Relating Resources to the Readiness and Sustainability of Combined Arms Units

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for Army maneuver units. The methodology
can be adapted to other types of general
purpose forces as well. Section II
summarizes the concepts behind the resource
readiness and sustainability index.
Section III presents the results of
applying these concepts to a combined arms
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PREFACE

This report was prepared as part of Rand's Manpower, Mobilization and Readiness Program, sponsored by the Office of the Assistant Secretary of Defense (Manpower, Reserve Affairs, and Logistics)—OASD(MRA&L). The study was conducted under Task Order 80-IV-2, Quantifying the Effect of Resource Levels on the Readiness of Ground Forces.

Readiness and sustainability issues are assuming an ever greater importance in defense planning and budgeting. Dealing with these issues requires the development of new methodologies for examining the relationship of resources to readiness and sustainability. This study is intended to contribute to a better understanding of that relationship and to the broader questions of readiness and sustainability confronting the Department of Defense. It is not intended as a cost-effectiveness study recommending specific policies.

This report extends work reported in N-1299-MRAL, *Resource Readiness of Armored Units,* November 1979. Although the analysis here is based on the same readiness and sustainability concepts and uses the same AURA simulation model, it differs in several major respects. These include:

- Assessment of readiness and sustainability that encompasses a combined arms brigade with its associated divisional support echelons.
- Examination of more than one operational scenario for the same resource and organizational set.
- Evaluation of the effects of a wider range of resource constraints, both individually and jointly, on brigade output.
- Measurement of readiness and sustainability over different base line assumptions.

In short, this report describes a more mature application of the AURA simulation model than in previous documents. Another change concerns terminology. In this report, the phrase "readiness and sustainability" is used in place of the single word "readiness" used in N-1299-MRAL. Otherwise, the conceptual content of N-1299-MRAL and this report is the same. This change is desirable from the point of view of standardizing the definitions of terms relating to "military capability." Readiness, according to recent official documents, is essentially a measure of pre-D-day status (extending, at most, into initial combat operations), while sustainability is a post-D-day measure, encompassing the "staying power" of combat units. The concept presented in this report clearly overlaps both readiness and sustainability, and our terminology reflects this. The report should be of interest to those concerned with readiness, sustainability, and resource requirements for general purpose forces.

SUMMARY

The readiness and sustainability of U.S. military forces has become a major budget issue. Yet few tools are available to help readiness managers and DoD decisionmakers relate changes in resource-flow decisions to the readiness and sustainability status of forces. This report describes such a tool for Army combined arms units, though the concepts are applicable to a variety of general purpose forces.

Recent definitions of readiness and sustainability emphasize the capability of a unit to deliver its inherent product or service at some period in time and to continue to deliver that product or service over some extended time horizon. Clearly, more is required than a mere list of available resources and an appraisal of their current condition. At a minimum, a readiness and sustainability measure must be *output-related* and *time-conscious*—that is, it must take into account the timeliness with which a unit can respond, the length of time and circumstances under which the unit is expected to operate. Quite simply, readiness and sustainability cannot be ascertained without asking, "Ready for what?"

In peacetime, Army units train to do specific tasks; in wartime, they must execute these tasks with great precision in order to survive on the battlefield. When performed in a sequence, these tasks form an operation. It is useful, therefore, to think of a combined arms unit's output in terms of a vector of its ability to perform notional operations of several specific types. We use the term *specific operational capability (SOC)* to represent each such notional operation within the vector of output.

This concept of output quantifies the unit's ability to marshal its equipment, crews, maintenance personnel, consumables, and other resources in a timely fashion. The unit's adequacy to defeat the enemy or hold territory is a consideration apart from this definition of output. The latter concept, which we call capability, is two-sided, while readiness and sustainability as defined here are only one-sided. Readiness and sustainability, then, are components of capability.

For each SOC, it is possible to define a readiness and sustainability index for a unit as its cumulative output over some period *relative* to a reference unit. The idea of standardizing on the output of a reference unit is based on the belief that commanders will have a greater appreciation for the readiness and sustainability of their unit when compared with a commonly accepted yardstick. The choice of a reference unit is arbitrary, but it makes sense to choose something Army commanders are attuned to. We chose, as our reference unit, a combined arms brigade with its full authorized complement of manpower and equipment and unconstrained (at consumption rates specified in each SOC) ammunition, POL, and spares. This set of resources should allow the brigade to reach its maximum potential output.

We used a model called AURA (Army Unit Readiness Assessor) to determine the relationship between brigade resources and output for several SOCs. AURA is a powerful event simulation model that permits decisionmakers to examine the prospective impact of alternative resource levels on a combat unit's output levels and to assess a broad range of policy options on a theatre-wide basis. It also allows examination of the effects of attrition, replenishment, and higher-echelon repair on continued operations. The readiness and sustainability concepts do not, however, depend on the use of AURA or any other particular model.

AURA was used to simulate a combined arms brigade consisting of two armored battalions and one mechanized infantry battalion embedded within division and corps structures.

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For analytical purposes, the brigade's battalions were divided into three identical tank-heavy task forces, which were supported by a dedicated Forward Area Support Team (FAST), spares from a Division Support Command (DISCOM), and by division and corps-level major end item replacements. The simulation produced estimates of the brigade's output under two SOCs—an attack SOC and an active defense SOC. Both were representative of what a combined arms brigade might have to do in a major conventional conflict in Europe.

As could be expected, a brigade with more (or better) manpower, consumables, and replacement end items produced more output than a brigade with fewer resources for both SOCs investigated. The readiness and sustainability index, using the reference unit described above, confirmed this. Although the index depended, as it should, on the assumed daily attrition rate and time horizon over which the brigade must sustain operations, with those parameters held constant, a combined arms brigade with constrained resources was found to be not equally prepared for both SOCs. As a general rule, a combined arms brigade's readiness and sustainability index will be higher for those SOCs that demand *relatively* less of the brigade's scarcest resources. The reason for this is straightforward—in some SOCs, substitute resources are better able to compensate for the shortage than in other SOCs.

The ability to translate inputs into output is significant not only for readiness and sustainability measurement, but for the opportunity it offers to dramatically improve the requirements determination process. With this ability a resource manager can tailor readiness and sustainability improvements according to the desired level of readiness and sustainability for each type of output (SOC) and to the relative marginal cost of each such improvement. Carefully used, such analyses can provide stronger justification for certain budget requests.

In addition to resource requirements issues, other management concerns can be addressed within the framework presented here. These concerns include the allocation and distribution of existing resources, the selection of units to perform specific operations during periods of crisis, and the evaluation of alternative support structures during such studies as Division 86.

Envisioned as a supplement to existing readiness reports is a system that rates each unit according to its ability to perform specific operational capabilities (SOCs) under various operation plans (oplans). The actual value of the resulting information depends on the ability of decisionmakers to allocate resources rapidly across units in response to readiness and sustainability deficiencies. Although the different uses of the readiness and sustainability measure described in this report may require different detailed information, all require some understanding of the relationship of inputs to outputs.

