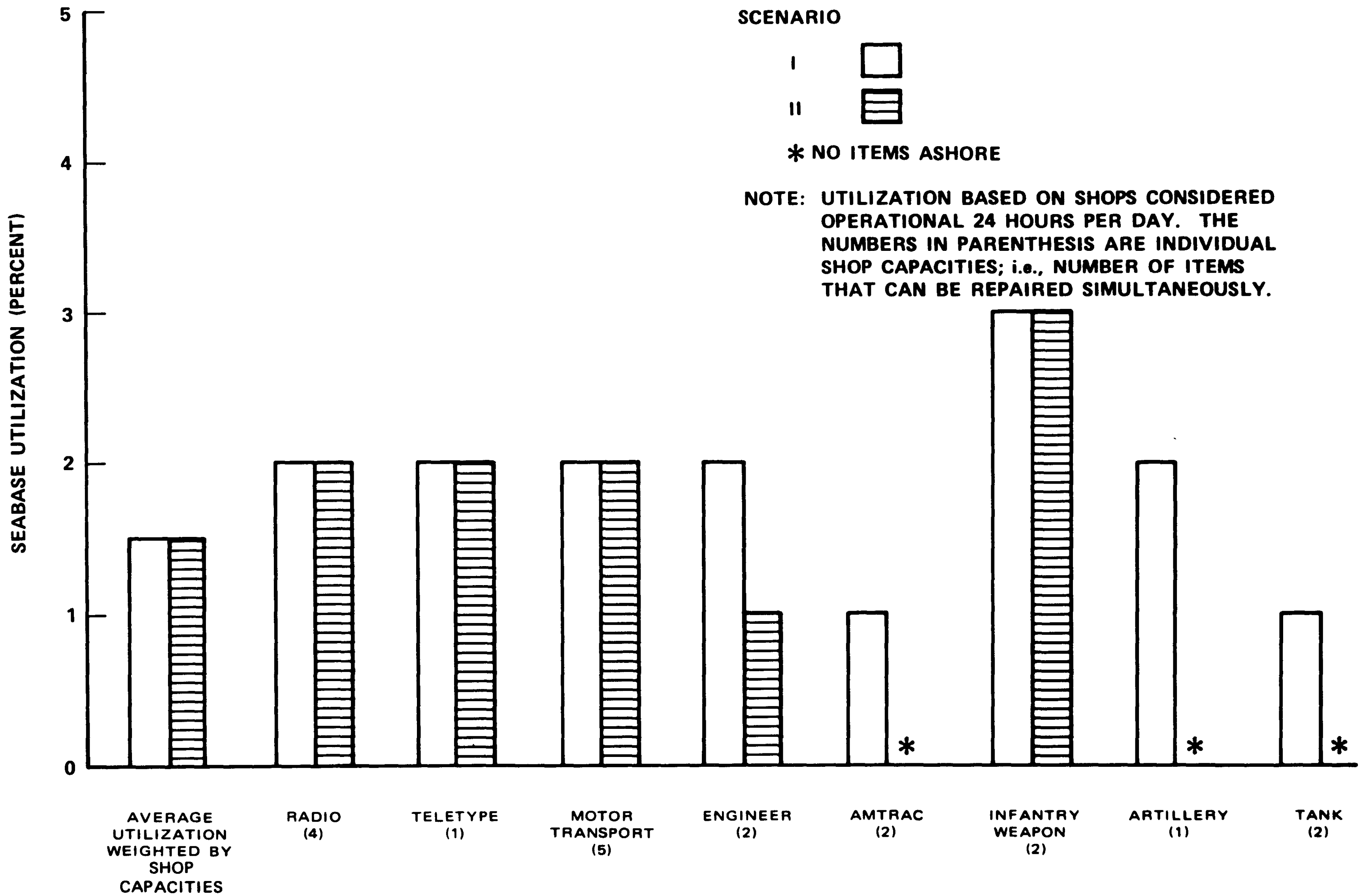


Figure 18 - Seabase Shop Utilization - MAU Scenarios I and II

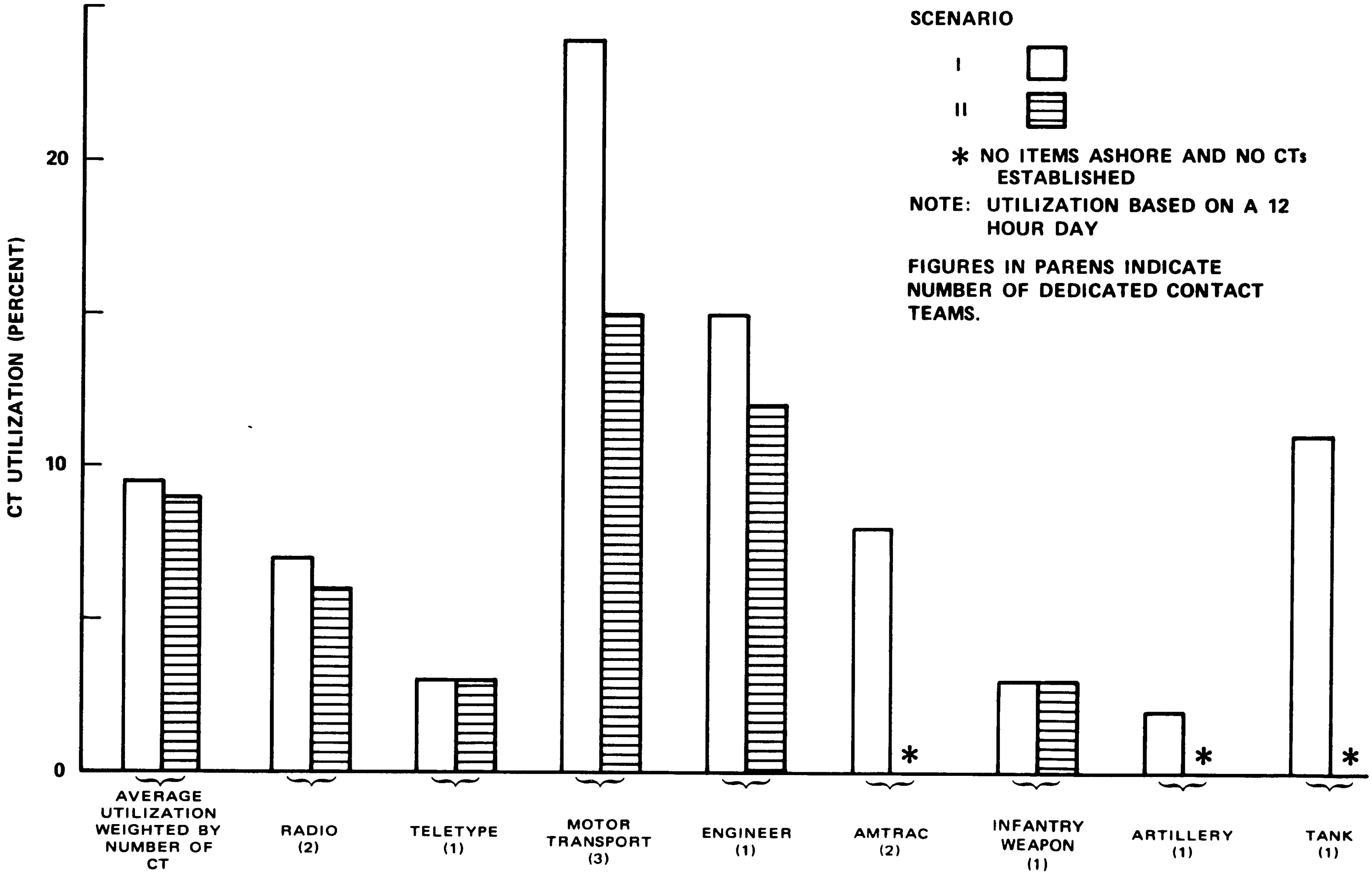


Figure 19 - Contact Team Utilization - MAU Scenarios I and II

8.8 NORM AND NORS

Items that are not operationally ready because they are waiting for maintenance (work to be performed) are referred to as being in "not operationally ready, maintenance" (NORM) status. Items that are not operationally ready because they are waiting for supply actions are referred to as being "not operationally ready, supply" (NORS) status. %NORM and %NORS are defined as

$$\%NORM = \frac{NORM \times 100}{NORM + NORS}$$

$$\%NORS = \frac{NORS \times 100}{NORM + NORS}$$

By definition, %NORM + %NORS = 100. Where NORM and NORS refer to the number of end items in the two categories respectively. %NORM and %NORS are plotted in Figure 20. The undulation of the curve is attributable to the small number of data points. The average values, %NORM = 29 and %NORS = 71, are reasonable. On the average, 29% of the items that are not operating because of failure are waiting for correctional maintenance at any given time. This could mean waiting for transportation to the seabase, or waiting in the CT for seabase queues because maintenance was not available, or because it was nighttime and maintenance was not possible.

On the average, 71% of the items that failed were waiting at any given time for supply action. This could mean waiting for repair parts from either the seabase or outside the seabase. It is evident that, to reduce the number of out-of-action items and consequently the downtime, a better repair parts availability is required.

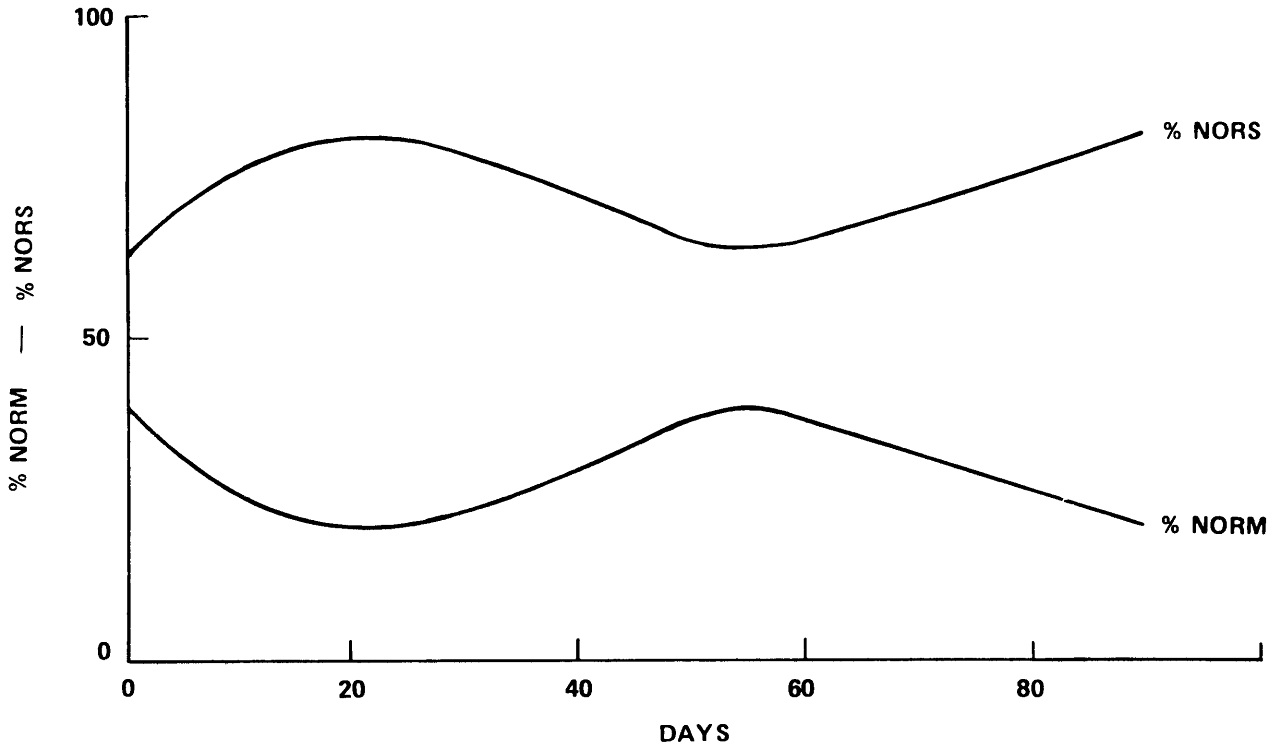


Figure 20 - Percent Distribution of NORS-NORM Status of Failed Equipment in the Total Force for All Subcommodities - MAU Scenario II

SECTION 9
MAB ANALYSIS

9.1 ORGANIZATION

The organization of the MAB considered in this analysis consists of Infantry Battalions (two for Scenarios I and II, and three for Scenario III), a Forward Logistics Unit (FLU), Regimental Headquarters (RLT), and a Beach Support Area (BSA) (only in Scenarios II and III). Each Infantry Battalion is considered as a unit and consists of an H & S Company, four Rifle Companies, and a supporting Artillery Battery. The headquarters of the RLT and FLU are considered to be colocated and treated as a single unit in the analysis. The BSA is also considered a single unit.

Two alternatives for performing 2nd- and limited 3rd-echelon repair ashore were investigated:

- Contact Team Maintenance
  Second- and limited 3rd-echelon maintenance performed by contact teams (CT) ashore.

- Unit Repair
  Second- and limited 3rd-echelon maintenance performed by selected units ashore.

In both alternatives the remaining 3rd-echelon and all 4th-echelon repair is performed at the seabase. Items requiring 5th-echelon repair are stored for subsequent maintenance outside the seabase.

Although in SMLS the total MAB is embarked in the ships of the ATF, regardless of whether repair by CT or the units is used, only a portion of the units in the MAB are deployed ashore; the other units remain in the ATF. However, if the situation dictates, the non-deployed units can be brought ashore in a conventional amphibious operation.

9.2 EQUIPMENT READINESS

9.2.1 Availability

The measure of equipment readiness used in this analysis is the availability, the probability that at a given time an item or a group of items is operational.

9.2.2 Average Daily Failure Rate

The average daily failure rate per 100 items (ADFR) was defined in Section 8.3.1.

9.3 RESULTS FOR THREE SCENARIOS

Three scenarios[8] are examined over a duration of 60 days and the results analyzed and graphed. Scenario I is a low-level deterrence operation where land lines of communication are either very poorly developed or are not available. Two battalion landing teams are lifted ashore and entirely supported by helicopters. Scenario II is a low-level deterrence operation with two battalions ashore using both surface and air transportation to support the force. Scenario III is a low-level deterrence conflict situation approaching mid-intensity. Three battalions are ashore supported by both surface and air transportation. Availability and ADRF values for the three Scenarios are shown in Figures 21-38.

9.3.1 Scenario I Results

Figure 21 shows that items of the Teletype (TTY), Engineering (ENG), Motor Transport (MT), and Artillery (ART) subcommodity classes exhibit average daily failure rates (ADFR) in the range of 4 to 5. Radio and Infantry (INF) items are less prone to failure with ADFR's of 2.05 and 1.67, respectively. There are no AMTRAC or Tank items in this scenario. Figure 22 illustrates the number of failures occurring daily for each subcommodity.

Figures 23 through 38 show availability versus mission duration for all subcommodity classes for the three Scenarios, both for the total force and the ashore force. TTY and ART items experience the greatest

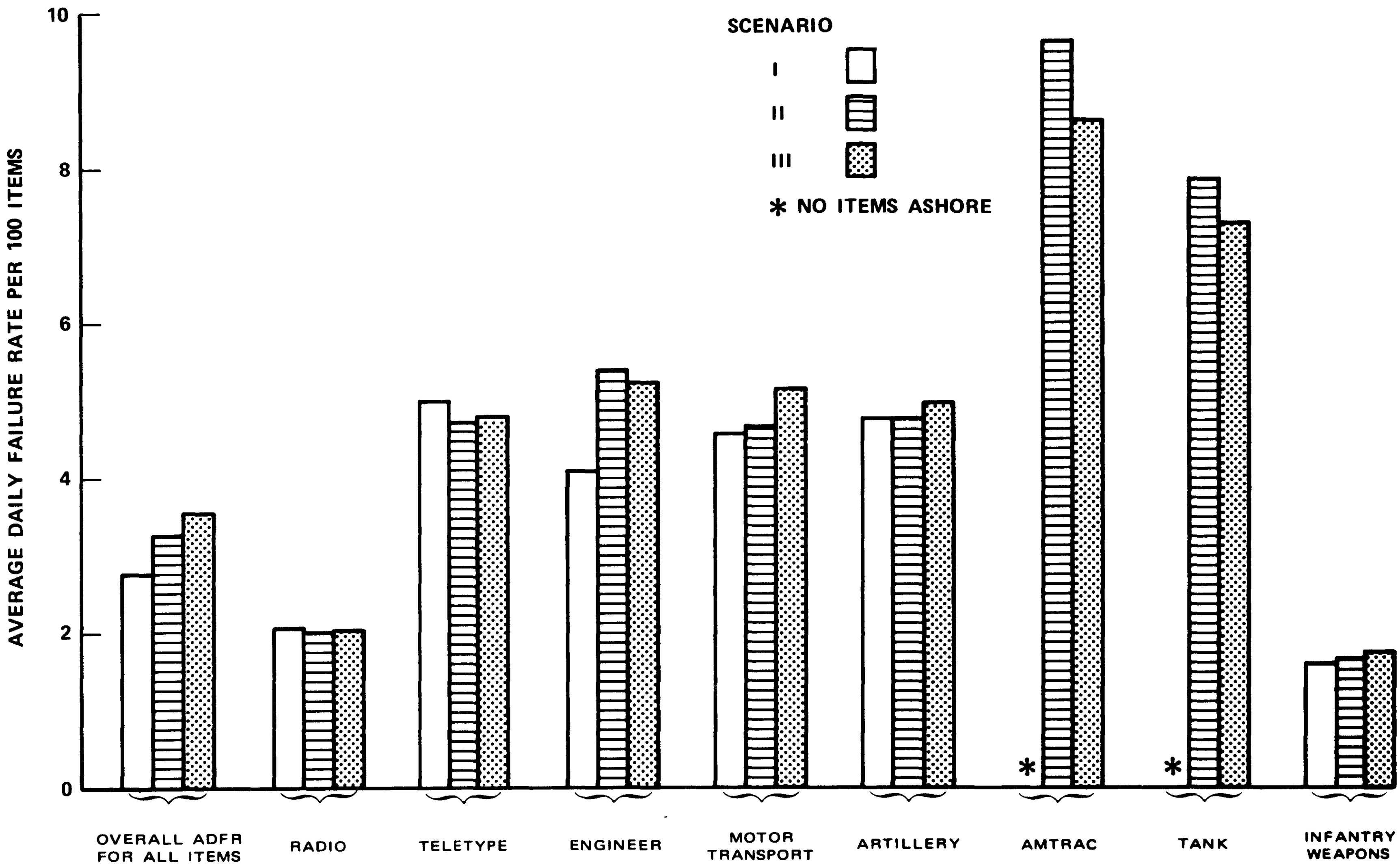


Figure 21 - Average Daily Failure Rate (ADFR) Per 100 Items - MAB Scenarios I, II, and III

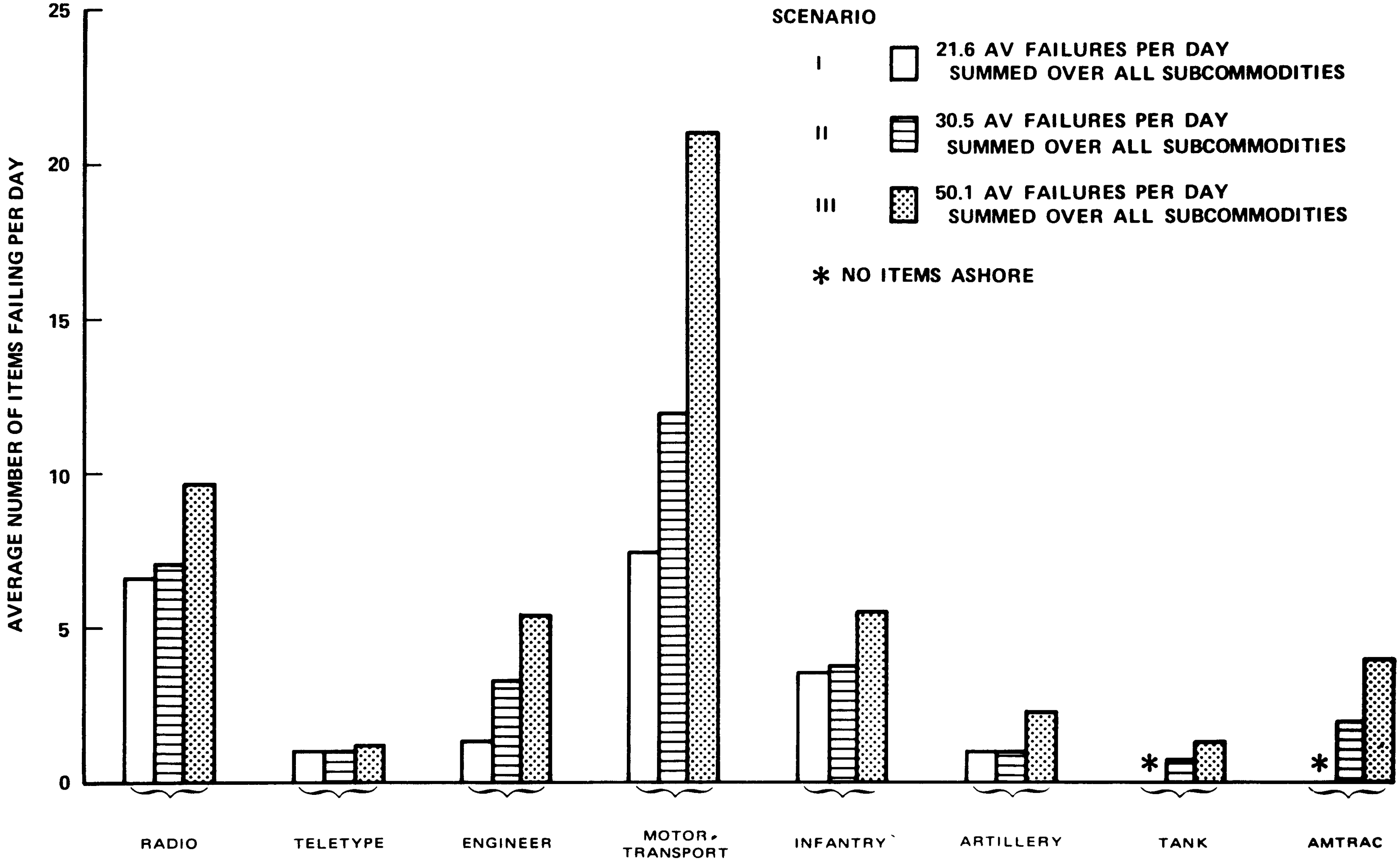


Figure 22 - Average Number of Equipment Failures Per Day - MAB Scenarios I, II, and III

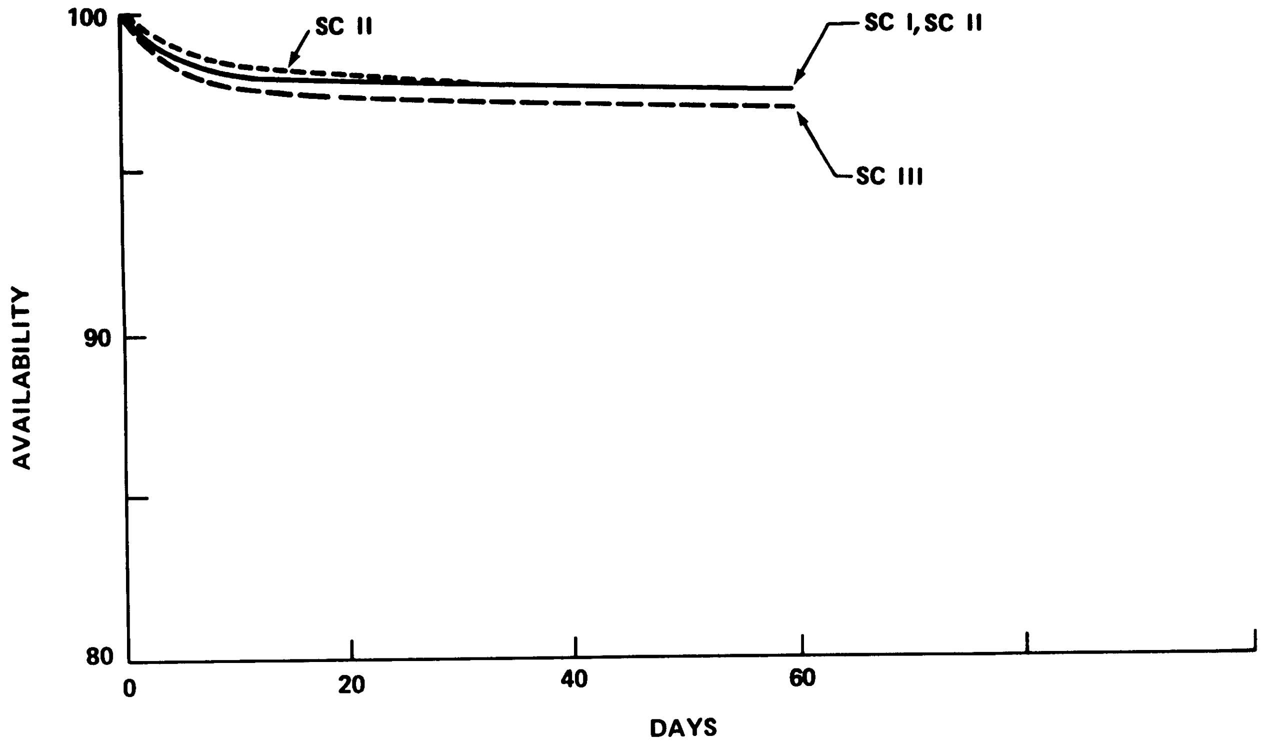


Figure 23 - Radio Equipment Availability of Ashore Forces - MAB Scenarios I, II, and III

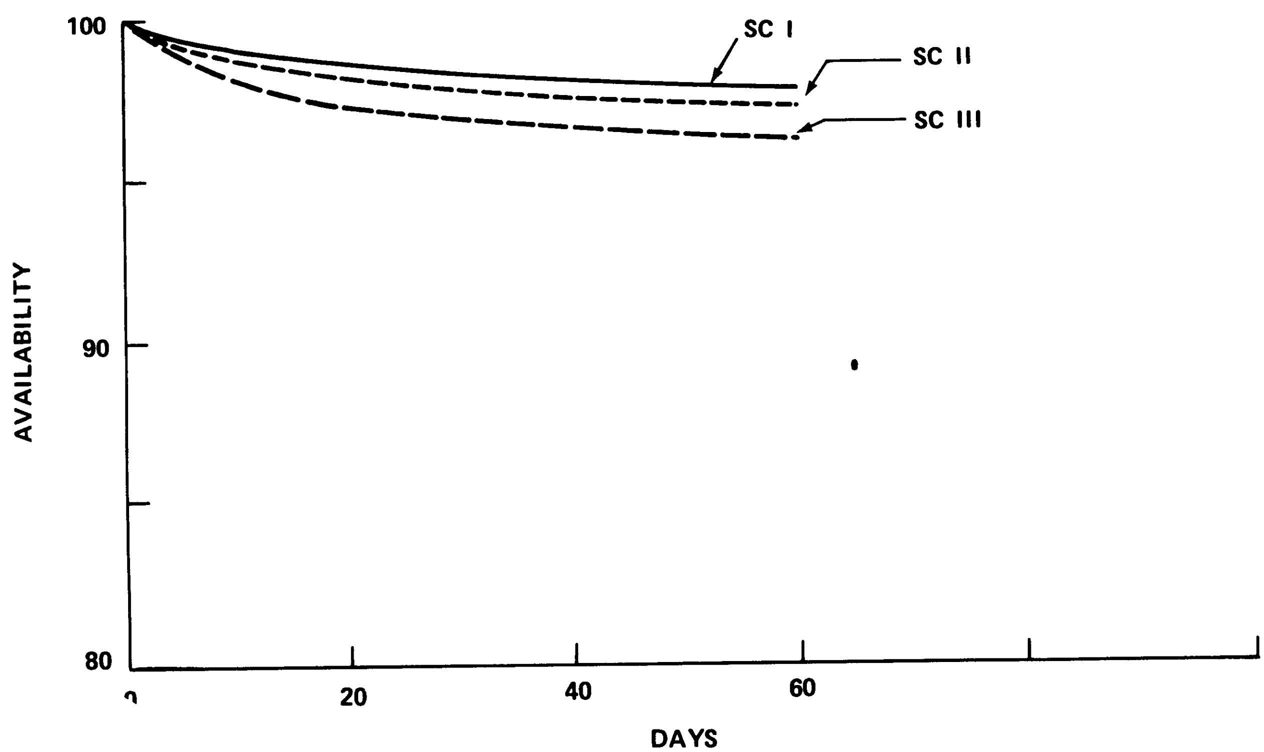


Figure 24 - Radio Equipment Availability of Total Forces - MAB Scenarios I, II, and III

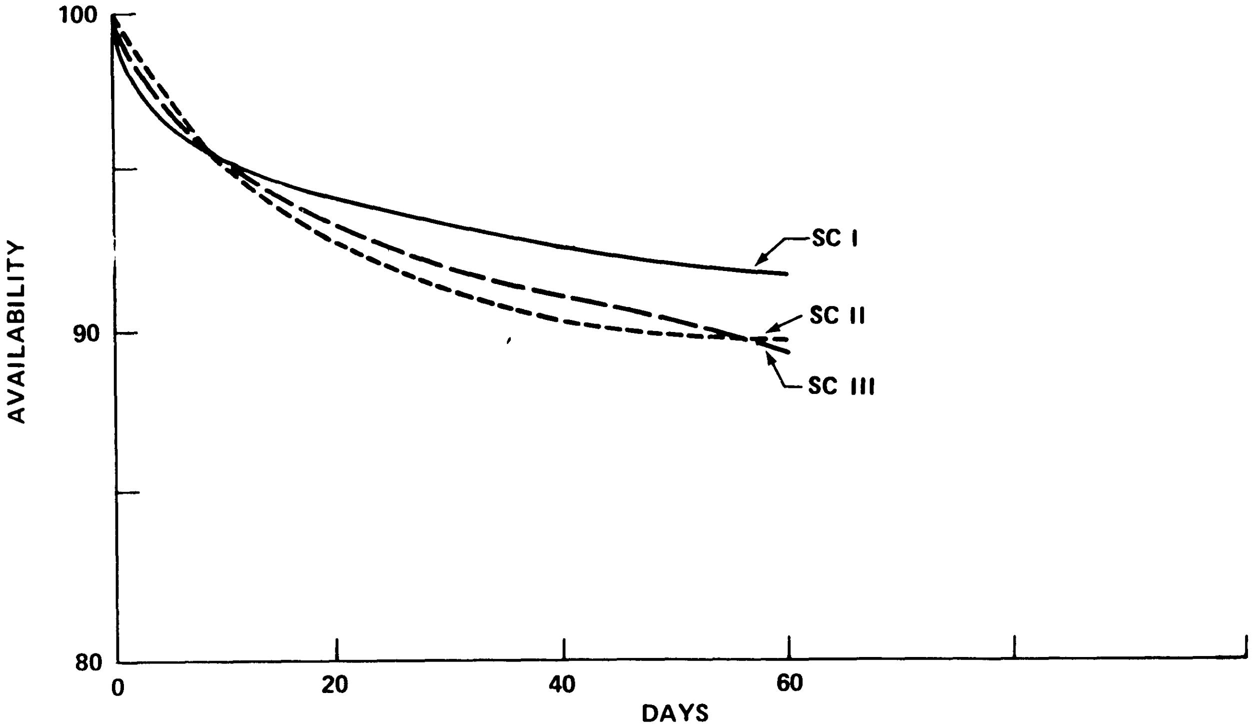


Figure 25 - Teletype Equipment Availability of Ashore Forces - MAB Scenarios I, II, and III

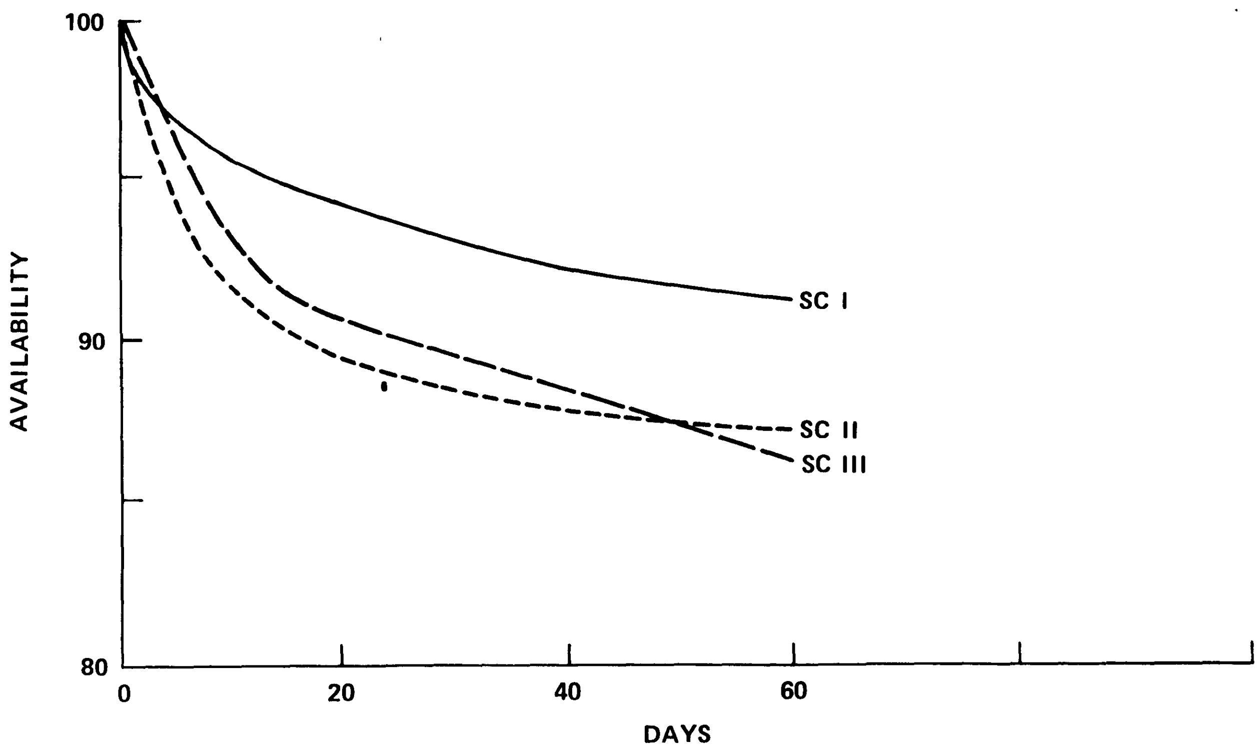


Figure 26 - Teletype Equipment Availability of Total Forces - MAB Scenarios I, II, and III

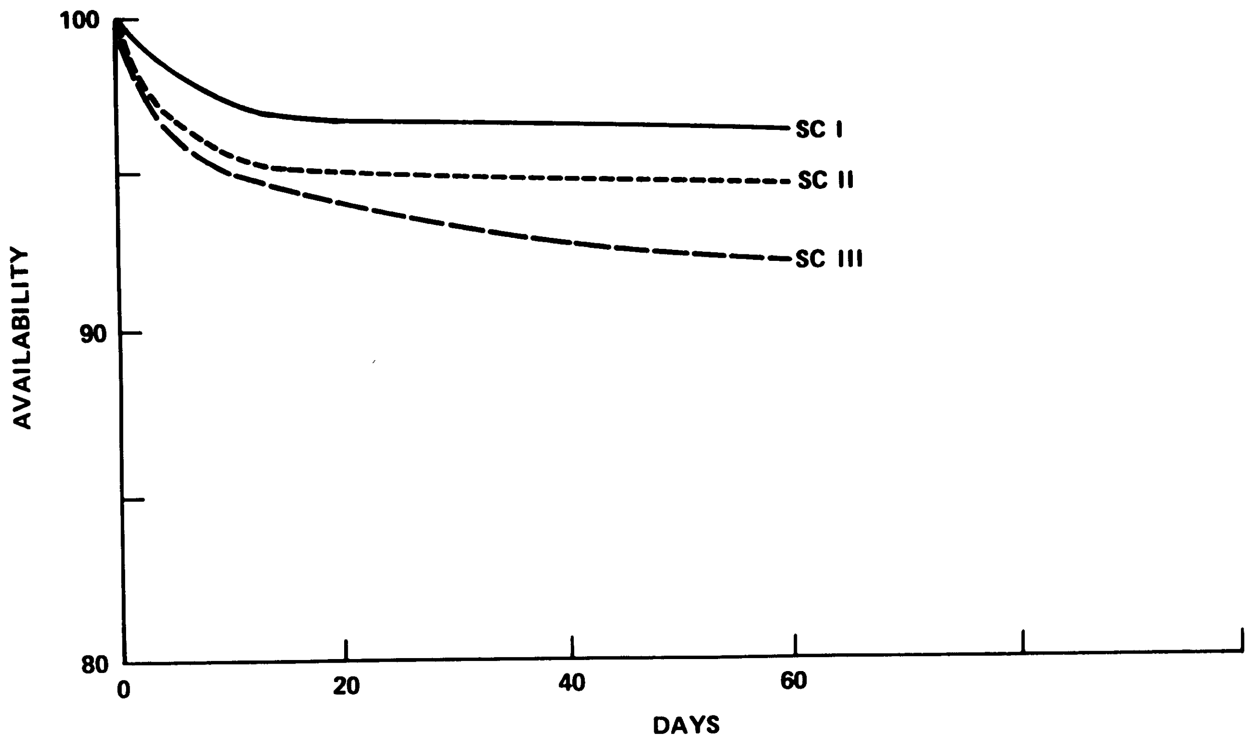


Figure 27 - Engineer Equipment Availability of Ashore Forces - MAB Scenarios I, II, and III

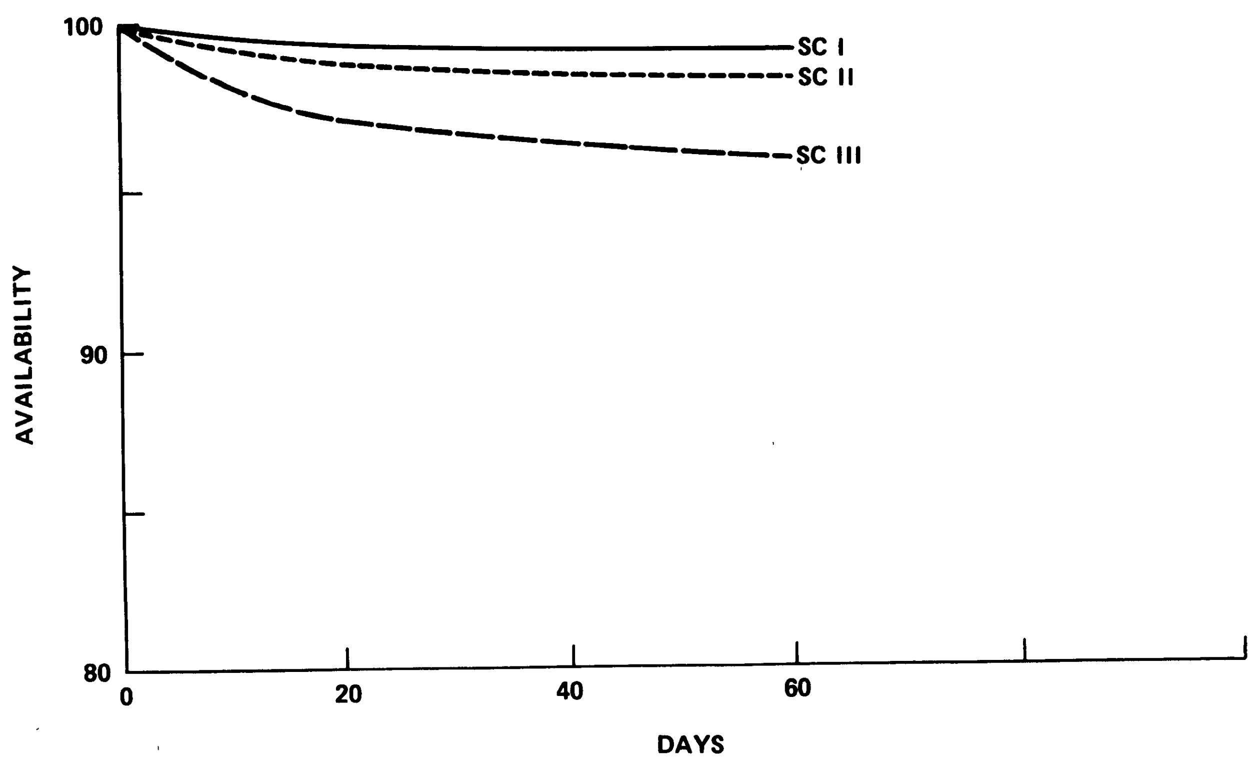


Figure 28 - Engineer Equipment Availability of Total Forces - MAB Scenarios I, II, and III