ACKNOWLEDGMENTS

GLOSSARY OF ACRONYMS

ADA	Air Defense Artillery
APC	Armored Personnel Carrier
ARTEP	Army Training and Evaluation Program
ASL	Authorized Stockage List
AURA	Armored Unit Readiness Assessor
CBR	Chemical, Biological, Radiological
CEM	Concepts Evaluation Model
CMAC	Contingency Maintenance Allocation Chart
CONUS	Continental United States
DA	Department of the Army
DARCOM	Development and Readiness Command
DISCOM	Division Support Command
DS	Direct Support
FAST	Forward Area Support Team
FEBA	Forward Edge of the Battle Area
FORSCOM	Forces Command
GDP	General Defense Plan
GS	General Support
JCS	Joint Chiefs of Staff
MOS	Military Occupational Specialty
MERPL	Mission Essential Repair Parts List
O&M	Operations and Maintenance
NRTS	Not Reparable This Station
PLL	Prescribed Load List
POL	Petroleum, Oil, and Lubricants
POM	Program Objective Memorandum
POMCUS	Prepositioned Overseas Materiel Configured to Unit Sets
PWRMS	Prepositioned War Reserve Materiel Stocks
RDD	Required Delivery Date
RISE	Reliability Improvements Engine
SOC	Specific Operational Capability
TAA	Total Army Analysis
TLR/S	Total Logistics Readiness/Sustainability
TO&E	Table of Organization and Equipment
TRADOC	Training and Doctrine Command
TR-1	Theatre Reserves/1
TSAR	Theatre Simulation of Airbase Resources

USAREUR   United States Army, Europe
USR   Unit Status Reporting
WRSK   War Reserve Spares Kit

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FIGURES

TABLES

I. THE READINESS AND SUSTAINABILITY PROBLEM

As Soviet forces have modernized and increased in size over the past ten years, U.S. military commanders have become noticeably more concerned not only about sustaining U.S. qualitative superiority in the 1980s, but also about improving the readiness and sustainability of forces already in the field. Because major investment programs and manpower policy changes affect readiness and sustainability only in the long run, the management of O&M resources and the promulgation of standards for the management of in-place units are the basic policy variables that can affect the day-to-day status of forces. Yet few analytical tools are available to help readiness managers and DoD decisionmakers relate changes in the readiness and sustainability status of forces to resource-flow decisions. This report offers an approach to this problem for Army maneuver units. The methodology can, however, be adapted to other types of general purpose forces as well.

READINESS AND SUSTAINABILITY DEFINITIONS AND MEASUREMENT

Readiness ratings reported by maneuver units are no more or less precise than those for other units reported under the Joint Chiefs of Staff (JCS) *Unit Status and Identity Report (UNITREP),* which defines an operationally ready organization, shop, or weapon system as one "capable of performing the missions or functions for which it is organized and designed."[1]

This heuristic approach is consistent with the official DoD view of readiness and sustainability promulgated in several recent documents:[2]

> *Readiness.* The ability of forces, units, weapon systems, or equipments to deliver the outputs for which they were designed (including the ability to be deployed and employed without unacceptable delays).
>
> *Sustainability:* The "staying power" of forces, units, weapon systems, and equipments (often measured in number of days).

In this view, readiness is essentially a measure of pre-D-day status, extending at most into initial combat operations, while sustainability is a post-D-day measure. Readiness and sustainability are closely related in these definitions because the resources that produce readiness—personnel, equipment, and consumables—overlap to a large extent with those that produce sustainability. Moreover, readiness and sustainability are two key components of the broader concept of *military capability,* which is currently defined as "the ability to achieve a specified wartime objective."[3]

Recently, the House Armed Services Committee Readiness Panel took a more fiscal approach in defining readiness as the "balancing of manpower, investment, and operations and

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[1]Joint Chiefs of Staff, *Joint Reporting Structure Unit Status and Identity Report (UNITREP),* JCS Publication No. 6, Washington, D C., April 1980.

[2]Office of the Secretary of Defense, *Justification of Estimates for Fiscal Year 1982 Submitted to Congress. Operation and Maintenance Overview,* Vol II, Washington, D C , February 1981, p 1 See also *DoD Annual Report, Fiscal Year 1982,* p 93

[3]Ibid., p 1. The other two components are force structure and force modernization

maintenance (O&M) expenditures that produces a force structure capable of a rapid, sustained, and ultimately successful response to a threat."[4]

These definitions of readiness and sustainability emphasize the capability of an operating unit to deliver a *product or service at some point in time and to continue to deliver that product or service over some extended time horizon.* It is clear from the above illustrations that more than a list of resources available and their current (static) condition is required. At a minimum, the above definitions suggest that a readiness and sustainability measure must be output-related and time-conscious—that is, take into account the timeliness with which a unit can respond and how long and under what circumstances the unit is expected to operate. Although these ideas are not new, the current Army Regulation AR220-1 (1 June 1981), *Unit Status Reporting (USR),* which establishes a system for reporting the readiness status of selected active and reserve units, is not responsive to them.

UNIT STATUS REPORTING (AR220-1)

The stated purpose of AR220-1 dated 1 June 1981 is to satisfy:

a. The requirements of the Army portions of Section 6, JCS Publication 6, Volume II, Part 2, Chapter 1; and

b. Other Department of the Army (DA) information needs (p. 1-1).

These other information needs are further defined to provide the following:

a. Current status of U.S. Army units to National Command Authorities (NCA); the Joint Chiefs of Staff (JCS); Headquarters, Department of the Army (HQDA); and all chain of command levels.

b. Indicators to the Department of the Army which:
   (1) Identify factors which degrade unit status,
   (2) Assist the Department of the Army and intermediate commands to allocate resources,
   (3) Identify the differences between current personnel and equipment assets in units and full wartime requirements,
   (4) Determine Army-wide conditions and trends (p. 1-1).

The reports are required to provide information of two types: objective assessments of resources available and subjective assessments of unit capability. As a consequence, the USR provides rather specific estimates of the availability and status of manpower and equipment, but only conditional estimates of mission capability or the output of the unit.

Given this environment for reporting and the past experience with readiness reporting, it is not surprising that AR220-1 as updated provides some caveats concerning the reported overall status of units. The overall unit ratings, reflecting the unit's ability to perform the mission for which it was organized, are determined by the judgment of the unit commander, considering both the objective status of resources and the judgmental synthesis of all other factors. This rating is on a scale of one to five based upon a series of combinations of resource standards (see Table 1). The end result is designed to indicate to what degree the unit can perform its TO&E (Table of Organization and Equipment) mission.

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[4]U S. Congress, *Readiness Panel Report to the Armed Services Committee,* House Committee on Armed Services, 96th Cong., 2d Sess., Washington, D C, December 30, 1980, p. 1

Table 1

RATING CRITERIA

	C-1	C-2	C-3
Personnel Strength	Available strength not less than 90% of full MTOE	Available strength not less than 80% of full MTOE	Available strength not less than 70% of full MTOE.
MOS	Not less than 85% of full MTOE required strength are personnel in the available strength who are qualified to perform duties of the position to which assigned.	Not less than 75% of full MTOE required strength are personnel in the available strength who are qualified to perform duties of the position to which assigned.	Not less than 65% of full MTOE required strength are personnel in the available strength who are qualified to perform the duties of the position to which assigned.
Senior Grade	85% or more of required E5 and above assigned and available.	75% or more of required E5 and above assigned and available.	65% or more required E5 and above assigned and available.
Equipment On Hand	Not less than 90% of full MTOE reportable lines at or above 90% fill and pacing item at or above 90% fill. (Same for aircraft)	Not less than 90% of full MTOE reportable lines at or above 80% fill and pacing item at or above 80% fill. (Same as aircraft)	Not less than 90% of full MTOE reportable lines at or above 65% (60% for aircraft) fill and pacing item at or above 65% fill (60% for aircraft)
Equipment Readiness:	Average mission capable (MC) rate equals or exceeds 90%. (75% Full Mission Capable [FMC] for aircraft)	Average MC rate equals or exceeds 70%. (60% FMC for aircraft)	Average MC rate equals or exceeds 60%. (50% FMC for aircraft)
	Pacing Item MC rate must be 90% or greater. (75% FMC for aircraft)	Pacing Item MC rate between 70% and 89%. (60% and 74% FMC for aircraft)	Pacing Item rate between 60% and 69%. (50% and 59% FMC for aircraft)
Training	Two weeks or less (0-2) required to attain a fully trained status.	More than 2, but less than 5 (3-4) weeks required to attain a fully trained status.	More than 4, but less than 7 (5-6) weeks required to attain a fully trained status.