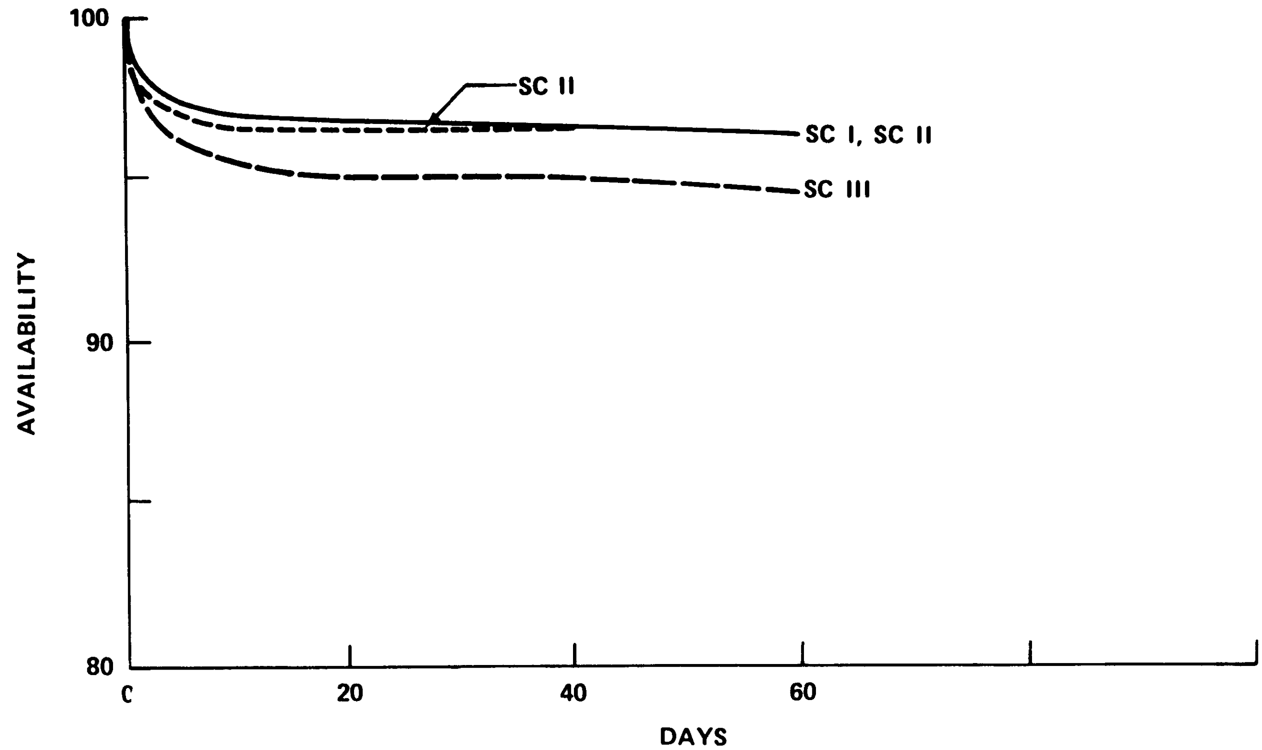


Figure 29 - Motor Transport Equipment Availability of Ashore Forces - MAB Scenarios I, II, and III

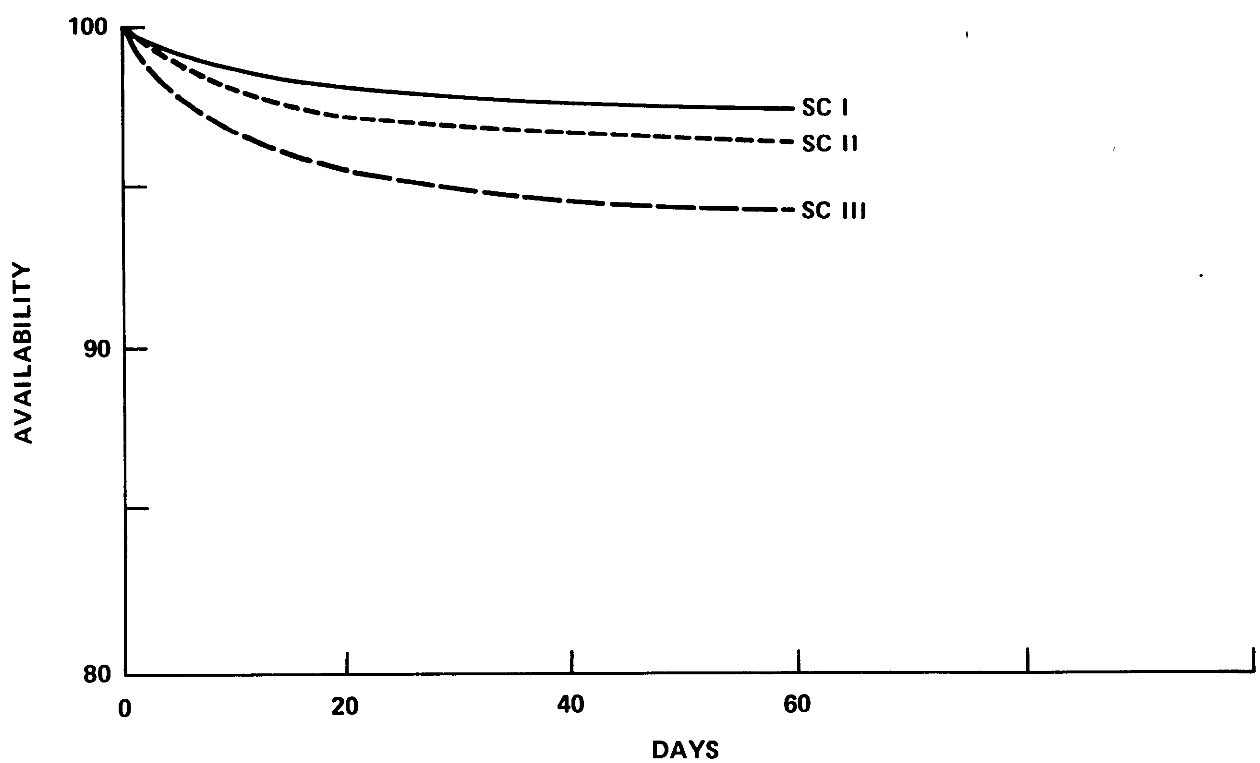


Figure 30 - Motor Transport Equipment Availability of Total Forces - MAB Scenarios I, II, and III

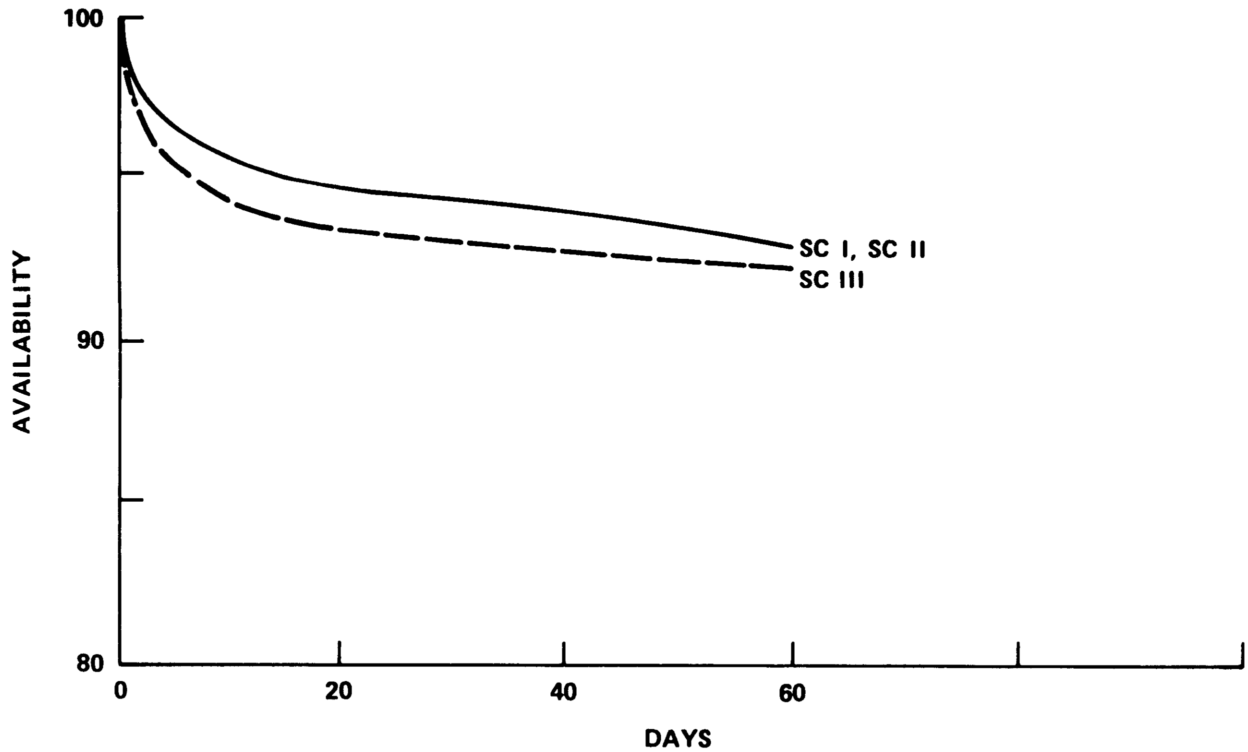


Figure 31 - Artillery Equipment Availability of Ashore Forces - MAB Scenarios I, II, and III

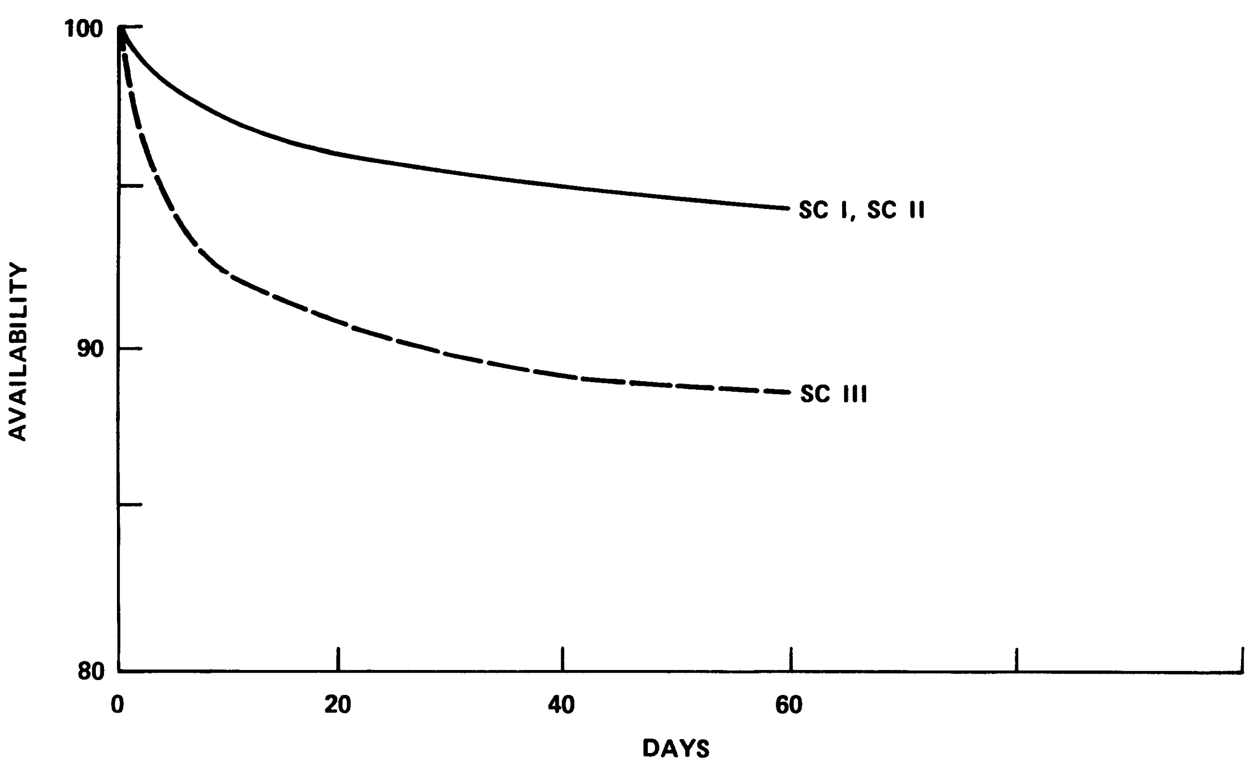


Figure 32 - Artillery Equipment Availability of Total Forces - MAB Scenarios I, II, and III

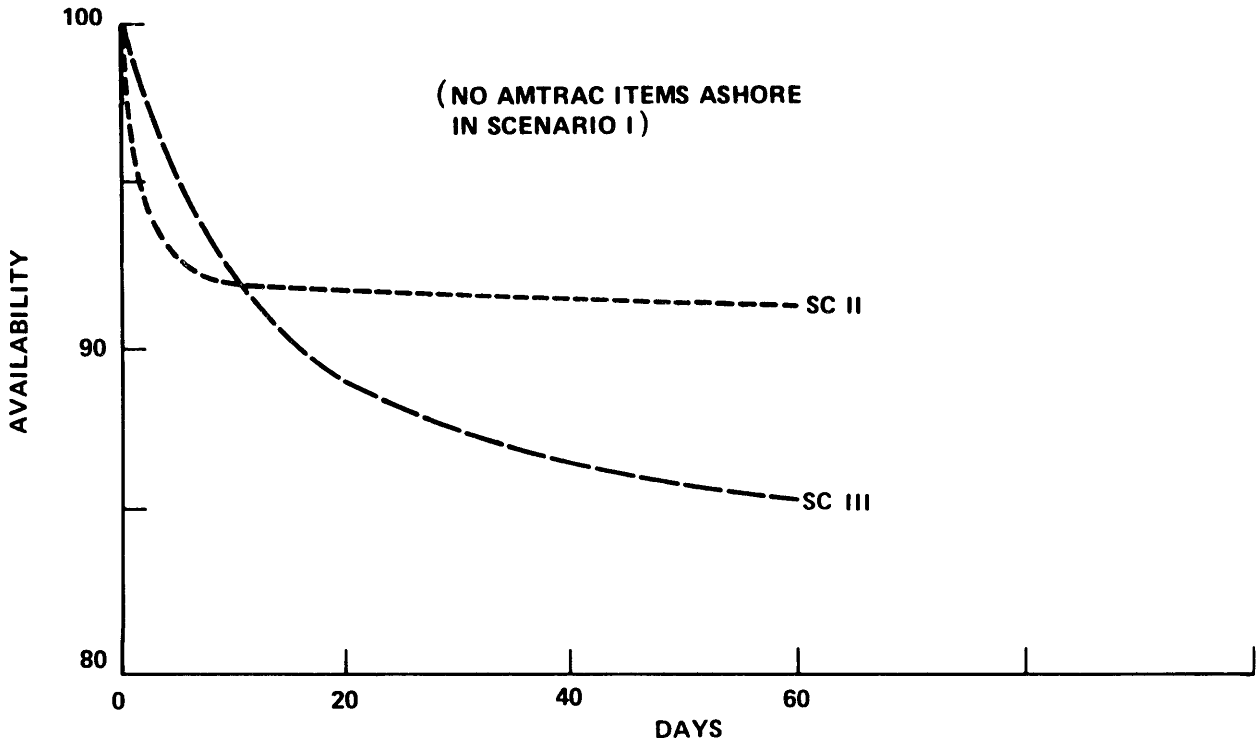


Figure 33 - Amphibian Tractor (AMTRAC) Availability of Ashore Forces - MAB Scenarios II and III

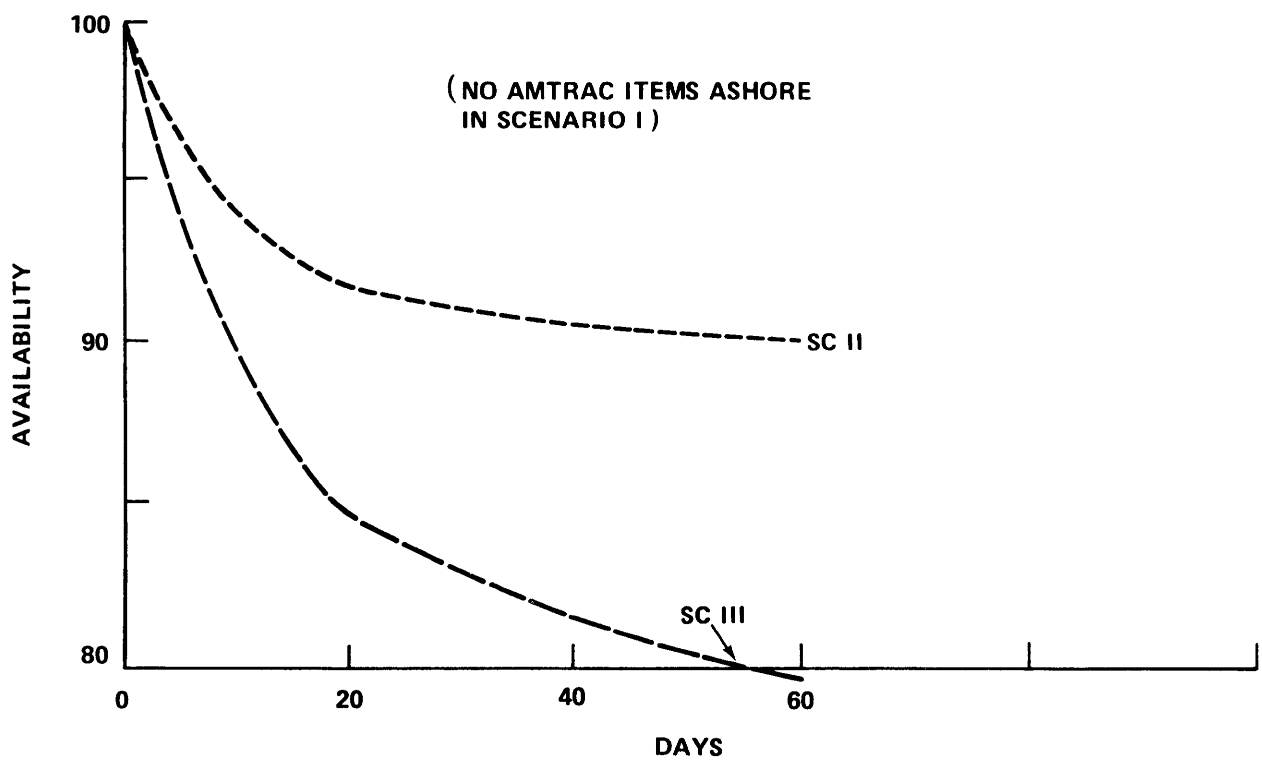


Figure 34 - Amphibian Tractor (AMTRAC) Availability of Total Forces - MAB Scenarios II and III

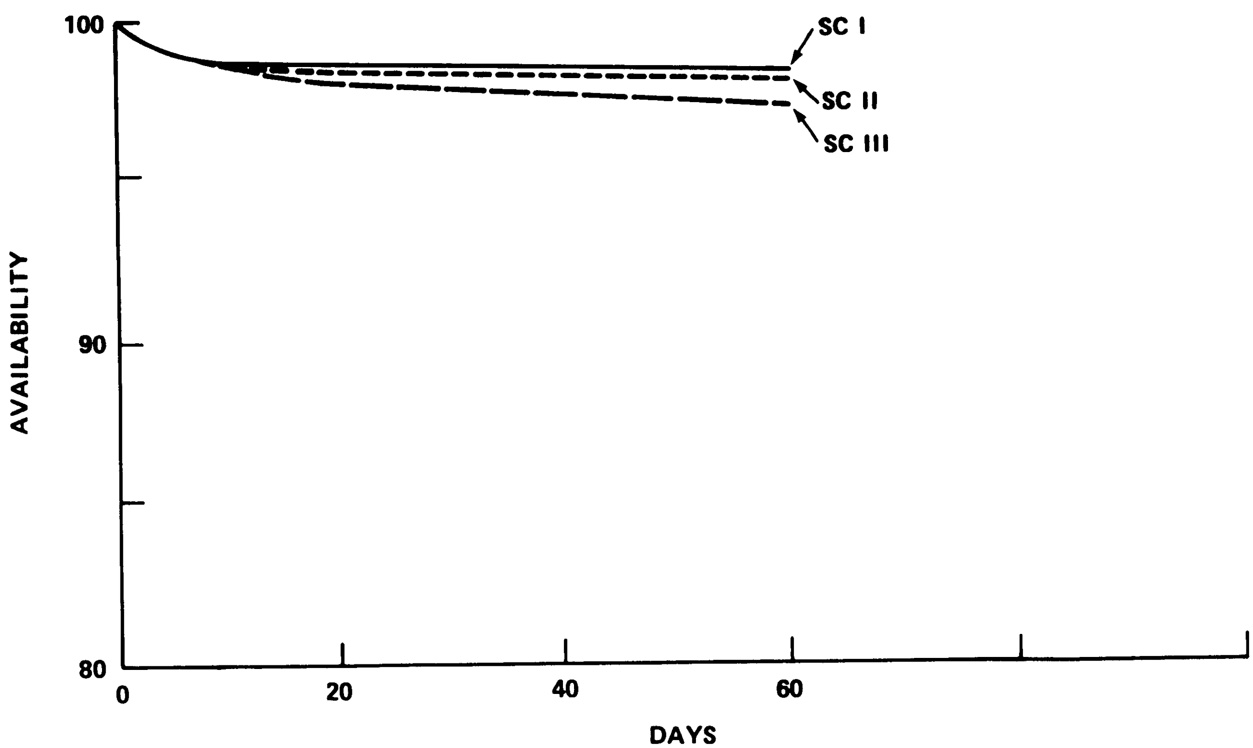


Figure 35 - Infantry Weapons Availability of Ashore Forces - MAB Scenarios I, II, and III

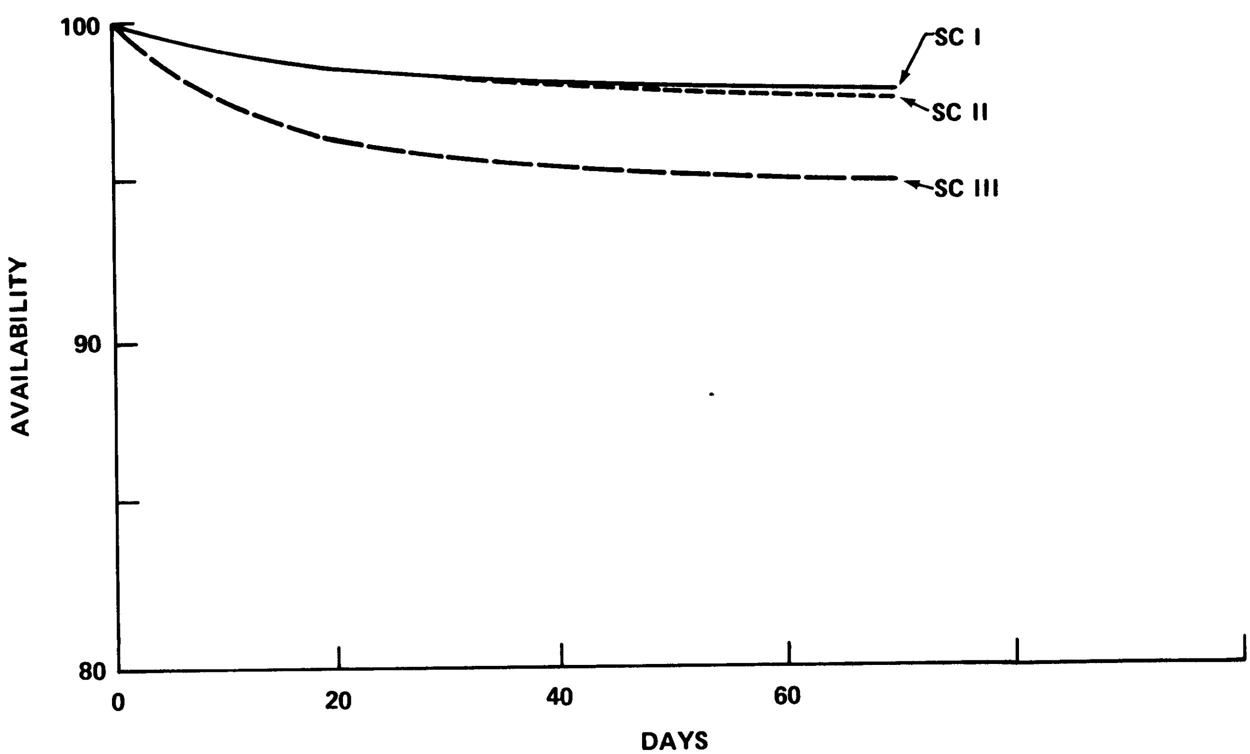


Figure 36 - Infantry Weapons Availability of Total Forces - MAB Scenarios I, II, and III

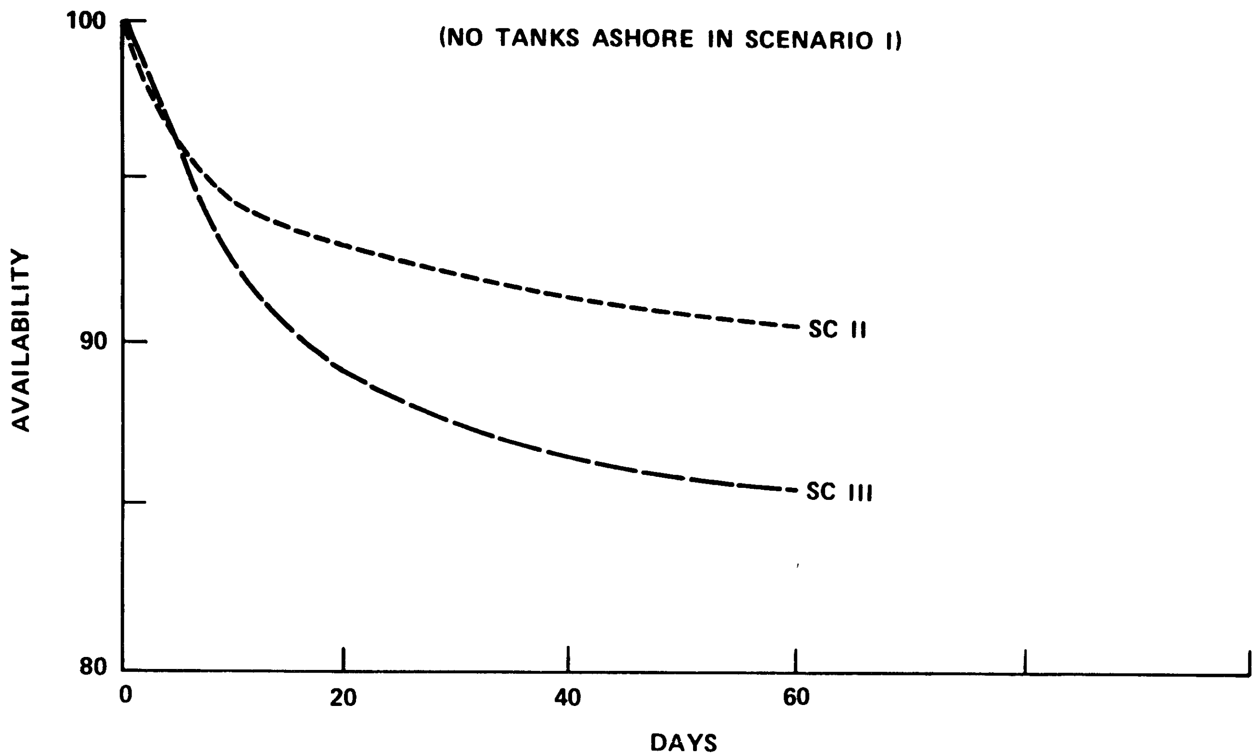


Figure 37 - Tank Availability of Ashore Forces - MAB Scenarios II and III

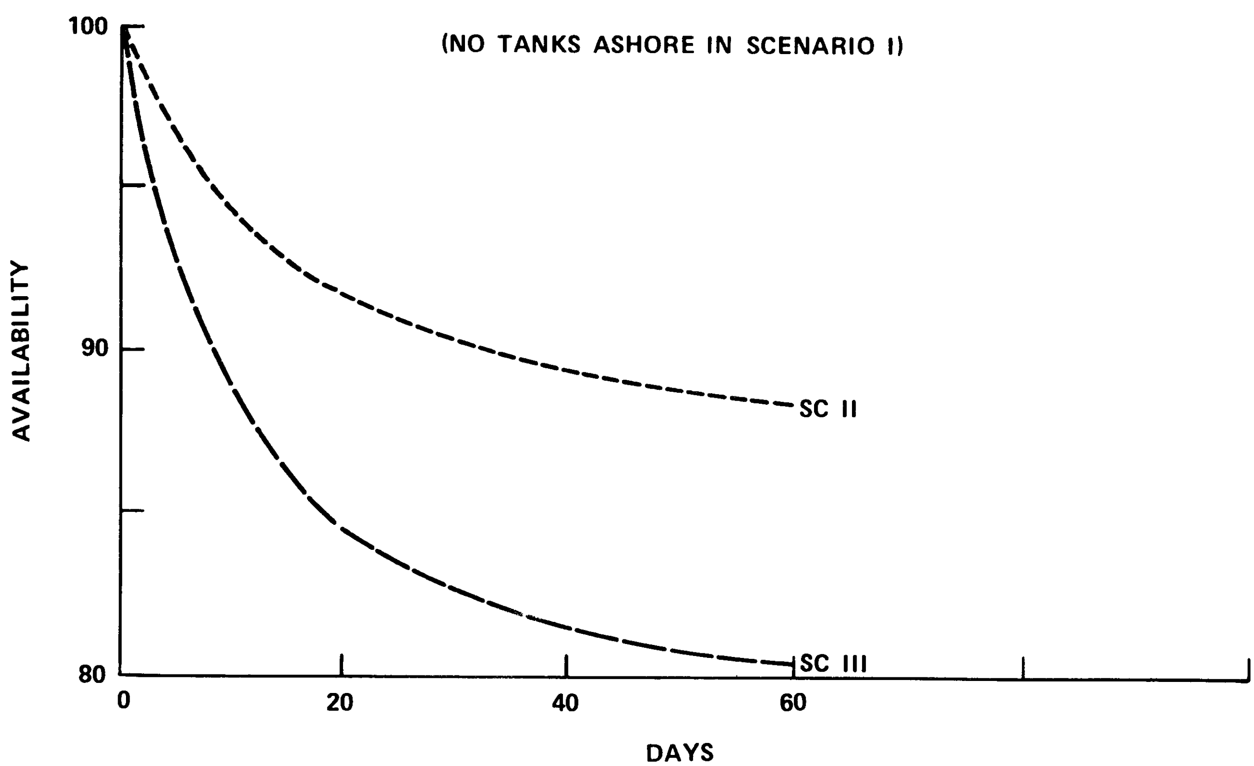


Figure 38 - Tank Availability of Total Forces - MAB Scenarios II and III

decrease in availability as a direct result of (a) the small number of ORF items allocated (1 ORF item for TTY and 2 for ART), and (b) the fact that the ADFR's, for these two subcommodities are the highest of all subcommodities. Even so, additional ORF allocations are not needed since the availabilities of TTY and ART always remain greater than 90%, the value chosen as the lower limit of successful end item operation.

Both TTY and ART experienced relatively high ashore force average downtime per failure (DT/F) as shown in Figure 39, nearly twice as high as the overall value (23.8 hr). These high downtimes were caused by the relatively low number of ORF items. Although the low ORF levels for ART and TTY items do not adversely affect the availability of the total force as shown in Figures 31 and 32, they can have a deleterious affect on ashore force downtime. Similarly, the low ORF levels of TTY and ART items do not materially affect the DT/F of the total force, as shown in Figure 40. The overall value for all items is 68.4 hr.

9.3.2 Scenario II Results

ADFR characteristics shown in Figure 21 for Scenario II are similar to those of Scenario I except for Engineer items which show a 33% increase over the Scenario I ADFR value because more than twice as many Engineer items were brought ashore in this scenario. The ADFR's of the AMTRAC and Tank subcommodities are more than twice the overall value of 3.26, indicating the relatively high maintenance requirements associated with these items.

Again, as shown by Figures 25 and 26, TTY equipment exhibits the greatest decrease in availability, even though its ADFR is close to the average ADFR for all items, because only one ORF item of this subcommodity is available. The effect of ORF items is seen also in the high ashore DT/F (Figure 39) of TTY equipment, more than twice the overall DT/F value. For a comparison of the effect of ORF items, note the ADFR of the Engineer subcommodity items in Figure 22. This ADFR is higher than for TTY items, but because the ratio $\frac{\text{No. of ORF Items}}{\text{No. of Deployed Items}}$ is 36% for the Engineer subcommodity as compared to 5% for TTY, the DT/F of ashore Engineer items is one-half that of TTY.

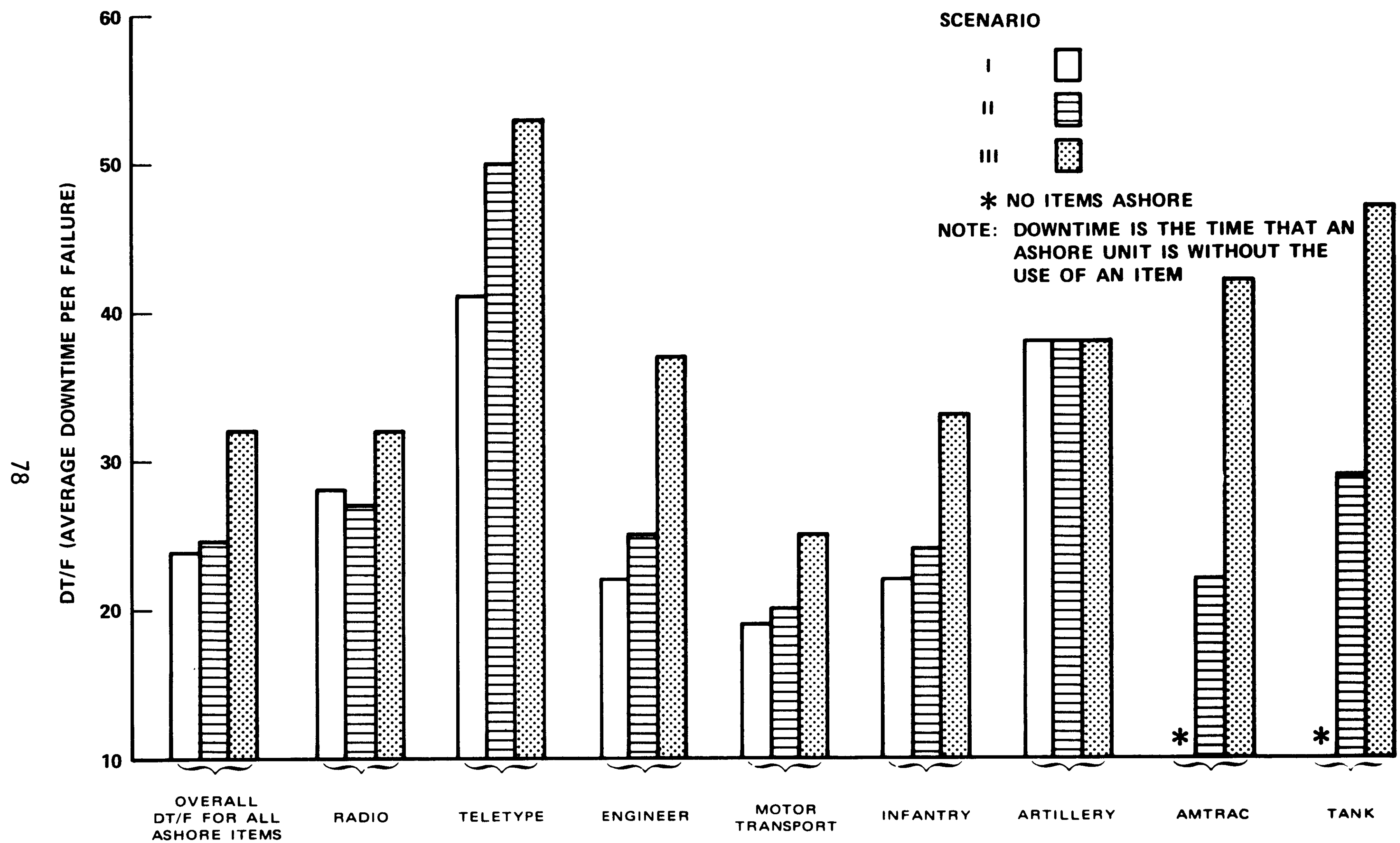


Figure 39 - Average Equipment Downtime per Failure (DT/F) for Ashore Force - MAB Scenarios I, II, III

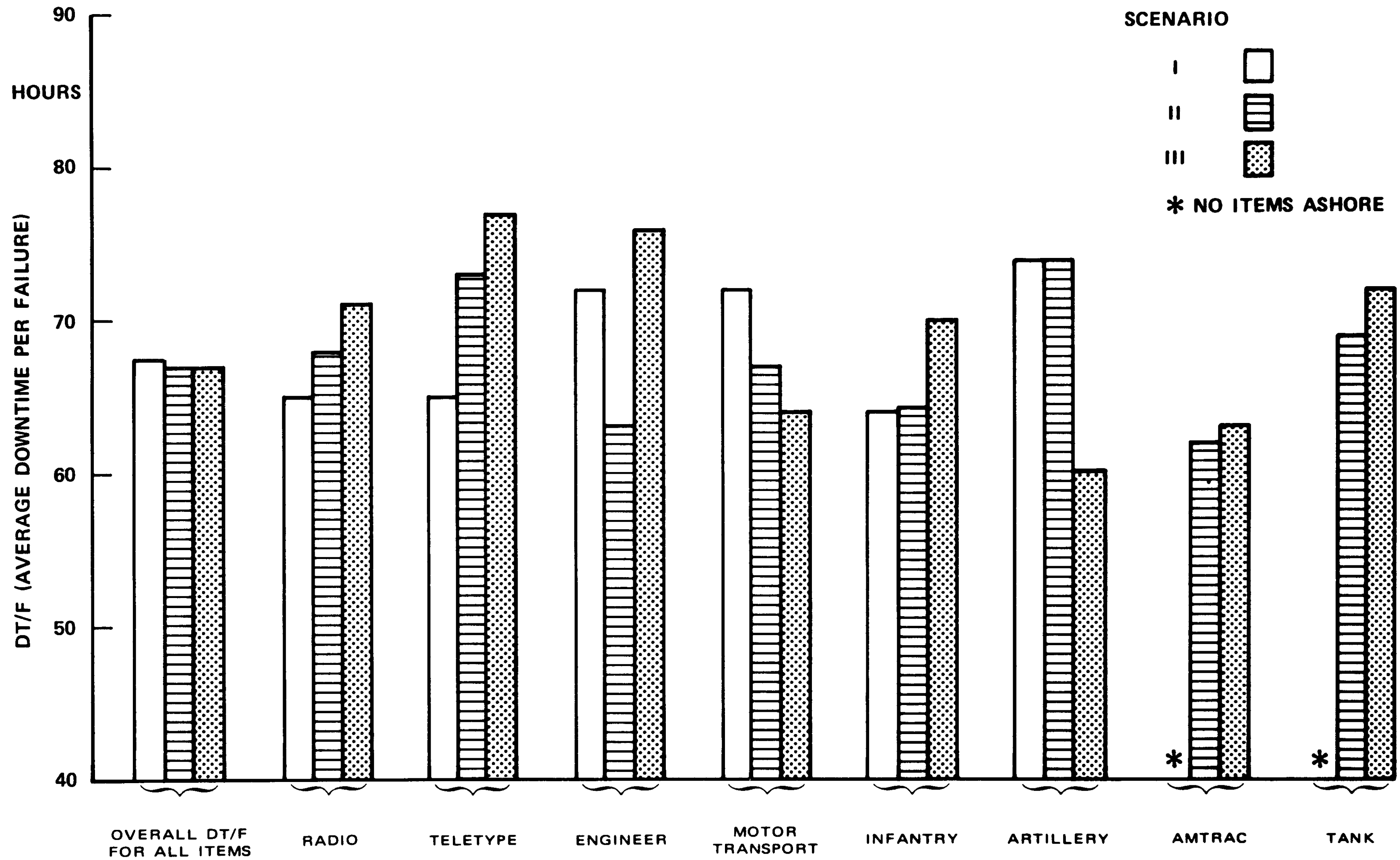


Figure 40 - Average Equipment Downtime Per Failure (DT/F) for Total Force - MAB Scenarios I, II, and III

9.3.3 Scenario III Results

Items of the AMTRAC and Tank subcommodities have the two highest ADFR's and experience the largest decrease in availability because of the large number of LVT's and Tanks deployed in Scenario III, an average of twice as many as in Scenario II.