Notes.

C-1
(Combat ready, no deficiencies)
The unit has its prescribed levels of wartime resources and is trained so that it is capable of being deployed. If outside CONUS, it can perform its operational contingency mission.

C-2
(Combat ready, minor deficiencies)
The unit has only minor deficiencies in its prescribed levels of wartime resources or training. Its capability to perform the wartime mission for which it is organized, designed, or tasked is limited. If in CONUS, a unit is capable of being deployed, but minor additional training or resources are desirable. If outside CONUS, it can perform its operational contingency mission.

C-3
(Combat ready, major deficiencies)
The unit has major deficiencies in its prescribed levels of wartime resources or training. Its capability to perform the wartime mission for which it is organized, designed, or tasked is limited. It can deploy or execute its operational contingency mission at reduced capability, but normally it will first be given additional training or resources to increase its readiness posture.

C-4
(Not combat ready)
The unit has major deficiencies in its prescribed wartime resources or training and cannot effectively perform the wartime mission for which it is organized, designed, or tasked. It requires major upgrading prior to deployment or employment in combat. However, if conditions dictate, the unit might be deployed or employed for whatever residual capability it does have. (For example: A three brigade division rated C-4 may be able to provide two fully supported mission capable brigades.)

C-5
(Not combat ready, programmed)
Due to HQDA action or programs, the unit is not ready and does not have the prescribed wartime resources or cannot perform the wartime mission for which it is organized, designed, or tasked. C-4 deployment and employment considerations apply. Units rated C-5 are restricted to the following:

(1) Units undergoing reorganization or major equipment conversion or transition.
(2) Units placed in cadre status by HQDA.
(3) Units which are being activated or inactivated.
(4) Units which are not manned or equipped but are required in the wartime force structure.
(5) Units with primary tasking as training units that could be tasked to perform a wartime mission.

ISSUES IN CURRENT ARMY READINESS REPORTING SYSTEMS

Many others studying this subject have noted deficiencies in the current Army readiness reporting system. The deficiencies we discuss below apply to UNITREP in general and therefore affect all the Services. Our purpose here is to bring some of these to light in the context of the OSD definitions of readiness and sustainability.

First, the Army's current readiness reporting system as embodied in AR220-1 is not reconcilable to currently expressed definitions. Although those definitions emphasize output measurement, AR220-1 emphasizes the quantification of inputs and intermediate products—in particular, mission capable (MC) weapon systems. Even at the level of the lowest reporting unit, the battalion, the Army has clearly not come to grips with a measure of unit output or product over some time period. The USR can provide a rather precise picture of a unit's resources and condition, but it says nothing about its capability in output terms. A perusal of the mission statements in the TO&Es further reveals the problem of trying to quantify or even assess output potential. Table 2 shows mission statements taken from a representative set of armored and aviation unit TO&Es. Quantification is at best difficult, yet there is a need to generate something more quantitative than a C-rating to determine the status of army units and to manage resources to maximize war fighting output. The current system does not provide this.

Second, several problems are associated with measuring *force* as opposed to *unit* readiness and sustainability. An armored battalion commander is required to report on the readiness of his unit without knowing how much and what kinds of support he will receive from brigade and corps level organizations. AR220-1 recognizes that the readiness and sustainability of a unit may be dependent upon decisions and conditions that are beyond the ability of the unit to control:

> Unit status is mainly the end product of a total command effort at all levels, Army-wide Therefore, attributing a given status rating solely to the leadership and managerial efforts of reporting unit commanders may ignore limitations beyond unit influence which exist within the system.[5]

Force readiness and sustainability are not merely composites of unit readiness and sustainability. Unless a force has achieved proficiency in the command and control of maneuver, fire support, and combat support units, the fact that each unit may be ready does not imply that the force is ready.

Third, current Army readiness reporting systems are not responsive to the needs of resource managers. A decisionmaker faced with the problem of allocating scarce resources for Army units does not have sufficient guidance from current measures to *project* the effect of varying resource levels on output.

This problem has received the attention of Congress in the report of the House Armed Services Committee Readiness Panel. The report notes that because DoD and the Armed Services use readiness measures that are designed for operational rather than fiscal and policy planners, Congress has little ability "to address and correct readiness deficiencies in future years."[6]

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[5]AR220-1, *Unit Status Reporting*. 1 June 1981, pp 1-2 The regulation continues by saying "The report is not designed to evaluate commanders Its full purpose can only be realized when the true status of each unit is determined and reported by its commander. No unit is expected to attain status ratings that exceed the level at which it has been provided personnel or equipment However, each unit is expected to train to the highest level possible with the resources that are available"

[6]U.S. House of Representatives, op. cit., p 1

Table 2

TABLE OF ORGANIZATION AND EQUIPMENT MISSION STATEMENTS

Mission Statement	Type of Unit	TO&E
To close with and destroy enemy forces using fire, maneuver, and shock effect	Tank Co ACS, ACR Tank Bn, Armor Inf or Mech Inf Tank Co, Tank Bn Armor; Mech Inf	17-27H 17-35H 17-37H
To provide security and perform reconnaissance for the unit to which assigned or attached and to engage in offensive, defensive, or delaying action as an economy of force unit	Armored Cav Sqdn ACR Armored Cav Troop ACR Armored Cav Troop Sep Light Inf Brigade Armored Cav Sqdn Arm & Inf Div Armored Cav Troop ACS	17-55H 17-57H 17-117H 17-105H 17-107H
To perform reconnaissance and security, to accomplish surveillance tasks and engage in offensive, defensive, and retrograde operation as an economy of force unit	Air Cavalry Sqdn, Inf Div Air Cavalry Troop ACS Air Cavalry Sqdn, Airborne Div Cav Troop ACS, Airborne Div Air Cav Troop ACC Air Cav Troop ACC, Air Mobile D Cav Troop ACS, Air Mobile Dac	17-205H 17-207H 17-275H 17-277H 17-278H 17-98H 17-99H
To destroy enemy armored and mechanized forces by aerial combat power using fire and maneuver as an integral part of the combined arms team during offensive, defensive, and retrograde operations	Attack Helicopter Bn ACCB Attack Helicopter Co AHB, ACCB	17-385H 17-387H
To extend by aerial means the reconnaissance and security capabilities of ground units. To engage in offensive, defensive, or delaying actions within its capability and to seize and dominate defended areas or terrain features	Air Cav Troop, Armored Cav Reg Air Cav Troop Armored Cav Sqdn Armor or Inf Div Air Cav Troop Armored Cav Sqdn Inf Div	17-58H 17-108H 17-208H

Finally, the current readiness measures lack specificity in the kinds of military actions the unit can undertake, i.e., what specific training the unit has received, for what regions it is equipped to fight, how long it is capable of performing its mission, and so on. It cannot be true that a unit is *equally* ready for all contingencies, regions, and weather, yet the C-ratings do not make any distinction regarding these variables. In particular, the C-ratings do not refer to any particular oplan. A unit that may be ready to perform its mission under one oplan may be unprepared to perform its mission under another. The current readiness reporting system does not ask: "Ready for what?"