Figure 21 shows that the ADFR of MT equipment is 5.16; Figure 22 shows that the average number of failures occurring per day is 21, the highest of all subcommodities. From an overall maintenance point of view, MT equipment requires the largest repair capacity, although the ADFR's of MT end items are close to the average value for all items.

9.4 COMPARISON OF RESULTS FROM THE THREE SCENARIOS

The three 60-day MAB scenarios differ greatly in the number of items deployed ashore. In Scenario I, 28% of the total force is deployed; in Scenario II, 34% is deployed, and in Scenario III, 52% is deployed. More failures occur when more items are deployed ashore. In Scenario I, 1287 failures (21 per day) occurred; in Scenario II, 43% more than in Scenario I or 1825 (30 per day) occurred; and in Scenario III, 135% more than in Scenario I or 3003 (50 per day) occurred. The number of failures per day of items of each subcommodity class is shown in Figure 22.

Figure 41, which shows overall availability for the ashore force (all subcommodities) for 60 days, indicates little difference among scenarios. The maximum decrease in availability at 60 days is 5% for Scenario III. Availability for items of the entire force (Figure 42) also do not vary much. Although the overall force availabilities (ashore and total) show small decreases, the TTY, ART, LVT, and Tank subcommodities show greater than average decreases in availability. Since these subcommodity categories contain only 10% of the items of the ashore force and 5% of the items of the total force, their effect on the curves of Figures 40 and 41 is not apparent.

Radio availability curves (Figures 23 and 24) are quite flat for all three scenarios. TTY availability curves (Figures 25 and 26) exhibit decreases up to 14% (Scenario III) due to the large percentage of items deployed and the low number of ORF items.

Engineer equipment availability curves (Figures 27 and 28) and Motor Transport equipment availability curves (Figures 29 and 30) show acceptable performance; i.e., availability for these items remains above 90%. The largest decrease in availability (6%) exhibited by MT equipment is in the availability of the total force in Scenario III, which is close to the overall decrease in availability of all equipment of 5% (Figure 42); the difference in MT equipment availability in the total force between Scenarios II and III is not greater than 3%.

The total force availability of LVT equipment (Figure 43) decreases at 60 days from 90% to 80% in going from Scenario II to III. The decrease in total force availability of Artillery equipment (Figure 32) in Scenario II is 6% as compared to about 12% in Scenario III. And the decrease in total force availability of Tank equipment (Figure 38) in Scenario II is 12% as compared to about 20% in Scenario III. A larger number of items in the Tank, LVT, and ART subcommodities were brought ashore in Scenario III; on the average 91% of the items in these subcommodities were deployed. In comparison, the percentage of deployed items of the entire force is 52%. In Scenario II, an average of 41% of these items available in the total force were deployed while only 34% of the items of the entire force were deployed. Consequently, high rates of deployment, high failure rates, and low ORF levels cause large availability decreases in ART, Tank and LVT subcommodity classes.

Infantry item availability curves (Figure 35 and 36) exhibit overall decreases of less than 5%. With one exception, the availabilities of the Radio (Figures 23 and 24), ENG (Figures 27* and 28), and MT (Figures 29 and 30) subcommodity items for any scenario do not decrease by more than 6% for 60 days. Since the items in the Radio, ENG, MT, and INF subcommodities compose 95% of the equipment of the total force, it is evident that these subcommodities determine the shapes of the availability curves of equipment of the total force (Figures 41 and 42).

9.5 COMPARISON OF UNIT REPAIR VS CONTACT TEAM REPAIR

Two alternative approaches to the repair of end items ashore in SMLS were investigated. The effectiveness of CT's positioned ashore for

* Engineer equipment availability of ashore forces in Scenario III exhibits a decrease of 8% in 60 days.

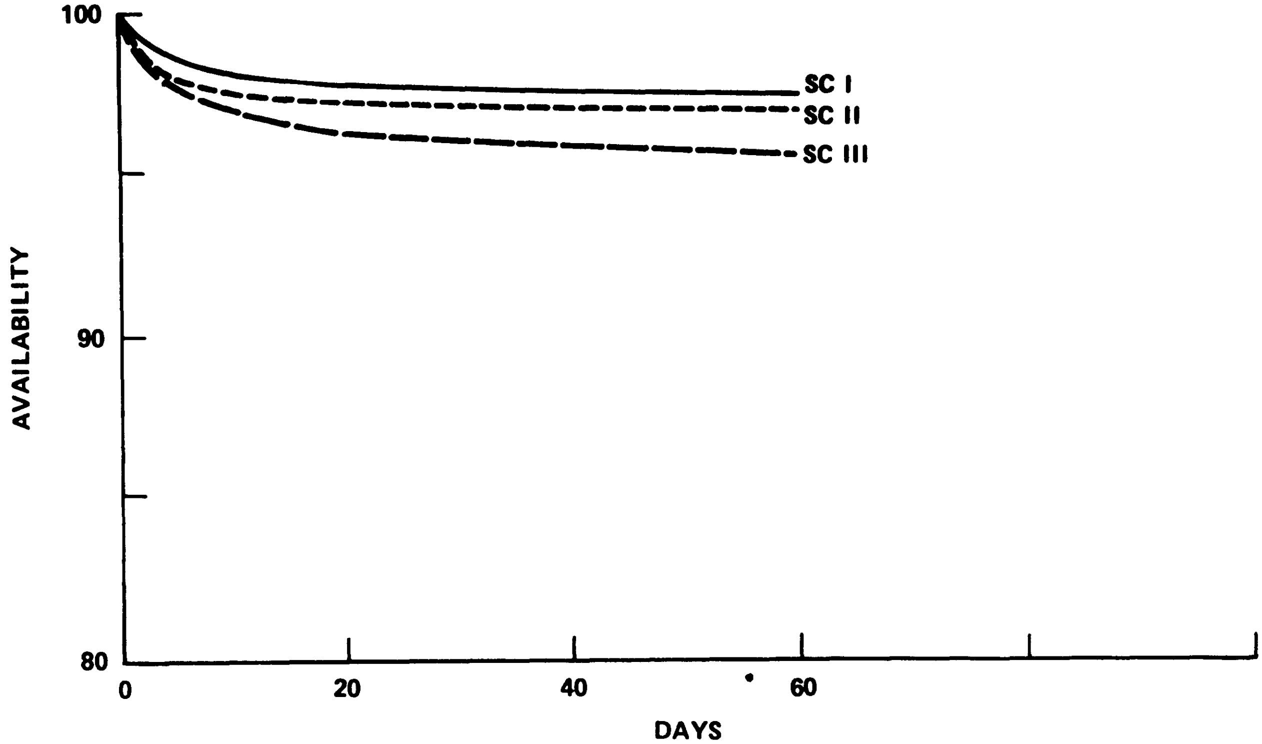


Figure 41 - Overall Equipment Availability of Ashore Forces - MAB Scenarios I, II, and III

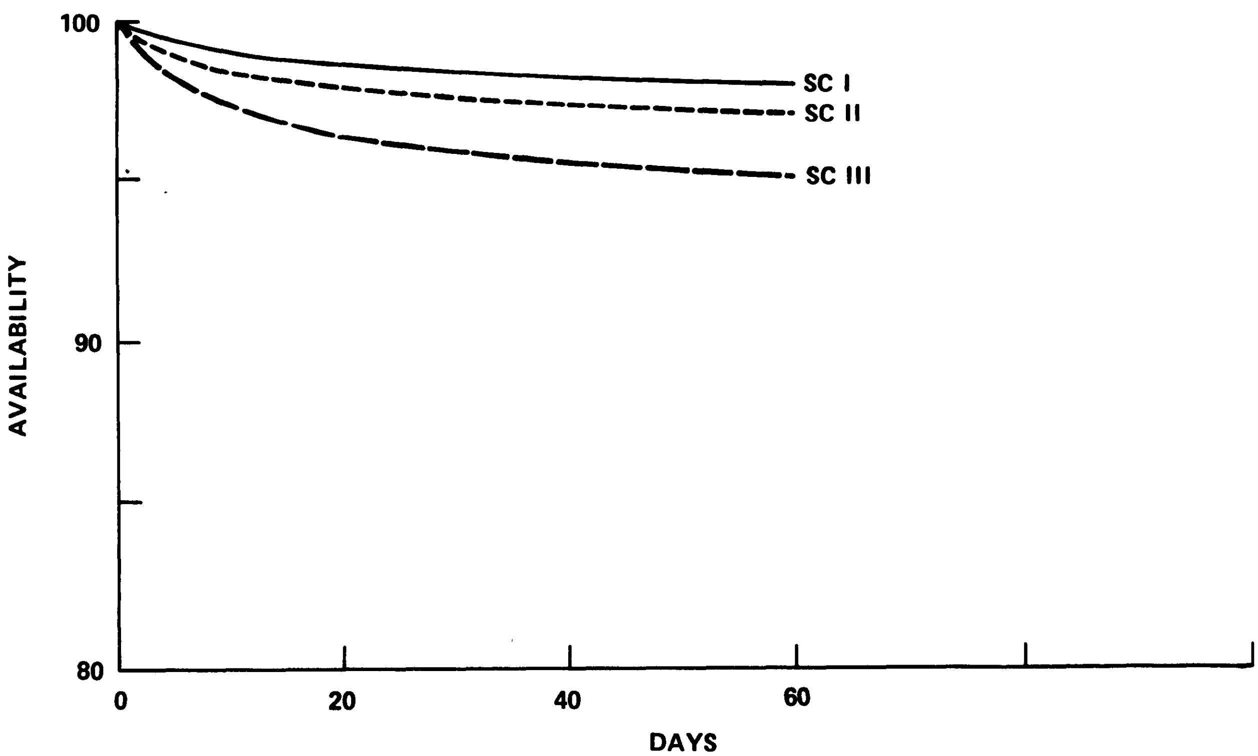


Figure 42 - Overall Equipment Availability of Total Forces - MAB Scenarios I, II, and III

2nd- and limited 3rd-echelon maintenance and the retention of these maintenance capabilities in the units were examined.

The results of the analyses performed for Scenarios I and II were inconclusive because of the low conflict level and the relatively low densities of items ashore. Availabilities for the ashore force and total force in Scenario III are plotted in Figures 43 and 44, respectively, showing that unit maintenance provides a slightly higher availability than CT maintenance, but never more than 0.6% greater. This difference is too small to permit the conclusion that unit maintenance is more effective than CT maintenance. The ashore force experiences a consistently but slightly higher availability with unit repair than does the total force, because the ashore force benefits somewhat more from the time saved in the unit method of conducting maintenance.

Figure 45 graphs overall DT/F for all three MAB scenarios, comparing unit and CT maintenance. DT/F for unit maintenance is on the average 11% less than for CT maintenance for the ashore force and 6% less for the total force for all scenarios. Since repair capabilities at the unit are close to the scene of item failures, the units will be able to initiate repair sooner than can CT's which must be transported to the failed item.

Although not considered explicitly, the resources required for CT and unit maintenance are different. Unit repair provides a slightly higher availability but requires more resources. Each unit with a maintenance capability requires separate personnel and test equipment to perform its organizational maintenance functions. On the other hand, CT's are routed only where they are required and carry their own equipment. However, CT's are very dependent on transportation and communications, and lack of either could seriously degrade their effectiveness. The tradeoff between effectiveness (availability) and cost (resource requirements) must be considered in determining the optimal repair policy for SMLS.

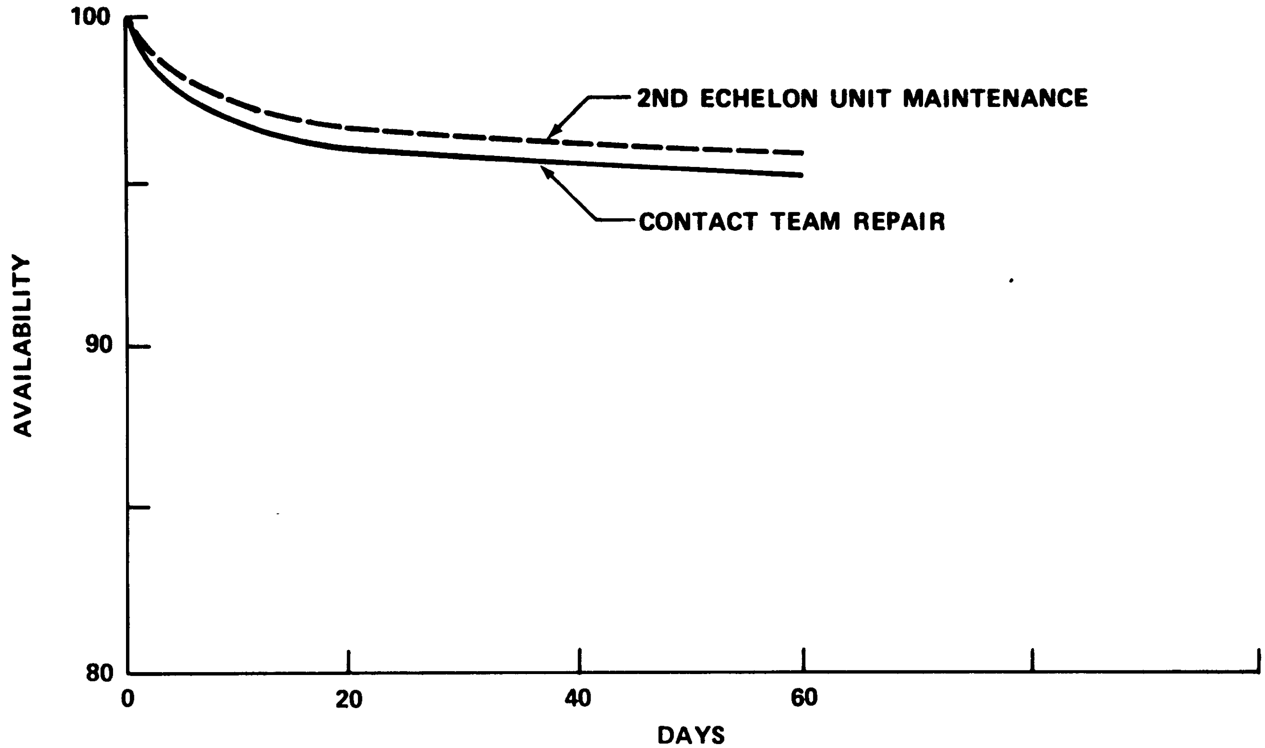


Figure 43 - Availability of Ashore Landing Force Equipment with 2nd- and Limited 3rd-Echelon Maintenance Capability at Units vs. Contact Team Support - MAB Scenario III

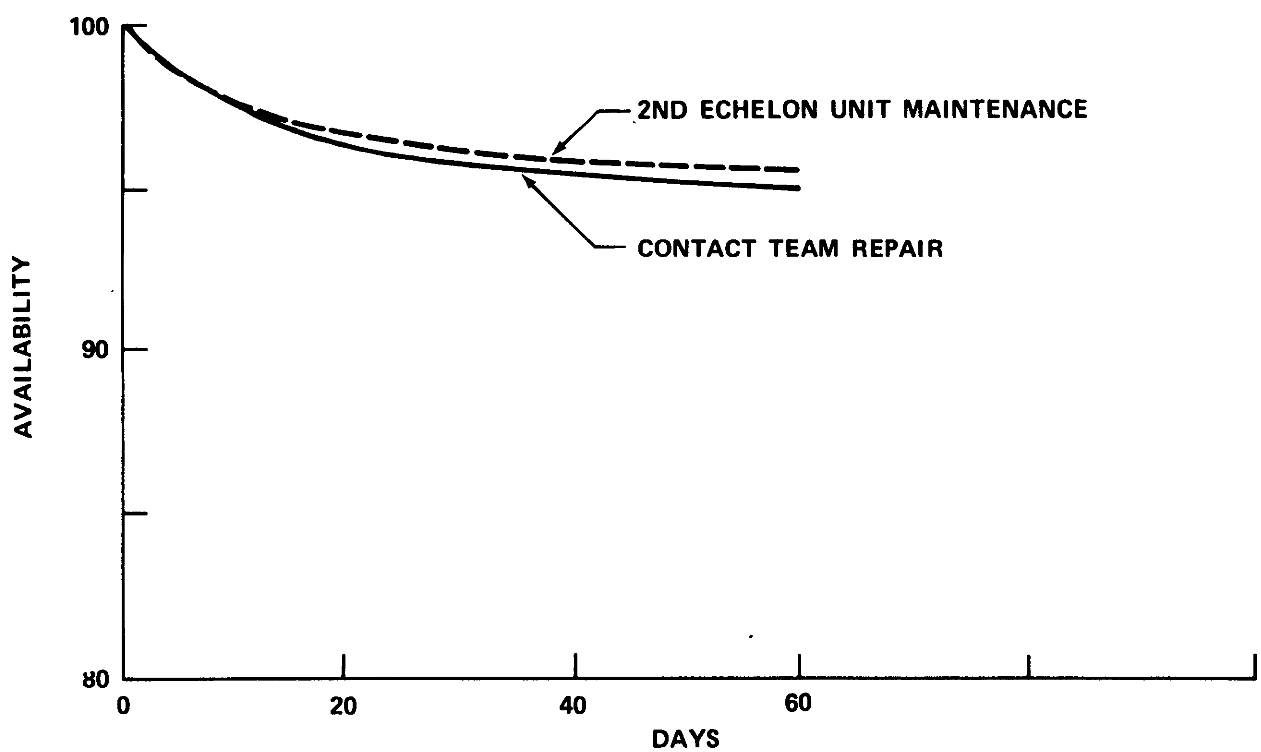


Figure 44 - Availability of Total Landing Force Equipment with 2nd- and Limited 3rd-Echelon Maintenance Capability at Units vs Contact Team Support - MAB Scenario III

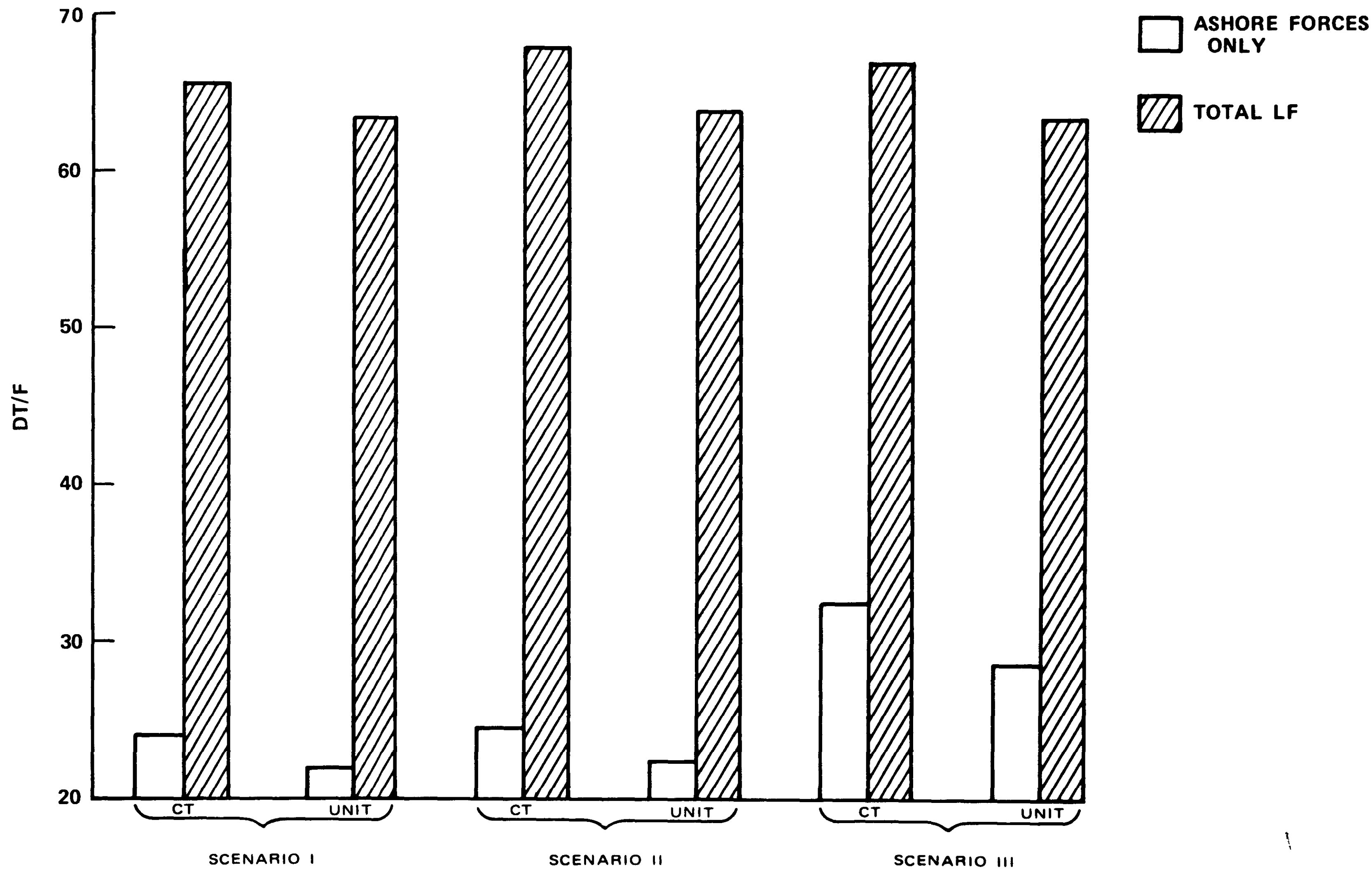


Figure 45 - Overall Equipment Downtime per Failure with 2nd- and Limited 3rd-Echelon Maintenance Capability at Unit vs Contact Team Support - MAB Scenarios I, II, and III

9.6 THE EFFECT OF THE OPERATIONAL READINESS FLOAT

The availability of the end items in the ashore force with and without an ORF is plotted in Figures 46 through 48. The average difference in availability between the two situations is 7% for all three scenarios. The total downtime does not vary appreciably since the number of failures occuring in the two situations is similar. However, when ORF items are not utilized, failed items ashore are not replaced, a factor which lowers the ashore force availability.