RELATIONSHIP TO N-1299-MRAL

This report extends work reported by us in N-1299-MRAL, *Resource Readiness of Armored Units,* November 1979. That work was designed to demonstrate that a readiness and sustainability measure based on output could be developed and applied to a maneuver unit—in particular, an armored battalion—in a meaningful way. The work reported here is conceptually identical and uses the same AURA simulation model, but differs in several major respects. First, readiness and sustainability are assessed with respect to a combined arms brigade consisting of both armored and mechanized infantry units, as well as a supporting Forward Area Support Team (FAST) and Division Support Command (DISCOM). Reporting readiness and sustainability by brigade more closely reflects how the Army plans to fight in wartime.

Second, a wider variety of notional operations for this brigade is examined, and as a result some general principles about how resource shortages affect different types of output are identified.

Third, we investigate a number of resource shortages that were not addressed in our earlier work. As in N-1299-MRAL, we consider shortages of manpower, spares and consumables, but we perform additional analyses to examine skill shortages, support echelon contributions, replacement policies, and various combinations of resource constraints.

In sum, we provide in this report a more operationally useful demonstration and application of the principles first elucidated in N-1299-MRAL.

PLAN OF THE REPORT

With the preceding material on readiness and sustainability measurement issues as background, the remainder of this report is organized as follows: In Sec. II we summarize the concepts behind our resource readiness and sustainability index. Section III presents the results of applying these concepts to a combined arms brigade supported by its associated FAST and DISCOM, using the AURA simulation model. Section IV discusses some policy and research implications of our results for resource and readiness managers.

II. CONCEPTUALIZING MANEUVER UNIT READINESS AND SUSTAINABILITY

MEASURING OUTPUT

Each TO&E unit is ostensibly designed to produce a product or service over some time horizon; in other words, each TO&E unit is built to perform a mission. An *ideal* readiness and sustainability measure should be responsive to changes in the ability of the unit being measured to produce its inherent product or service. It should also change whenever prevailing operating conditions or required operating duration changes.

Defining the output of an Army maneuver/firepower unit is especially difficult because such units have no single output or product that can be directly related to their mission (see Table 2). Maneuver units are designed to be used as a part of a combined arms team. In this respect, the readiness assessment problem is similar to that of other multipurpose units—for example, Navy carrier wings or Air Force multipurpose fighter wings. These units have many outputs and missions. That maneuver/firepower units perform a wide variety of battlefield assignments is not a handicap so long as the analyst is specific about which element of the output vector is being measured.

In peacetime, Army units train to do specific tasks; in wartime, they must execute these tasks with great precision. When performed in a particular sequence, the tasks form an operation.[1] Operations in turn can define a battle plan. Although no one can predict how a battle will proceed in actuality—that is, when a unit will be on the attack and when it will be on defense—it is useful to think of a unit's output as described by a vector of its ability to perform *conceptual operations* of several specific types. We use the term *specific operational capability* (SOC) to describe each type of conceptual operation in this definition of output.

This concept of output measures the unit's ability to marshal its resources—equipment, crews, consumables—to carry out a conceptual operation. The unit's adequacy to defeat the enemy or to hold territory is a consideration apart from this definition of output. Clearly, this measure of output is one-sided—that is, it does not determine the outcome of a battle between two specified forces. Although prediction of the outcome of a battle between two forces is important in measuring *capability,* it is not needed to measure *readiness and sustainability.* Capability, readiness, and sustainability are, however, closely related: In the simplest scheme, capability is a function of readiness, sustainability, the effectiveness of individual weapon systems attainable in the field (modernization), the number of units (force structure), and the efficacy of doctrine, leadership, and morale.

Specific Operational Capabilities (SOC)

An SOC is determined by a usage profile and special conditions of employment.[2] In general, both the usage profile and special conditions should depend on the oplan, i.e.,

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[1] In this discussion an operation is deemed complete when the objective is seized (on attack) or when a new position is established (on active defense)

[2] A condition of employment is considered special *only if* it mandates the use of special equipment or requires special training.

employment scenario. For example, one would expect distances, terrain, and weather during combat operations in the Middle East to differ appreciably from those in Central Europe. Consequently, assumptions concerning attrition (temporary and permanent), consumption and movement rates, maintenance task times, resupply schedules, unit rotation, and personnel fatigue and efficiency factors should be specific to an oplan where possible. In other words, because each unit is designed to generate a product that contributes to some oplan, a readiness and sustainability measure must be responsive to the employment and logistics concepts of that plan.[3]

Each SOC should also identify the operation-essential subsystems and training requirements. For example, if an SOC calls for night operations by combined arms units, then the unit should be equipped with the appropriate numbers and types of night-sight devices, and the crews should be trained in their use. Some suggested SOCs for combined arms units are discussed in Appendix A, and the relationship of SOCs to unit training is discussed in Appendix B.

Mass

Tanks and armored personnel carriers (APCs) are employed in mass during combined arms operations, with platoons generally being the smallest maneuver elements. Consequently, in our conceptualization, tanks or APCs produce a meaningful unit of output only when massed together as platoons.

Sustainability

The time over which one chooses to measure output brings in sustainability. A unit that may be able to sustain operations at some rate for seven days may be inadequate if operations must continue for 15 days at the same rate. Conceptually, a unit's readiness and sustainability measure must specify the time period of operations because it could be different for alternative choices of the time horizon. Typically, the larger the unit, the longer one would want to make the time horizon for readiness and sustainability measurement. For example, one might want to assess the readiness and sustainability of a battalion to operate for 15 days using its own and brigade support assets, but one would probably want to assess the readiness and sustainability of a division to operate for 60 days using organic and theatre support assets.[4]

Deployment

A unit that may be ready to begin operations—that is, produce its inherent product or service—in seven days may not be ready at all to fight immediately. To measure readiness and sustainability, the analyst must specify when the unit is expected to begin operations.[5]

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[3]The revised *Unit Status Reporting* (AR220-1) recognizes that readiness must be oplan-related. POMCUS (Prepositioned Overseas Materiel Configured to Unit Sets) units will be given two readiness codes, one for the unit with just its CONUS-based equipment, and a second for the unit when matched up with its prepositioned equipment The Army has implicitly recognized that it is important to know how a unit can perform with respect to a specific oplan, in this case for Europe, and that a unit may be ready for one oplan but not another.

[4]The reason is straightforward. A division might be continuously engaged for 60 days, but an individual battalion within it probably would not be.

[5]AR220-1 is mute about the role of deployment schedules in readiness measurement; readiness is implicitly measured as if every unit is supposed to go to war immediately or within a few hours.