When an ORF is not used, replacements are not available for failed items. Therefore, downtime is registered by the ashore force (whose availability decreases) until the item can be repaired and returned ashore. On the other hand, if ORF items are available, a failed item can be replaced, and the bulk of the downtime will be registered (during repair) by the ORF which then owns the failed item. Because the number of items deployed ashore during the mission is the same whether or not an ORF exists, a similar number of item failures will occur, and downtime of the <u>total</u> force with an ORF will be similar to the downtime of the ashore force without an ORF. As noted, when an ORF exists, most of the downtime is transferred from the ashore force to the ORF. The overall change in downtime (of the <u>total</u> force) is accordingly negligible.

Availabilities of ORF items (Section 8.6.2) are shown in Figures 49 to 51 for Scenarios I, II, and III, respectively. For all scenarios, items of the MT and Ordnance* subcommodities experience the greatest decrease in availability in the ORF because of high utilization. ORF availability also decreases at a higher rate for those subcommodities (e.g., ORF or MT) with higher failure rates, because more replacement transactions are required.

ORF utilization is also indicated by the turnover percentages shown in Figure 52. Turnover percentage is defined as the ratio of the number of replacements from the ORF to the total initial ORF assets of a given subcommodity category, multiplied by 100. This figure demonstrates that

---

* Ordnance refers to the subcommodities of ART, LVT, Tank, and Infantry as a whole.

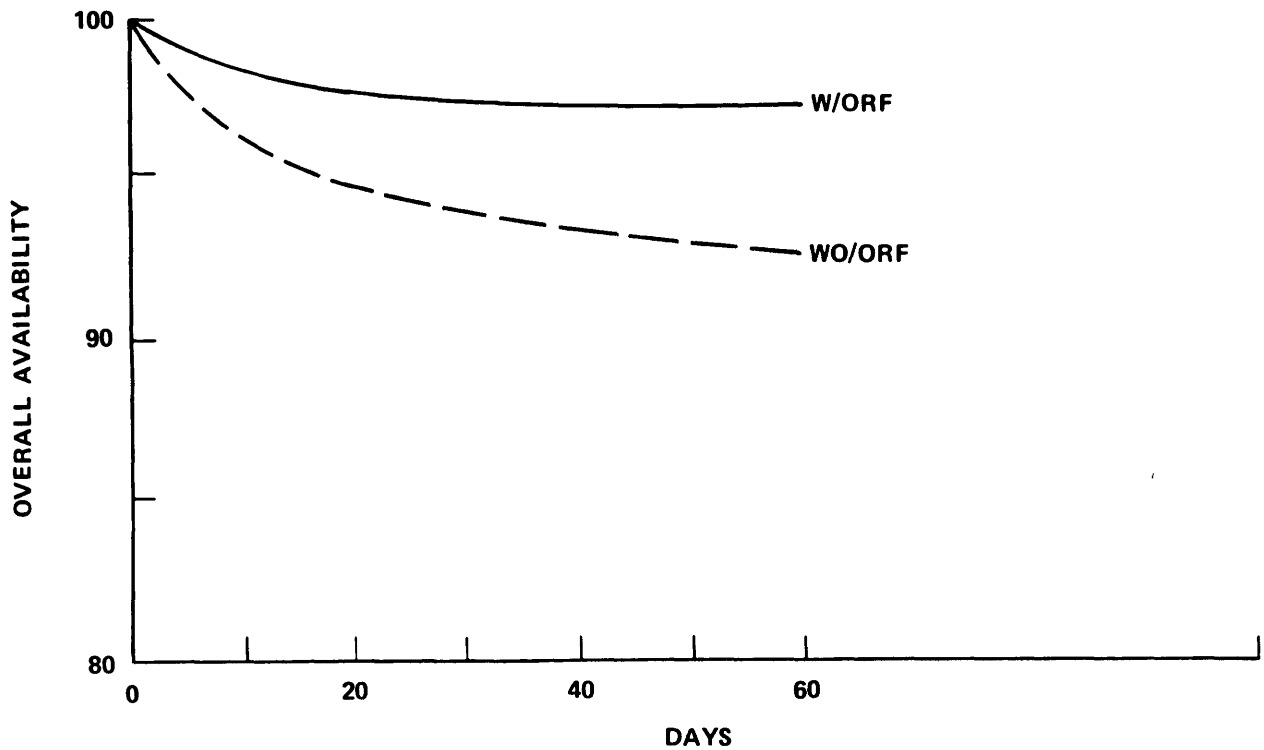


Figure 46 - Effect of Using an ORF on Availability of Ashore Force - MAB Scenario I

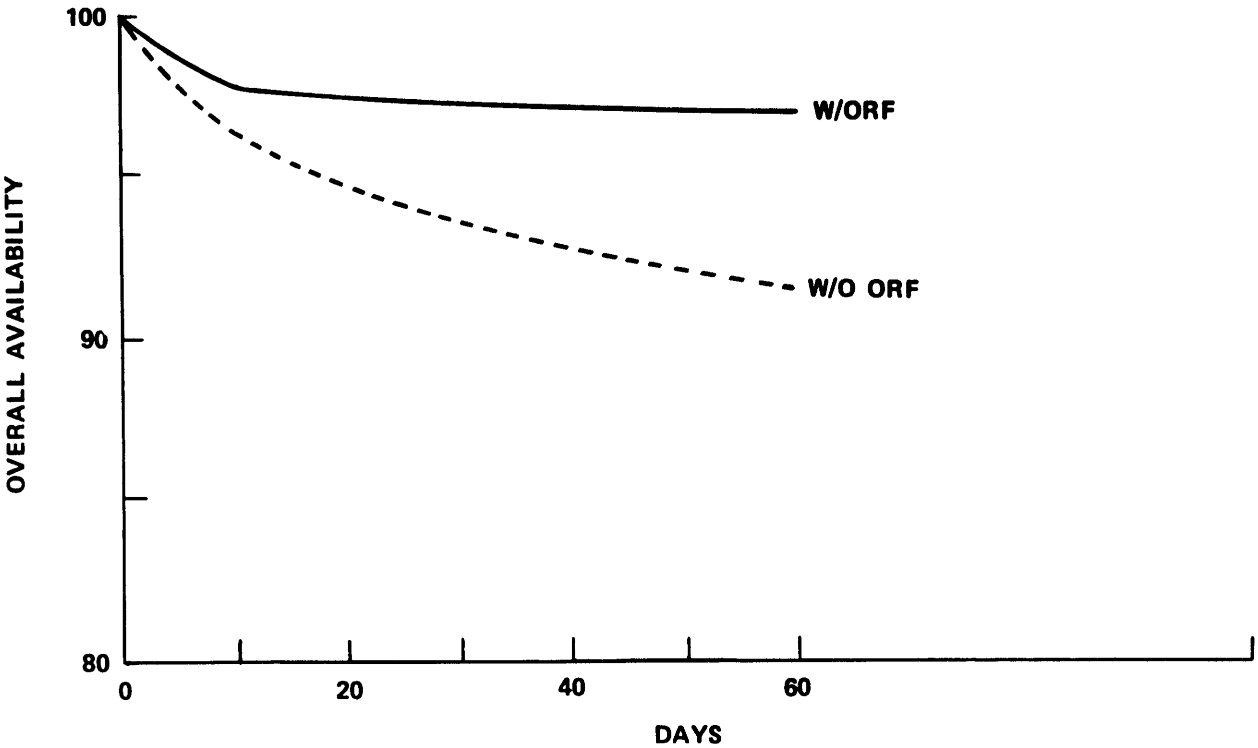


Figure 47 - Effect of Using an ORF on Availability of Ashore Forces - MAB Scenario II

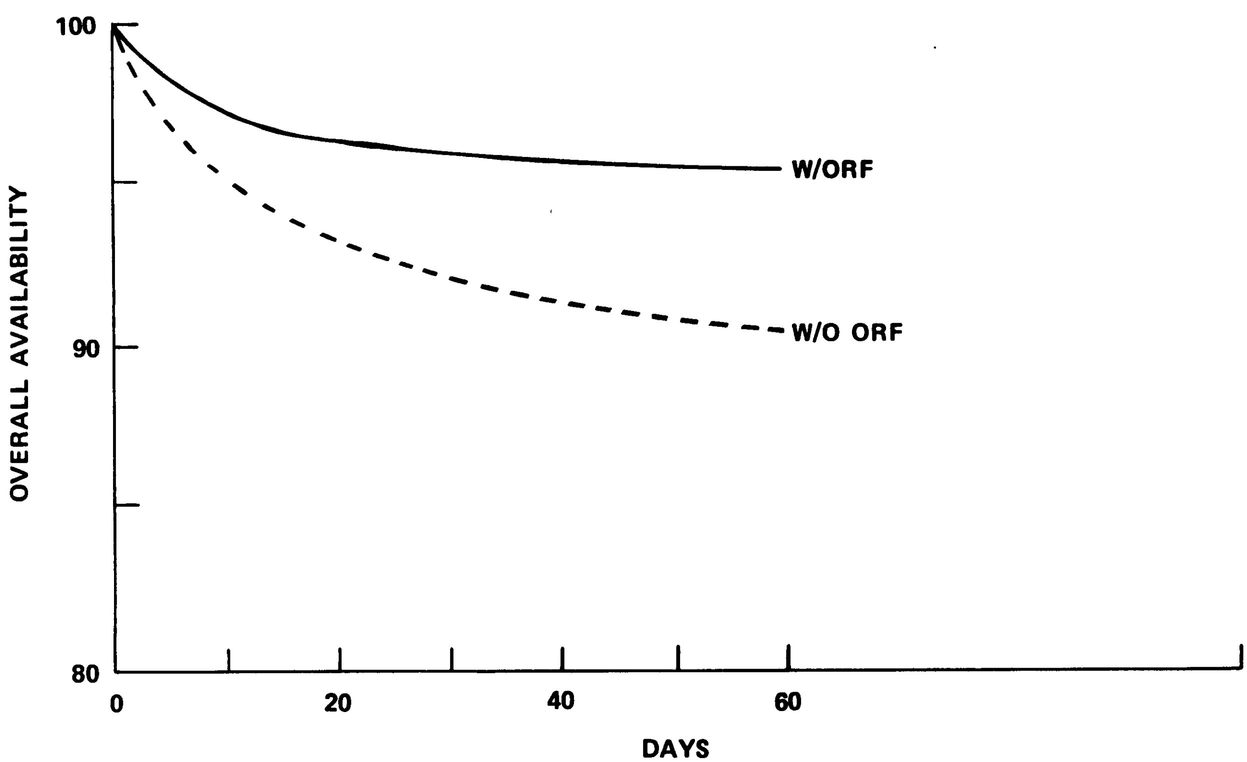


Figure 48 - Effect of Using an ORF on Availability of Ashore Forces - MAB Scenario III