For units in, say, USAREUR, it might make sense to specify that operations must begin immediately or within a warning time measured in hours. For CONUS units, two additional considerations arise. First, many units will not be deployed immediately; and second, units must demonstrate an additional readiness task—the ability to pack and move to an airhead or railhead for deployment in accordance with an oplan schedule. For these units, it seems sensible to answer the question: "When can the unit start producing its output?" by reference to the RDD (Required Delivery Date) for that unit in a particular oplan. The principal advantage in that case is that the readiness and sustainability measure of the unit captures the ability of the unit to respond to and fulfill its obligations under that oplan.

THE MATHEMATICS OF READINESS INDEXES

Once each of the questions raised above is answered quantitatively by reference to either an SOC, an oplan, DA policy, or explicit DA assumption, it is possible to define a readiness and sustainability index. Let $q^k_{ij}(t;m)$ be the rate of output with mass m for the ith SOC under the jth oplan of the kth unit at time t. Let T be the time horizon over which output is to be measured and τ the starting time for measuring output; then cumulative output with mass m of the ith SOC under the jth oplan by the kth unit produced between τ and $\tau + T$ is given by

$$Q^k_{ij}(m, T, \tau) = \int_\tau^{\tau+T} q^k_{ij}(t;m)dt \ . \tag{1}$$

The rate of output of the kth unit is a function of the resources consumed by the unit. Let $x^k_1(t), x^k_2(t), \ldots, x^k_n(t)$ be that set of resources—manpower, equipment, spares, POL, munitions, and so on—consumed by the kth unit. Then the left-hand side of Eq. (1) is more aptly written as EQ MS13

$$Q^k_{ij}(m, T, \tau) = Q^k_{ij}(x^k_1, x^k_2, \ldots, x^k_n; m, T, \tau) \ .$$

Another unit might have a different set of resources at its disposal and may therefore produce output at a different rate. Let $Q^o_{ij}(m, T, \tau)$ be the cumulative output of a *reference* unit holding everything constant except the resource set; then we can define a simple readiness and sustainability index for the kth unit as[6]

$$R^k_{ij} = \frac{Q^k_{ij}(x^k_1, x^k_2, \ldots, x^k_n; m, T, \tau)}{Q^o_{ij}(x^o_1, x^o_2, \ldots, x^o_n; m, T, \tau)} \ . \tag{2}$$

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[6]Q^o_{ij} is assumed to be nonzero.

In other words, a simple readiness and sustainability index for the kth unit is its output *relative* to a reference unit. The idea of standardizing on the output of a reference unit is that we believe commande.s will have a greater appreciation for the readiness and sustainability of their unit when it is compared with a common accepted yardstick. The choice of the reference unit is arbitrary, but it makes sense to choose something Army commanders are attuned to For example, one might choose a unit with its full TO&E complement of manpower and equipment and unconstrained (at the SOC usage rate) ammunition, POL, and spares. Although no unit in the Army can expect these conditions in wartime, this set of resources should allow the unit to reach its maximum potential output.[7] In theory, the denominator of Eq. (2) could be any number, but regardless of what number is chosen for the denominator, the percentage change in the readiness and sustainability index is equal to the percentage change in output under that SOC.

As a readiness and sustainability index, Eq. (2) does not take into account two further considerations. First, for a particular SOC, the *utility of output* at a time t might grow faster or slower than the *output itself.* Second, within a particular oplan, output early in the battle might be worth more than output later—that is, a commander might be willing to exchange two units of output on D + 15 for one unit on D + 1. To allow for these possibilities, we can define a general readiness and sustainability index for the kth unit as

$$R^k_{ij} = \frac{\int_\tau^{\tau+T} U_{ij}[q^k_{ij}(t, m), t]dt}{\int_\tau^{\tau+T} U_{ij}[q^0_{ij}(t, m), t]dt}, \qquad (3)$$

where U_{ij} is a utility of output function under the ith SOC and j^{th} oplan.

Advantages of Proposed Index

The readiness and sustainability index defined by Eq. (2) or Eq. (3) has a number of advantages over the C-ratings in AR220-1. First, it is a continuous function rather than a four-cell classification scheme. Second, the index is responsive to all *resources* that affect output. AR220-1 requires reports only on some inputs. Third, the substitutability of resources is recognized by the proposed index. Thus two units with different resource sets that produce the same output would be rated identically, whereas under AR220-1 they might not be. As a result, the proposed index permits the management of resources to achieve various readiness and sustainability levels. Because AR220-1 does not recognize input substitutability, the resource manager has little discretion to alter the mix of inputs to maintain a readiness and sustainability level when relative scarcities change.

Relationship of Readiness and Resource Requirements

Resource requirements are theoretically related to readiness and sustainability because the same relationship of inputs to output used to compute the readiness and sustainability

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[7]Alternatively, the reference unit could be defined not with unconstrained spares, but with a PLL (Prescribed Load List) or ASL (Authorized Stockage List) defined by the MERPL (Mission Essential Repair Part List)

index, Eq. (2) or Eq. (3), should be used to compute resource requirements. Such a computation would involve, say, maximizing Q^k_u (or R^k_u) subject to a budget constraint. Although this procedure would lead to an "optimal" mix of resources for the unit, it oversimplifies the problem. The output measure refers only to a specific operational capability (SOC) in a particular oplan. The problem remains of aggregating over SOCs and oplans for the individual unit, and then "rolling up" resource requirements to the theatre or world-wide level. Doing that is a formidable task, requiring one to look at which resources must be dedicated to a unit and which can be shared by many units. Yet once the problem has been overcome, the link between readiness measurement and requirements determination can be established operationally as well as theoretically.

III. APPLICATION TO A COMBINED ARMS BRIGADE

In this section, we move from a conceptual discussion of how to measure readiness and sustainability for maneuver/firepower units to a concrete application. Such an application requires a research tool that can relate a unit's inputs—manpower, equipment, and consumables—to its output for each SOC. In the absence of a readily available Army model, we used a model called AURA (Army Unit Readiness Assessor) to determine that relationship for each SOC. AURA, which is described in detail in App. C, is a powerful event simulation model that permits decisionmakers to examine the effect of alternative resource levels on a combat unit's output and to assess a broad range of policy options that could affect resource allocation decisions on a theatre-wide basis. It also allows examination of the effects of attrition, replenishment, and higher-echelon repair on continued operations. It should be emphasized, however, that the readiness and sustainability concepts in Sec. II do not depend on the use of any particular model; in principle, one could use any analytic tool that translates a flow of inputs into SOC-related outputs.

AURA was used to simulate a combined arms brigade consisting of two armored battalions and one mechanized infantry battalion embedded within division and corps structures. For analytic purposes, the brigade was divided into three identical combined arms task forces consisting of two armored companies and one mechanized infantry company.[1] These task forces were augmented with direct support (DS) maintenance contact teams and had higher-echelon maintenance support from a Forward Area Support Team (FAST) constituted from the division maintenance battalion's Forward Support Company. The brigade was also supported by a Division Support Command (DISCOM) capable of supplying spare parts and transportation, and received a supply of replacement end items from corps to the division refit point when this feature of the simulation was invoked.

The brigade had to conduct operations described by the SOCs using the resources available to it. In each simulation, AURA organized and assigned these resources, monitored the status of the brigade's assets, and reported on the brigade's output—the number of *operationally ready* platoons of tanks and armored personnel carriers (APCs) that could be *massed* at the *time* required by the SOC.[2] Some details on the scope of the simulations are discussed in what follows.

BRIGADE RESOURCES

Equipment and Manpower

The brigade task forces were formed from battalions described in TO&Es 17-35HO (Armored Battalion) and 7-45HO (Mechanized Infantry Battalion) The brigade's two main pac-

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[1]Current doctrine calls for the employment of combined arms brigades organized into task forces These task forces are constituted from the armored and mechanized infantry battalions assigned to the brigade. For more details, see FM 71-100, *Armored and Mechanized Division Operations*, HQDA, September 29, 1978, pp 1-5, 1-6.

[2]*Operationally ready* means fully crewed, fueled, and armed. Some flexibility was permitted, however. The simulation allowed each task force to send out a platoon that was short one combat vehicle, e g , a four-tank platoon instead of a five-tank platoon. The simulation also allowed a platoon to be sent out up to one hour after the task force was supposed to mass.

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ing items, the M60A1 tank and the M113A1 (or M113-based TOW carrier), were assumed to be "fully mission capable" at the start of the simulation, which we allowed to run for 15 days. M88 and M578 tracked recovery vehicles were included as support equipment to each task force and the FAST.

Only crews and maintenance personnel directly related to the two pacing items—the M60A1 and M113A1—were simulated.[3] These personnel were considered fully qualified in their Military Occupational Specialties (MOSs), but when battalion task forces were constituted, no interchangeability of maintenance skills between pacing items was permitted—that is, an M113A1 tracked vehicle mechanic was not permitted to work on a tank and vice versa.[4] Appendix Tables D-1 and D-2 show the equipment and manpower (by MOS) simulated by AURA.

In certain simulations the brigade was resupplied with additional M60A1 tanks and M113A1 APCs and crews. On day 3, the brigade received its share of the division's maintenance float tanks and APCs. On day 6 and every other day thereafter, the brigade received one tank platoon from theatre reserves. The availabili y of replacement end items in these simulations was consistent with actual TR-1 Prepositioned War Reserve Materiel Stocks (PWRMS) for USAREUR. Appendix Table D-3 shows these replacements by day.

Spares

To support each critical maintenance task simulated, spares for both pacing items were identified from the WARPAC manuals for the M60A1 and the M113A1 published as FM 42-9-1 and FM 42-9-9, respectively. These manuals provide a Mission Essential Repair Parts List (MERPL) to support the Mission Essential Maintenance Operations (MEMO) found on the appropriate Contingency Maintenance Allocation Chart (CMAC) for each system.

In certain simulated cases, spares were supplied as demanded, while in others, spares were drawn from a "constructed" Prescribed Load List (PLL) at the organizational level and from a constructed Authorized Stockage List (ASL) at the FAST and DISCOM. The constructed PLL is a synthesis of the 2nd Armored Division and 4th Infantry Division (Mechanized) lists for the 2/67 Armor, 1/66 Armor, and 1/11 Infantry. The constructed ASL represented the combined range and maximal depth stockage of the ASLs for the 2nd and 3rd Armored Divisions and the 4th Infantry Division (Mechanized).[5] These constructed spares lists are larger than what any individual unit among them in fact has.

Other Consumables

POL (Class III) and ammunition (Class V) were supplied as required. Transportation requirements are calculated in Appendix Tables D-4 and D-5. Organic brigade transport vehicles were considered sufficient to provide the necessary lift from the Ammunition Transfer Points (ATPs) and fuel dumps located near the FAST to the consuming units.

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[3] Battalion and brigade support staffs, artillery, scouts, mortars, and engineers were no. simulated.

[4] This is an accurate reflection of current conditions found in USAREUR and FORSCOM units AURA can easily handle such crosstraining if it were required.

[5] It was possible to allocate the ASL stockage to the FAST and DISCOM using existing rules The parts in the ASL allocated to the FAST were determined by reference to the divisional Class IX repair parts stock status lists. The DSU code (Division Supply Unit) identified those items and quantities of the ASL that are stocked by Forward Support Maintenance Companies that constitute part of the brigade FAST.

BRIGADE OPERATIONS

The combined arms brigade was simulated under the attack and active defense SOCs described in Appendix A. Both SOCs are representative of what a combined arms brigade might have to do in a major conventional conflict in Europe—that is, distances, travel time, and tasking were similar to what might be found in the Cheb corridor area of the VII Corps. In the attack SOC, the task forces move to separate assembly areas, penetrate the Forward Edge of the Battle Area (FEBA), and exploit their breakthrough to their objectives. In the active defense SOC, the task forces defend an initial set of battle positions, redeploy to a second set, launch a hasty counterattack, defend and redeploy again, all within a limited sector.[6] In the simulations, each SOC was repeated for 15 consecutive days.

These SOCs provide an opportunity to examine different kinds of stress on the brigade's resources. The attack SOC is an assault and pursuit followed by a relatively long (overnight) recovery period before resuming operations. The active defense SOC is a series of three shorter engagements each day with relatively short periods in between for reconstitution and replenishment. As such, the SOCs differ in their demands on manpower, equipment, and consumables.[7]

In each SOC, the brigade rear area containing the FAST is located about 20 kms behind the FEBA, with the DISCOM located another 50 to 60 kms behind that. Figure 1 is a stylized schematic showing the three task forces and the FAST.

Attrition

We parametrically varied the overall (gross) attrition rate, i.e., the combat vehicle loss rate per operation, to test the sensitivity of our results to this variable. We then assigned probabilities to various attrition, recovery, and battle damage events. Based on an analysis of combat loss rates in DA's Concepts Evaluation Model (CEM), we chose to simulate M60A1 gross attrition rates of 0 (for a no-attrition baseline), 10, 20, and 30 percent per operation for the attack SOC, and 0, 3.33, 6.67, and 10 percent per operation for the active defense SOC. This reflects the different nature and operations rate of each SOC, and allows us to compare simulation results for both SOCs with roughly identical combat loss rates *per day*.[8]

Further analysis of CEM results supported the assumption that the M113A1 gross attrition rate would be one-half that of the M60A1. This allowed us then to talk in terms of a single attrition number on each simulation run, but the reader should keep in mind that the number refers to the M60A1 gross attrition rate, not the M113A1 rate.

Battle Damage and Recovery Probabilities

Although the gross attrition rate indicates the probability a tank will be *hit* on a particular operation, it does not provide an estimate of whether the hit will cause catastrophic damage (kill) to the vehicle. Each hit was therefore divided into various battle damage and

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[6]These SOCs typify the kinds of tasking for attack and active defense found in ARTEP 71-2 and FM 71-1, FM 71-2, and FM 71-100.