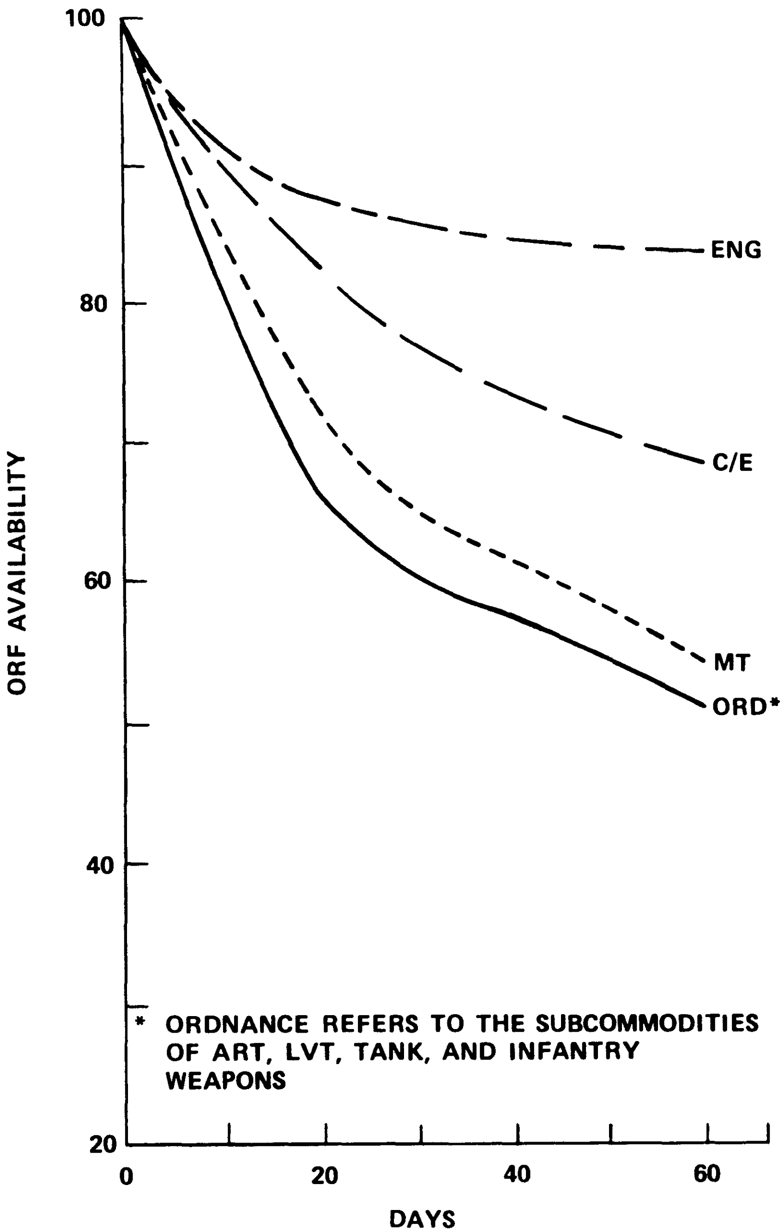


Figure 49 - Availability of ORF Items - MAB Scenario I

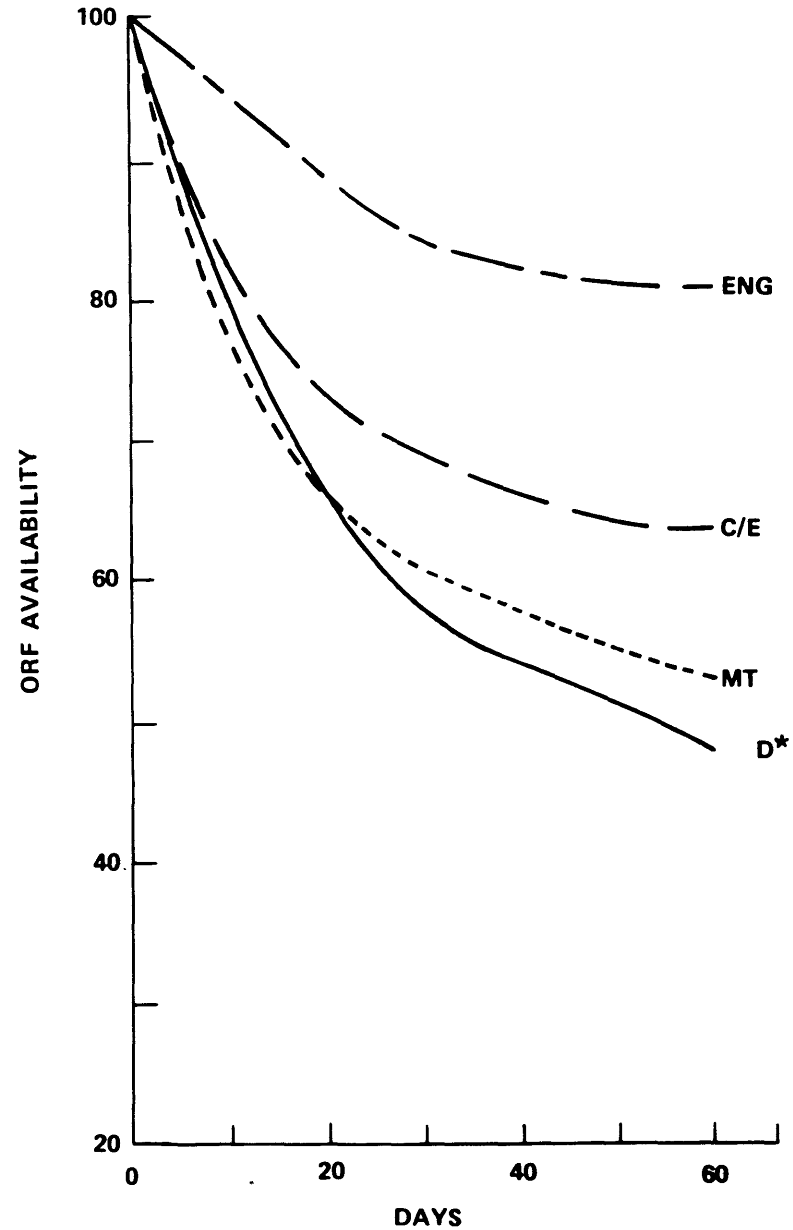


Figure 50 - Availability of ORF Items - MAB Scenario II

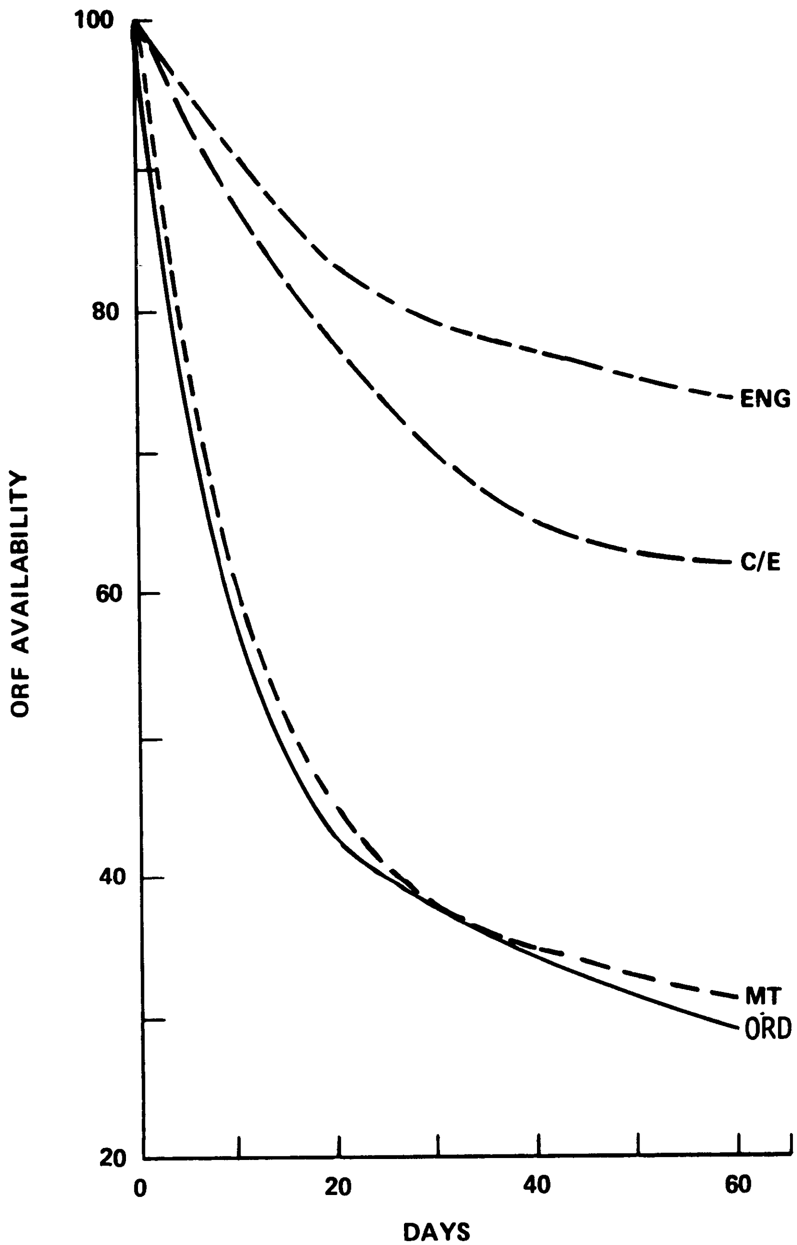


Figure 51 - Availability of ORF Items - MAB Scenario III

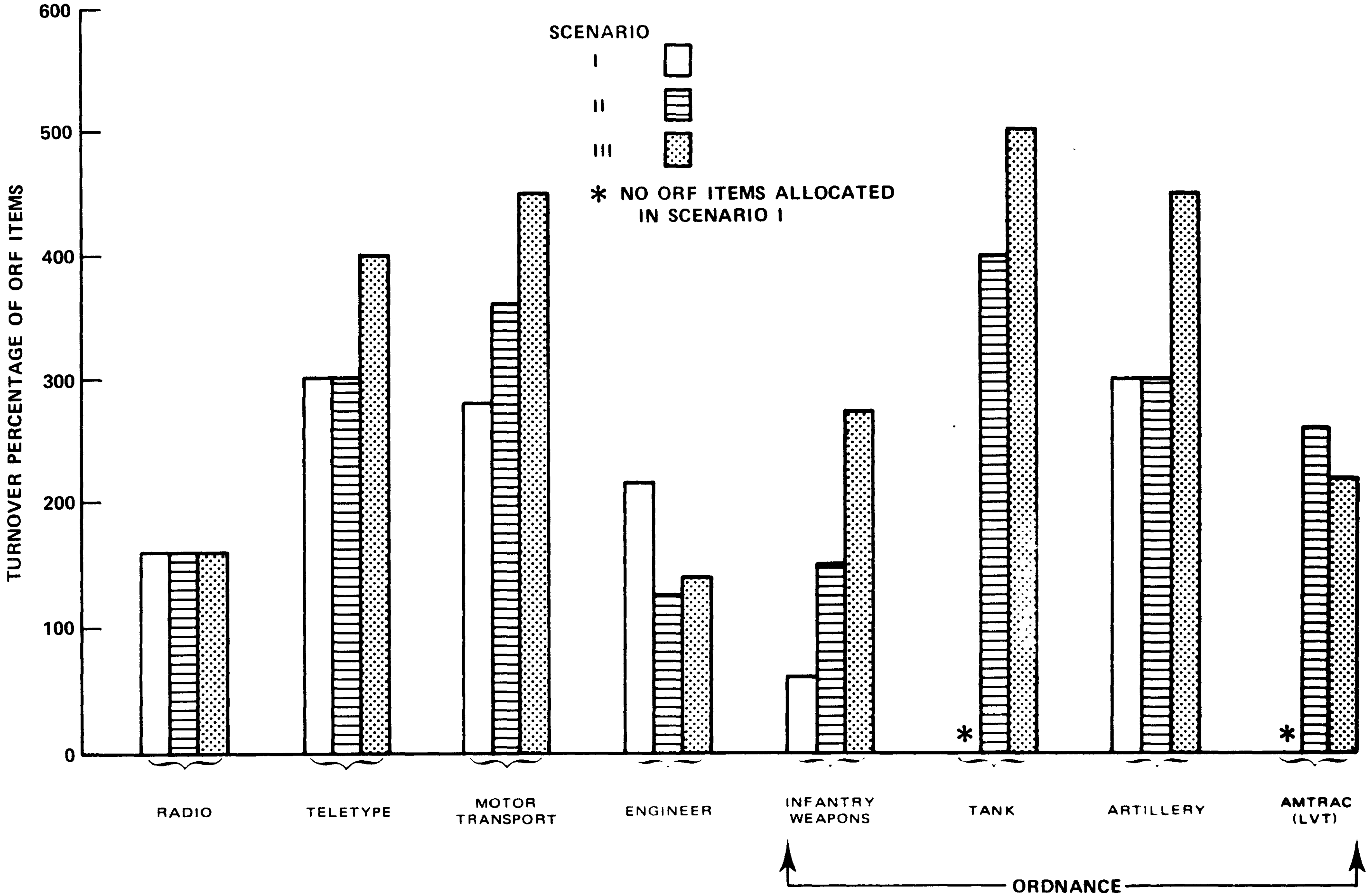


Figure 52 - Turnover Percentage of ORF Items - MAB Scenarios I, II, and III

the MT and Ordnance subcommodity items experience the greatest turnover. This large turnover is not necessarily undesirable for, unlike low availability of deployed items, low availability of ORF items does not always result in mission degradation. Of course, if the ORF utilization is high, administrative problems can arise in keeping track of all items and transactions. Furthermore, with a high ORF turnover, the risk of depletion of the ORF increases. Figure 53 illustrates the turnover rate for both ORF items and the designated items belonging to the non-deployed units (NDU). This turnover percentage is the ratio of the number of replacements from both the ORF and the NDU to the total initial assets in both the ORF and NDU, multiplied by 100.

Ordnance which has high failure rates and ORF utilization rates displays large decreases in availability because of low ORF levels. This effect is especially noticeable in the case of LVT and Tank items, as the cost and size of these items make it infeasible to provide a large number of ORF items.

Figures 49 and 50 (Scenarios I and II) show that availability of ORF items for all subcommodities starts to level off between 20 and 30 days, after a sharp initial decrease. This break in the curves is due to a reduced requirement for ORF items. The high initial ORF requirement levels are caused by the high rate of initial failures, which is evident in the initial steep decrease in availability of ashore items. This effect of initial sharp decrease in ORF item availability is evident in Figures 49 and 50 for a longer portion of the mission than is indicated by the availability curves in Figures 23 through 38 which start to level off ofter 10 days. Time delays involved in repairing the ORF items and sending them back to the ORF result in the delay effect evident in Figures 49 and 50.

Availability of ORF items for Scenario III, Figure 51, shows an unusually sharp decrease up to 14 days for MT and Ordnance items. This drop results from a high requirement for replacements as indicated by the high ORF turnover rate shown in Figure 52.

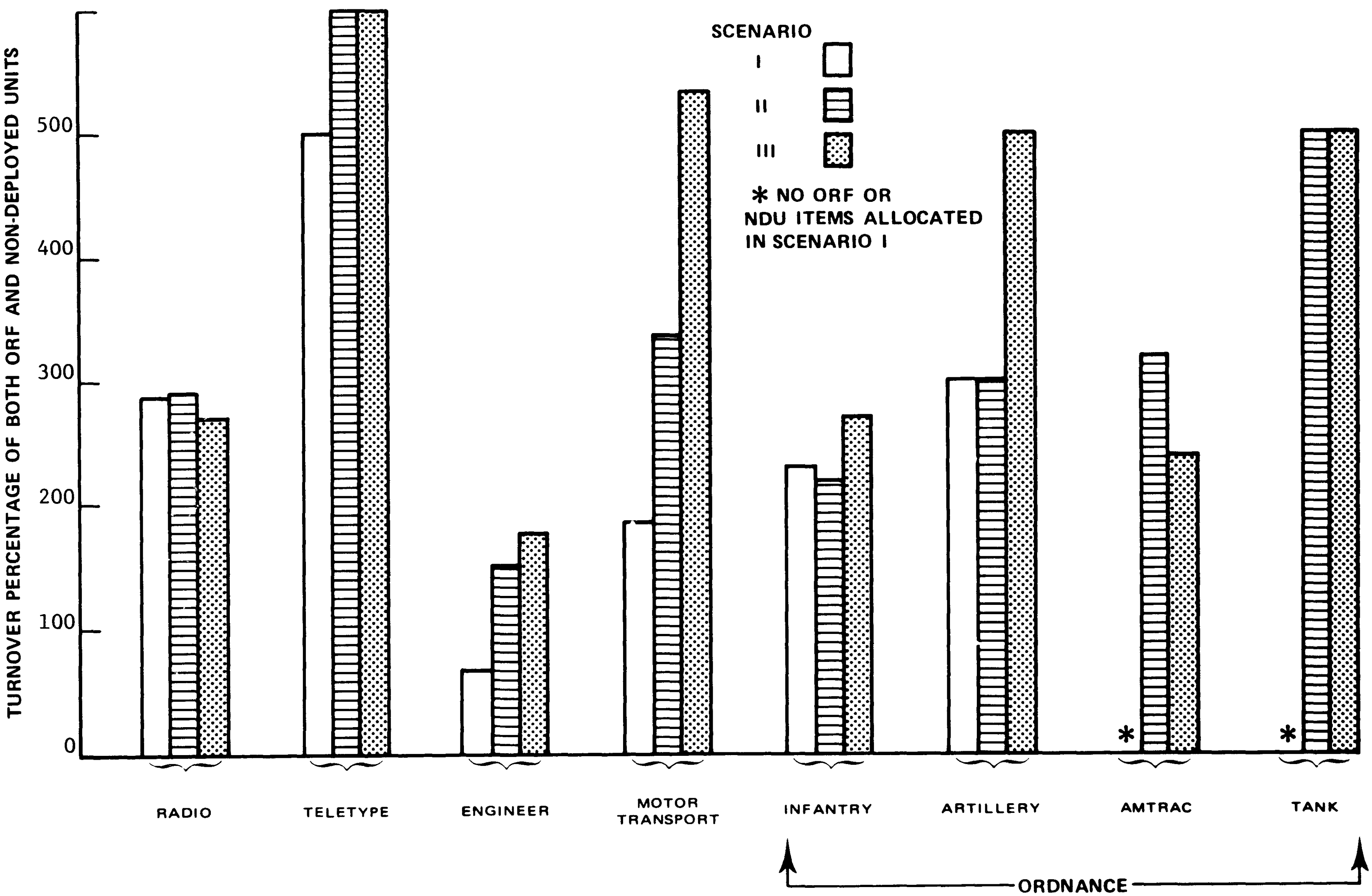


Figure 53 - Turnover Percentages of ORF and Designated NDU Assets - MAB Scenarios I, II, and III

9.7 CONTACT TEAM AND SEABASE UTILIZATION

Utilization statistics were computed for maintenance by CT's and for maintenance at the seabase. CT's were assumed to work only between the hours of 0600 - 1800; therefore, CT utilization is computed on the basis of a 12-hour day; thus, for example, 50% utilization represents six hours of CT work per day. Seabase shops, on the other hand, are assumed to operate 24 hours per day; thus, for example, 50% utilization would represent 12 hour usage. The number of CT's for each subcommodity was varied to obtain a CT utilization between 35 and 50%.

The final requirements established for CT's and seabase repair spaces are based on the requirements of Scenario III. This scenario has the highest equipment utilization, and, therefore, represents the "worst case." Utilization values of CT's and seabase repair spaces for all scenarios are given in Figures 54 and 55, respectively. A total of 21 CT's were used in Scenario I (Figure 54), with an overall utilization of 17%. In scenarios II and III, 25 CT's were used, with an overall utilization of 24% in Scenario II and 43% in Scenario III.

The repair spaces at the seabase were allocated on the basis of available Marine Corps repair personnel and space aboard ship. Overall, 38 repair spaces in two ships were available in all Scenarios, with an average utilization of 4% for Scenarios I and II, and 7% for Scenario III. In Scenario III, 24 x .07 = 1.7 hr/day; therefore, each space was utilized an average of 1.7 hours per day. Obviously, there is more than sufficient seabase capability for repair. In fact, if space were required for other logistics operations, reduction in maintenance space would be feasible.

On the basis of assigning 38 repair spaces for the two maintenance ships in the seabase, or an average of 19 spaces per ship, an attempt was made to determine roughly the total maintenance space required per ship. Total maintenance space for each subcommodity consists of (a) repair space, which is a function of the number of repair areas and the average square of repaired items, (b) queue space, based on maximum allowable queue lengths and average item square, and (c) maintenance van space. The results indicate that 6650 sq ft are required per ship. Previous calculations

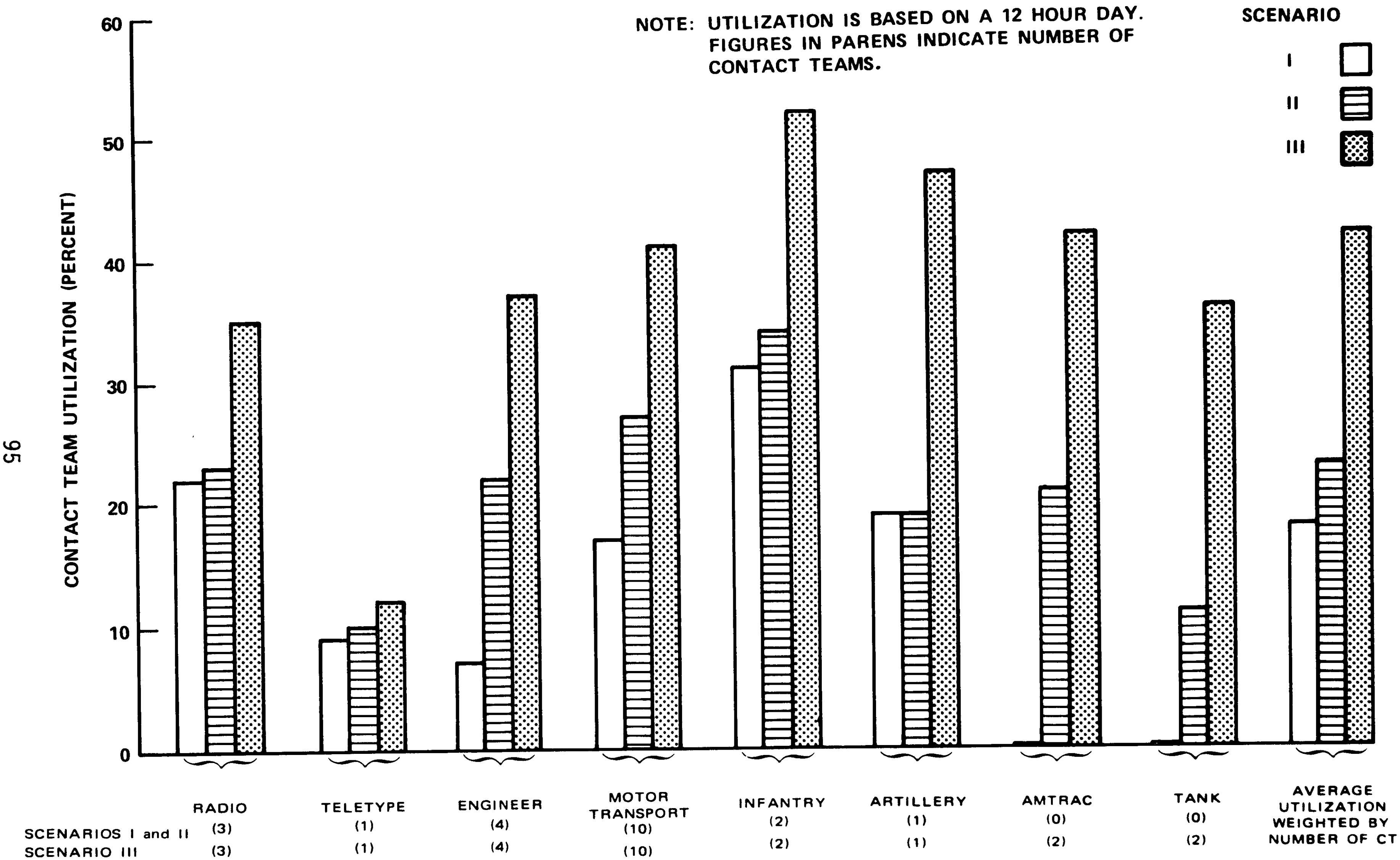


Figure 54 - Contact Team Utilization - MAB Scenarios I, II, and III

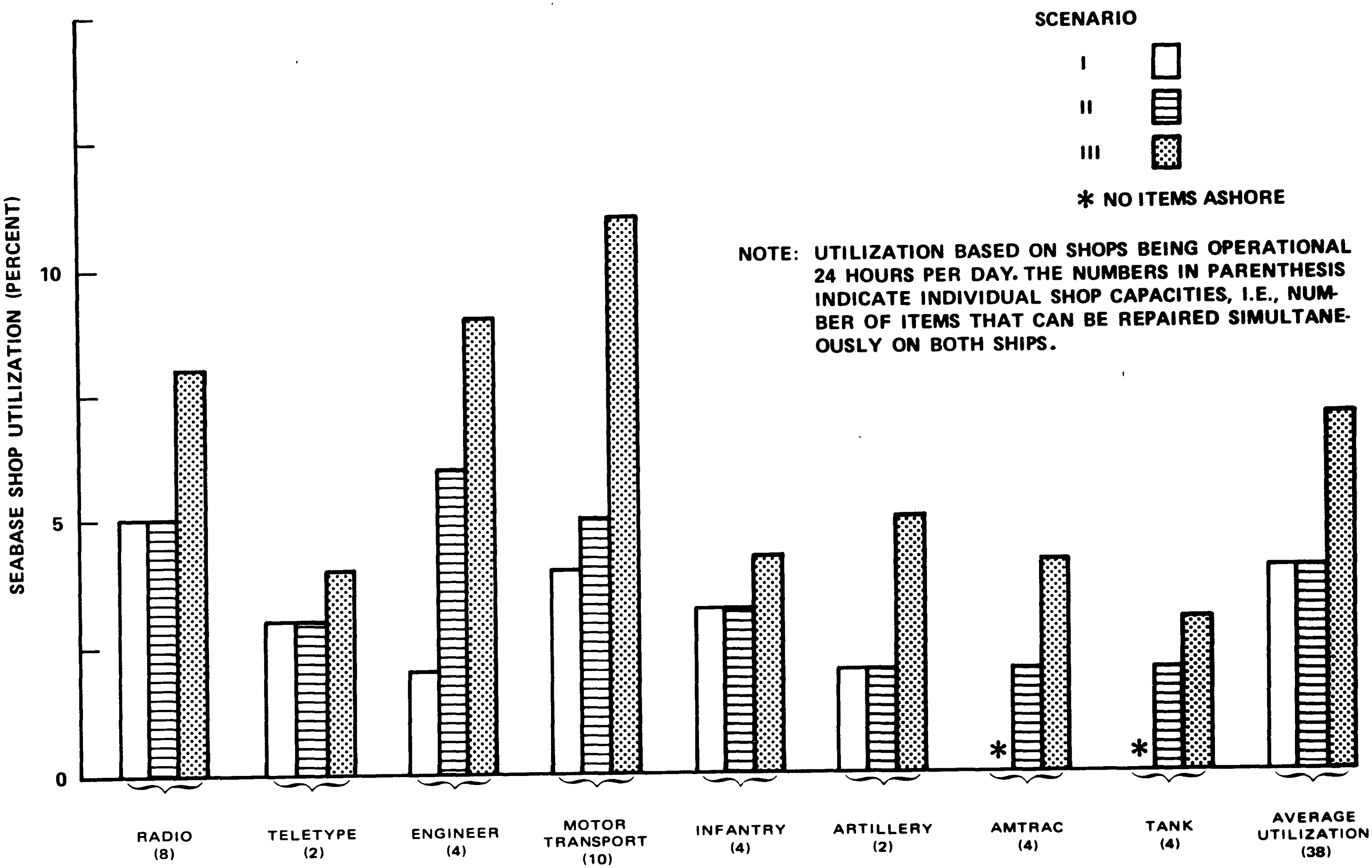


Figure 55 - Seabase Shop Utilization - MAB Scenarios I, II, and III

indicated that 7000 sq ft were available for maintenance on LPD-type ships. Therefore, based on initial calculations, two LPD-type ships would be sufficient to support the required seabase maintenance under SMLS. (However, the results of this present analysis indicates that one ship is sufficient.)