[7]The SOCs also differ in their demand on recovery assets

[8]See N-1299-MRAL, *Resource Readiness of Armored Units*, for details, especially pp. 30-33. The two attrition measures are related· The combat loss rate equals the gross attrition rate (per operation) times the rate of operations The active defense SOC has a rate of operations that is roughly three times that of the attack SOC.
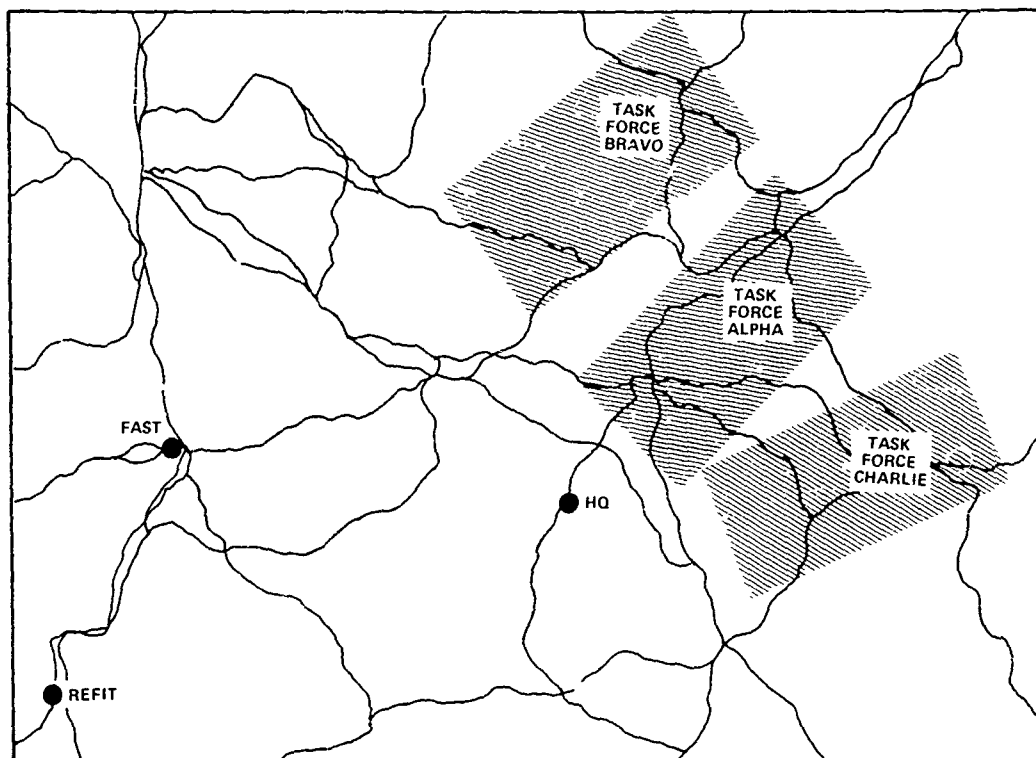
Fig. 1—Combined arms brigade

recovery events. Figure 2 shows the conditional probabilities assigned to each such event for the M60A1 in the attack SOC. The corresponding data for the active defense SOC and for both SOCs in the case of the M113A1 are shown in App. E. As Fig. 2 shows, we assumed that of those M60A1 tanks hit, 78 percent were permanently "killed" and the remaining 22 percent were temporarily "killed." The ratio of permanent to temporary M60A1 and M113A1 kills used in the simulation was taken from the CEM baseline European scenario. By design, this ratio in CEM is quite stable over length of the war.

Of those M60A1 tanks that are permanently killed, we assumed that 25 percent could be cannibalized, and the remaining 75 percent would be total losses—that is. K-killed. Only our judgment serves as justification for these particular percentages. Of those M60A1 tanks temporarily killed, we assumed that half would involve damage that rendered the tank immobile, that is, M-killed. Those tanks that were not M-killed could return to the battalion maintenance areas without assistance, but those that were had to be recovered first. We assumed that *for the attack SOC* almost all such M-killed tanks were recoverable because the FEBA was presumably moving forward, thus leaving M-killed tanks in friendly territory. Quite the opposite assumption was made *for the active defense SOC*.

We further assumed that of all the temporarily killed M60A1s that returned to the battalion maintenance area, only 20 percent were reparable with battalion resources only; the remaining 80 percent we assumed required some form of DS/GS support. Appendix E also
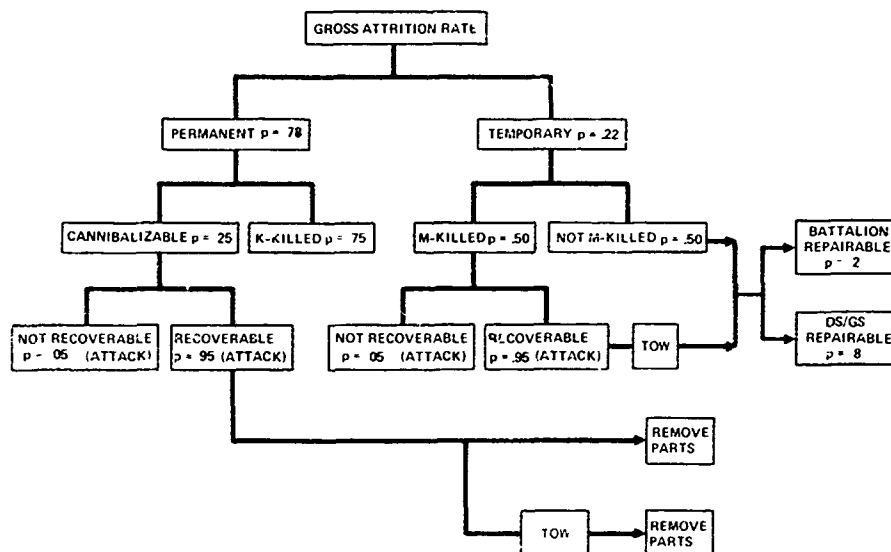
Fig. 2—Attrition, battle damage and recovery assumptions (M60A1 Attack)

shows recovery times and battle damage repair times, the latter based on recent tests at the Army Ordnance Center.[9]

Crew Casualties

We assumed that when a tank received battle damage, 42 percent of the crew survived uninjured and were available for the next operation. The remaining 58 percent were assumed to be KIA, WIA, or MIA.[10] In other words, for every tank put out of action, about 1.6 crew members remained unscathed. World War II experience was slightly better—about half could be returned to combat within a short time. Our assumption reflects a higher lethality of today's antitank weapons.

Other Losses

Although AURA does not model the enemy explicitly, it does model the effect of enemy actions. In particular, enemy actions cause the brigade to lose *resources* and *time*. In our simulations the resources lost were restricted to those tanks and APCs (and crews) that were destroyed or damaged during an operation. No enemy attacks on the task force or brigade

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[9]U S Department of the Army, *CODAM Final Project Report,* U S. Army Ordnance and Chemical Center and School, Aberdeen Proving Ground, Maryland, 1979 (unpublished).

[10]Killed in Action, Wounded in Action, or Missing in Action.

trains or maintenance areas were permitted; hence no maintenance personnel, or stocks of spares, POL, or ammunition were lost to enemy action. AURA has the capability, however, to model these losses as well; in particular, if it is possible to describe a maintenance or storage area and the type of enemy attack, AURA can compute losses and damage using standard munitions effects data.

Time plays an important role in each simulation. In AURA, the time it takes for a task force to take its objective or redeploy is a random variable designed to simulate lighter or heavier than expected enemy resistance. Similarly, *when* a particular tank or APC is hit during an operation is also randomly selected.

MAINTENANCE AND SUPPLY

We assumed that maintenance task times and frequencies for the M60A1 and M113A1 were those in the previously mentioned Contingency Maintenance Allocation Charts (CMAC).[11] Only those tasks and parts that were considered "mission-essential" were modeled. Task frequencies were converted to a probability of failure per operation by classifying the associated parts or components according to whether they would be expected to break on the basis of kilometers driven, rounds fired, or days on line. These, in turn, depended on the particular SOC being simulated. For each failure, we determined whether the tank would be immobilized and would consequently need to be towed by the brigade's M88s or M578s.