9.8 NORM AND NORS

Items not operationally ready because they are waiting for maintenance are referred to as being in NORM status. Items not operationally ready because they are waiting for supply actions are referred to as being in NORS status. The terms %NORM and %NORS were defined in Section 8.7.

Figure 56 shows average %NORM and %NORS values for items of all sub-commodity classes in the total force for Scenario III. Maximum deviation of the data points from the %NORS curve was less than 3% and from the %NORM curve less than 7%.

Average values from day 10 to day 60 were 31% for %NORM and 69% for %NORS. Therefore, on the average, 31% of the items not operating at any given time because of failure are either undergoing maintenance or are waiting for maintenance; i.e., either waiting for transportation to the seabase, waiting in the SB queues for an available maintenance space, waiting in the CT queue for the arrival of an available CT, or waiting in the CT queue because they failed during the late afternoon and night hours and cannot be repaired until the next day.

On the average 69% of the items that are out of action due to failure at any given time were waiting for supply action; i.e., waiting for repair parts from either the seabase or outside the seabase. It is evident that to reduce downtime and the number of items out of action at any given time, a better repair parts availability is required.

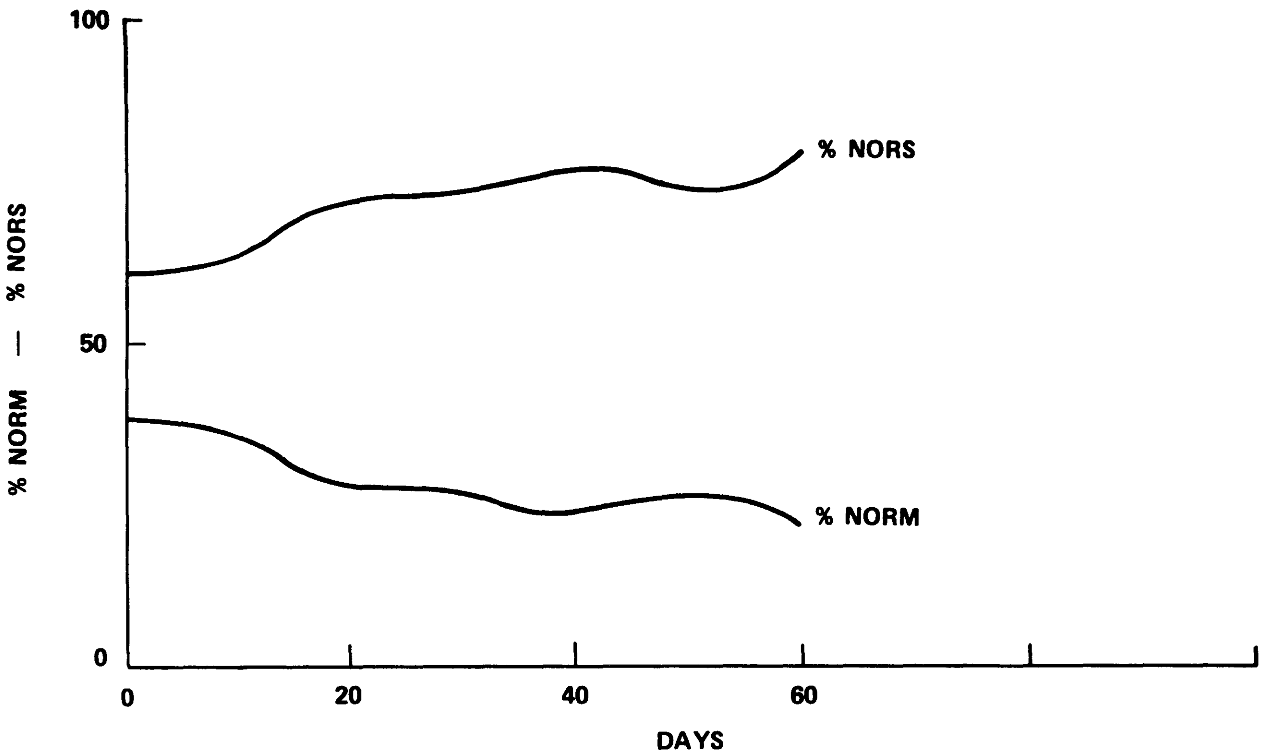


Figure 56 - Percent Distribution of NORS-NORM of Failed Equipment in the Total Force for All Subcommodities - MAB Scenario III

SECTION 10

EXPEDITIONARY AIRFIELD ASHORE

This section discusses the impact of an Expeditionary Airfield (EAF) ashore upon the ground maintenance capabilities of a MAB supported by SMLS. The model was used to assist in the analysis.

10.1 SCENARIO DESCRIPTION

Units 1 through 5 as defined in Scenario III make up the assault echelon and were deployed ashore at D-day. A sixth unit supplied with 726 additional end items was required to establish and support an EAF ashore. These items came ashore gradually as required between D+2 and D+16. This situation, incorporating an extra unit used to establish an EAF in an SMLS operation, and run for 30 days, is referred to as Scenario IV. Unit 6 contains items from five subcommodities: Radio, TTY, Engineer, MT, and Infantry. The subcommodity categories of Artillery, LVT, and Tank, were not included since they did not require supplementation over the assets assigned in Scenario III, and thus results for items of these categories are the same as those for Scenario III.

10.2 OVERALL RESULTS

Downtimes and item availabilities for this Scenario are shown in Table 5 along with those of Scenario III for comparison. The results indicate that, to support the additional 726 items in Unit 6 for Scenario IV, no additions to the 38 seabase maintenance spaces were required. However, Scenario IV required 10 more CT's than the 25 required in Scenario III. These additional CT's were required to obtain a CT utilization between 35 and 50% and give the same level of support in Scenario IV as in Scenario III.

10.3 EQUIPMENT READINESS

The increase in maintenance requirements in Scenario IV (over Scenario III) due to the EAF is evident from the downtimes given in

TABLE 5

COMPARISON OF RESULTS FOR SCENARIOS III AND IV AT 30 DAYS

Scenario III

Subcommodity	Downtime (hr.) Ashore	Downtime (hr.) Total	No. Items Ashore	No. Items Total	Availability Ashore	Availability Total	Total Numbers Failures	Downtime per Failure (hr.) Ashore	Downtime per Failure (hr.) Total	Daily Failure Rate (failures/day)
Radio	8526	17,363	474	815	.975	.968	291	29.3	59.7	9.7
TTY	1432	2067	24	27	.917	.894	37	38.7	55.9	1.2
Eng	5134	9845	105	494	.932	.967	162	31.7	60.8	5.4
MT	14,314	33,943	400	899	.950	.950	636	22.5	53.4	21.2
Art	2257	3492	46	50	.932	.903	75	30.1	46.6	2.5
LVT	4356	6590	48	53	.874	.827	124	35.1	53.1	4.1
Tank	1716	2630	19	21	.875	.826	43	39.9	61.1	1.4
Inf	4611	9952	309	401	.979	.957	164	28.1	60.7	5.5
Overall	42,346	85,882	1425	2760	.959	.957	1532	27.7	56.1	51.1

Scenario IV

Subcommodity	Downtime (hr.) Ashore	Downtime (hr.) Total	No. Items Ashore	No. Items Total	Availability Ashore	Availability Total	Total Numbers Failures	Downtime per Failure (hr.) Ashore	Downtime per Failure (hr.) Total	Daily Failure Rate (failures/day)
Radio	12,833	24,195	575	916	.909	.961	380	33.8	63.7	12.7
TTY	2267	3016	43	46	.927	.923	58	39.1	52	1.9
Eng	8091	14,164	338	727	.965	.969	298	27.2	47.5	9.9
MT	21,083	45,195	743	1242	.961	.953	861	24.5	52.5	28.7
Art*	2257	3492	46	50	.932	.903	75	30.1	46.6	2.5
LVT*	4356	6590	48	53	.874	.827	124	35.1	53.1	4.1
Tank*	1716	2630	19	21	.875	.826	43	39.9	61.1	1.4
Inf	4539	9725	339	431	.981	.962	170	26.7	57.2	5.67
Overall	57,142	109,007	2151	3486	.963	.957	2009	28.4	54.3	67.0

*Same as Scenario 3

Table 5. Overall ashore downtime increased by 35% and overall total downtime increased by 21% due to the increased number of end items (31%) failing ashore. However, Table 5 indicates that the availabilities of all subcommodities did not decrease significantly over 30 days. The largest decrease (9%) occurred in the total force availability of TTY equipment. Overall ashore availability increased, but by less than 0.5%, and overall total availability remained constant. The consistency of availability between Scenarios III and IV reflects the increase in maintenance capability in Scenario IV incorporated to handle the additional failing items.

The average downtime per failure parameter (DT/F) decreased by 3% in going from Scenario III to Scenario IV (56.1 to 54.3%). As a result of the greater number of items ashore, the daily failure rate increased 23% from 51.6 to 67.0. Thus the increased maintenance capability more than compensated for the additional failures, so that system DT/F time was not degraded.

Finally, the availability of ORF items, shown in Table 6, does decrease appreciably by 30 days, indicating high replacement demands. Since item availabilities for both the ashore force and the total force (Table 5) remain high (above 90%), the high replacement demand has evidently been accommodated by the ORF without degrading end item availability.

The equipment readiness MOE's availability and DT/F, show little change between Scenario III and IV when an EAF is supported through SMLS. Virtually no degradation results due to the extra 726 items brought ashore in Scenario IV. Ten additional CT's and the previous seabase maintenance capacity were adequate to support the additional maintenance requirements of the EAF.

10.4 CONTACT TEAM AND SEABASE UTILIZATION

Table 7 lists CT and seabase shop utilization by 30 days for Scenarios III and IV. Although seabase shop utilization increased slightly in Scenario IV, more than enough reserve capacity existed in the seabase

TABLE 6

AVAILABILITY OF ORF ITEMS FOR SCENARIO IV

Subcommodity*	10 Days	20 Days	30 Days
Radio	.837	.720	.653
TTY	.589	.433	.403
Eng	.903	.813	.724
MT	.635	.462	.380
Inf	.680	.544	.446

*Values for Art, LVT, and Tank subcommodity classes are the same as in Scenario III.

TABLE 7

CT AND SEABASE UTILIZATION FOR SCENARIOS III AND IV
AFTER 30 DAYS OF OPERATION

	Scenario IV				Scenario III			
Subcommodity	No. of SB Shop Spaces	SB Utilization	No.of CT's	CT Utilization	No. of SB Shop Spaces	SB Utilization	No.of CT's	CT Utilization
Radio	8	.09	4	.38	8	.07	3	.35
TTY	2	.06	2	.10	2	.04	1	.12
Eng	4	.17	8	.39	4	.09	4	.37
MT	10	.13	14	.51	10	.11	10	.51
Inf	4	.04	2	.54	4	.04	2	.52
Art*	2	.05	1	.47	2	.05	1	.47
LVT*	4	.04	2	.43	4	.04	2	.43
Tank*	4	.03	2	.36	4	.03	2	.36

*Since no additional end items were added, values are the same for Scenarios III and IV.

(in Scenario III) so that it could absorb the extra load generated in Scenario IV without an increase in the number of seabase maintenance spaces. The largest increase in seabase shop utilization occurred in items of the Engineer subcommodity which went from 9% to 17% due to the large increase of Engineer items ashore.

As noted above, additional CT's were added in Scenario IV so that the CT utilization values approached those values obtained in Scenario III. These additional personnel required are currently available in the maintenance company of the conventional MAB organization. For the Radio subcommodity, one CT was added to make a total of four, with a utilization of 38% (the value was 35% in Scenario III). For TTY items, only one CT was used in Scenario III with a utilization of 12%. With two CT's in Scenario IV, a utilization value of 10% resulted.

Engineer and MT subcommodity items experienced the largest increase in maintenance requirements, since the relative increase of the number of end items deployed was the largest in these subcommodity classes. For the ashore force, Engineer items were increased by 222%, MT items by 86%, Radio items by 21%, Infantry items by 10%, and TTY items by 79%. To obtain the same utilization as in Scenario III, four more CT's were added for Engineer items to make a total of eight, and four CT's were added for MT items to make a total of 14. Thus, in all 10 additional CT's were required in Scenario IV to obtain approximately the same utilization of CT's as that of Scenario III. Because of these additions, equipment readiness in Scenario IV (with 726 more items) was nearly equal to equipment readiness in Scenario III.

SECTION 11

CONCLUSIONS AND RECOMMENDATIONS

11.1 CONCLUSIONS RESULTING FROM MAU ANALYSIS

11.1.1 SMLS Compared to Conventional Maintenance

- SMLS has no advantages over conventional operations for short mission durations (10 days).
- SMLS becomes more advantageous for longer mission durations (90 days) since fewer items are deployed ashore because of lower ashore support requirements.
- SMLS exhibits better performance for the 90-day mission because it has a limited 4th-echelon capability-the conventional organization does not.

11.1.2 SMLS Performance

- Because of high failure rates and no ORF allocated, the AMTRAC and Tank subcommodities exhibit poor performance in comparison to the overall force.
- ORF items increase ashore force availability by transferring downtime from the ashore force to the ORF.
- Overall MAU performance is good (above 90%). But weak links; i.e., Tank, LVT, and TTY items with low reliability can jeopordize the performance of the mission.
- Longer mission durations require more repair parts and replacements. The ORF is adequate in maintaining performance by supplying end item replacements. However, a majority of items out of action for an extended time are waiting for repair parts.

11.2 RECOMMENDATIONS RESULTING FROM MAU ANALYSIS

- Use SMLS for longer missions where it has greater advantages.

- Examine the possibility of adding LVT or Tank ORF's. The tradeoff between increased mission performance and increased cost and space requirements should be considered.
- Study in detail the ORF levels to find the most cost effective mix.
- Improve the availability of repair parts.

11.3 CONCLUSIONS RESULTING FROM MAB ANALYSIS

- Both CT and unit maintenance are supportable with little difference in end item availability. Only in Scenario III does unit repair show a slight advantage over CT repair.
- The overall MAB performance is good (above 90%) with the exception of TTY, ART, AMTRAC, and Tank subcommodities which have low ORF levels and exhibit high failure rates.
- The use of an ORF significantly decreases downtime of end items in the ashore force, thus increasing availability of end items in the landing force.
- The ORF's of MT and ORD exhibit high utilization because of high failure rates and replacement requirements of these subcommodities.
- The use of two LPD-type ships provides sufficient reserve seabase maintenance capacity to support SMLS. More than adequate capacity exists to meet peak requirements.
- Since most repairs require repair parts, the availability of end items is largely dependent on repair parts availability.

11.4 RECOMMENDATIONS RESULTING FROM MAB ANALYSIS

- Study the resources required by CT and unit repair to further compare the two methods.
- Investigate selective retention of maintenance in some units, based on cost (maintenance resources required) and effectiveness (e.g., availability, DT/F of the Landing Force).

- Examine the possibility of adding more ORF items to TTY, ART, AMTRAC, and Tank subcommodities based on cost-effectiveness criterion.
- Improve repair parts availability.

11.5 CONCLUSIONS RESULTING FROM EAF ANALYSIS

The addition of end items required in a EAF to a MAB force being supported by SMLS caused virtually no degradation in Landing Force performance if 10 CT's are added. Existing seabase capacity is sufficient to support an EAF. Consequently, the addition of an EAF to a situation described by Scenario III is feasible from the maintenance standpoint.

REFERENCES

1. Hubai, P. et al., "Computer Simulation Model for Seaborne Mobile Logistic System (SMLS) at the Amphibious Task Unit/Marine Amphibious Unit (ATU/MAU) Level, Part 1 - Model Description," NSRDC Report 4114, December 1974.

2. Marcus, C. Y. and M. Gray, "Seaborne Mobile Logistic System (SMLS) Maintenance Optimization Model User's Manual, "NSRDC Report 4115, August 1973.

3. Van Eseltine, C. A., "Seaborne Mobile Logistic System (SMLS) Maintenance Optimization Model, Version II - User's Manual," NSRDC Report 4381, March 1974.

4. "Post Exercise Seaborne Mobile Logistic System Evaluation Report, Phiblex 5-72," Enclosure to COMPHIBGRUEASTPAC ltr FF8-3:01:mm, 3120, ser:010, 22 December 1972.

5. Fuller, J. J., and C. A. Van Eseltine, "Sea Log II, A Logistic War Game Employing The Seaborne Mobile Logistic System (SMLS) Concept at the Amphibious Task Group/Marine Amphibious Brigade (ATG/MAB) Force Level," NSRDC Report 4136, January 1974.

6. Gray, M., "Development of the Seaborne Mobile Logistic System (SMLS) Maintenance Optimization Model, Version I," NSRDC Report 4116, October 1973.

7. Seaborne Mobile Logistic System, Second Interim Report for Refined ATU/MAU and Interim ATG/MAB, enclosure (1) of CNO (OP-323)/CMC (A04R-615-2) ltr of 11 October 1973.

8. Seaborne Mobile Logistic System (SMLS) Study, Volume II Amphibious Task Unit/Marine Amphibious Unit (ATU/MAU) Analysis and Volume III Amphibious Task Group/Marine Amphibious Brigade (ATG/MAB) Analysis, enclosures (2) and (3) of MCDEC ltr D050-4/FDMJr:jmw of 18 July 1974.

9. Table of Authorized Material (TAM), Rev 1, USMC, NAVMC 1017, 20 April 1970.

INITIAL DISTRIBUTION

Copies	
1	USACDR (Mr. G. Hutchinson)
1	CHONR 463 (CDR W. F. Hodkins)
1	USMC (COL C. E. Parrott)
4	CMC LPC J. Flynn
4	MC-AX/A. Slafkosky
4	CMC SMLS PROJ OFF/COL Munn
4	MC MAINTENANCE SYS OFF (MIMMS), MCDEC
1	MCDEC (COL O. R. Swigert, Jr.)
6	CNO 2 OP 962F 3 OP 966 1 OP 323 (CAPT Christenson)
2	COMNAVSURFLANT 1 CAPT Roy Malone 1 Mr. L. W. Owen
1	COMNAVSURFPAC (CAPT Norman Wenger)
1	NRL (Mr. J. A. Reynolds)
1	USNA LIB
2	NAVPGSCOL 1 Library 1 Mr. R. E. Jamison
1	NROTC & NAVADMINU, MIT
5	NAVWARCOL CEN WAR GAMING (CDR Cate)
1	NCSL (Mr. C. B. Koesy)
1	NMC (Mr. W. L. McDonald)
1	NSWC, WHITE OAK (Mr. J. H. Armstrong)
1	NSWC, DAHLGREN (Mr. R. E. Lutman)
2	NELC 1 Mr. Robert Beitscher 1 Mr. Dale Hollabaugh
2	NUSC 1 NPTLAB (Mr. R. C. Ward) 1 NLONLAB (Mr. Louis Free)

Copies

1	NWC (Mr. D. H. Williams)
1	NADC (Mr. R. N. Becker)
1	NCEL (Mr. R. C. Towne)
1	NPRDC (Mr. R. E. Jamison)
1	NWRC (Mr. J. A. Saxten)
1	NTEC (Mr. R. G. Ryan)
1	NOS, LOUISVILLE (Mr. W. Haggerty)
12	DDC
2	Defense Logistics Studies/Info Exchange
1	APL/JHU (Mr. Robert Kemelhor)

CENTER DISTRIBUTION

Copies	Code	
1	00	CAPT P. W. Nelson
1	07	Norbert Schnippel
1	1105	Bruce J. Wooden
1	1175	T. E. Mansfield
1	1502	
1	18	G. H. Gleissner
4	1802	
	1	Daniel Shanks
	1	F. N. Frenkiel
	1	Hans J. Lugt
	1	Feodor Theilheimer
1	1805	E. H. Cuthill
1	1830	
1	1850	Thomas Corin
1	1860	Robert A. Sulit
1	1861	Samuel C. Rainey
1	1864	Ralph M. Santamaria
30	1867	Michael Gray
1	1880	Abel W. Camara
2	1890	
	1	Gilbert R. Gray
	1	Central Depository
30	5614	Reports Distribution
1	5641	UNCLASSIFIED LIB(C)
1	5642	UNCLASSIFIED LIB(A)