Using the CMAC for the M60A1 we entered 260 separate organizational and DS level maintenance and support tasks into AURA's jobs "library," and 201 similar tasks for M113A1. These tasks included those from the CMAC plus tasks representing towing, battle damage repair, regular servicing, and replenishment. The tank maintenance tasks collectively required 199 identifiable parts or kits, i.e., lines, while the APC tasks required 164 parts or kits.[12] Maintenance took place in 14 tank work centers and 11 APC work centers, and involved 6 types of tank specialists and 4 types of APC specialists. Longer jobs were naturally performed at the DS level.

If a part was not available from the task force's PLL, DS contact teams could request the part from the FAST, which held a portion of the division's ASL. Ultimately the part could be requested from the DISCOM itself. The structure and performance of this supply system is depicted in App. F. By having the FAST relocate as needed, the response times shown were assumed to hold for the entire period simulated.

Under certain conditions cannibalization was permitted.[13] When this occurred, maintenance personnel were instructed to cannibalize, *first,* an unserviceable vehicle with "holes," and *second,* an unserviceable vehicle without "holes." If a part was obtained by cannibalization, then the task time was automatically increased by 50 percent. Adding only 50 percent probably understates the true time.

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[11] These task times and frequencies are for the pre-RISE (Reliability Improvements Engine) M60A1 and hence do not reflect the reliability and maintainability of the latest M60 variant.

[12] Of the CMAC-identified parts or kits, only a portion were actually found in the constructed PLLs/ASL: 134 (67 percent) for the M60A1 and 102 (62 percent) for the M113A1 Of these items, some were momentarily out of stock; consequently, only 118 (59 percent) of the M60A1 parts or kits and only 79 (48 percent) of the M113A1 parts or kits were actually available

[13] Cannibalization was permitted under two major guidelines. The first was that given the need to cannibalize, items could be removed from unserviceable vehicles only when no more than ten removals ("holes") would be created in the vehicle Second, cannibalization of certain critical or illogical major components was not permitted. These components included such items as whole engines, transmissions, turrets, wiring harnesses, etc. Task times as multiplied were considered too long for battlefield repair

SIMULATION STRATEGY

Our overall simulation strategy was first to run a base case, which we used later as the reference unit to calculate the readiness and sustainability index, Eq. (2), second, to run other cases in which manpower levels, skill levels, and spares were varied separately, and third, to run a combination of resources shortages. Some of the cases were run both with and without replacement end items, but all major cases were run for both SOCs.[14] Table 3 lists the cases simulated, using a shorthand descriptor for each collection of related runs. The reader is urged to familiarize himself with these descriptors as they are used liberally in what follows.

Table 3

SIMULATION STRATEGY

Cases	Manpower	Task Time	Class IX (Spares)			Class VII Major End Items	Class V (Ammunition)	Class III (POL)
			Unit	FAST	DISCOM			
BASE	100% TO&E	CMAC	U	U	U	No	U	U
	100% TO&E	CMAC	U	U	U	Yes	U	U
SHORTMAN	70% MAINT 77% CREWS	CMAC	U	U	U	No	U	U
SHORTPARTS	100% TO&E	CMAC	PLL	ASL	ASL	No	U	U
	100% TO&E	CMAC	PLL	ASL	ASL	Yes	U	U
	100% TO&E	CMAC	PLL	ASL	No	No	U	U
SHORTSKILL	100% TO&E	1 5 x CMAC	U	U	U	No	U	U
	100% TO&E	2 5 x CMAC	U	U	U	No	U	U
EUROCOMBO	100% TO&E	1 5 x CMAC	PLL	ASL	ASL	Yes	U	U

U = Unconstrained

We first ran a base case brigade in which all three component battalions were at full TO&E strength in manpower and equipment. The brigade was unconstrained in POL, ammunition, and spares at the SOC consumption rates. A base case with replacement of major end items was also run as an alternative reference unit for the readiness index.

For the second set of runs (known as SHORTPARTS), we gave the brigade the "constructed" PLLs and ASL described earlier. Although the brigade was unconstrained in POL and ammunition, its access to spares was considerably reduced from the previous unconstrained assumption.

In a third set of runs (known as SHORTMAN), the brigade's manpower was reduced to about 75 percent of the full TO&E—that is, to 70 percent strength in maintenance manpower and 77 percent strength in M60A1 and M113A1 crews. According to *AR220-1*, this unit would be rated C-3 due to manpower shortages. POL, ammunition, and spares were unconstrained to the brigade.

Up to now, all runs assumed that maintenance personnel could perform up to CMAC standards—that is, they could complete CMAC maintenance tasks within the average time reported in the CMAC. In the next set of runs (known as SHORTSKILL), we restored man-

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[14]When the replacement option was exercised, the 0 percent attrition case was not run In a few cases only one or two attrition rates (not four) were run.

power to its full TO&E level, but increased average maintenance task times by 50 percent and by 150 percent to test the sensitivity of brigade output, i.e., readiness and sustainability, to this factor.[15] Increased task times could result directly from mechanic inexperience or insufficient training, and indirectly from the need of supervisory personnel to inspect, coach, and perform certain tasks themselves. Multiplying task times is a useful way of quantifying this kind of experience/training deficiency, but it is also a good representation of what might happen to even the most experienced mechanics in severe weather or in a CBR (chemical, biological, radiological) environment in which protective clothing would have to be worn.

In the last set of runs (known as the EUROCOMBO), we chose a combination of resource constraints and conditions that might be found in USAREUR units To be precise, we gave the brigade full TO&E strength in manpower and equipment, but maintenance personnel were assumed to take 50 percent longer than the CMAC task times. Access to consumables— POL, ammunition, and spares—was the same as in the SHORTPARTS case, and major end items were replaced according to the standard schedule already described.

SIMULATION RESULTS: ACTIVE DEFENSE SOC

In the series of figures that follows, we present the results of the AURA simulation for the active defense SOC. Recall that in this SOC three task forces are massed at three specific times during a 24-hour period. Brigade output is the number of platoons that can be so massed *given the resources available*.

The Base Case

Figures 3 and 4 show that output in platoons that can be massed on average for each operation by the base case brigade each day.[16] Maximum output for the armor components of the brigade, Fig. 3, is 18 platoons (six companies of three platoons each); for the mechanized infantry components, Fig. 4, it is 9 platoons (three companies of three platoons each).[17] The percentage above each of the four curves is the gross (M60A1) attrition rate used in that run times the number of operations per day, in this case, three. The number in parentheses at the end of each curve is the *cumulative* output over the 15 days of the simulation; this cumulative output was used in our readiness and sustainability index. The curves shown represent the average value of many trials—from 30 for the 0 percent attrition case to 120 for the highest attrition rate.[18] These sample sizes assured that the resulting curves closely resemble expected values.

The zero percent curve in Fig. 3 shows that even with no attrition, the base case brigade can generate only about 16 of its 18 tank platoons for each operation. This result is due in part to the *inherent r* ability of the pre-RISE M60A1. The same curve in Fig. 4 reflects not only the greater reliability of the M113A1, but also the fact that each task force is required

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[15]Crews were still expected to perform at Level 1 ARTEP proficiency

[16]A detailed analysis of brigade output showed that the proportion of each operation's output in daily output varied only very slightly across attrition rates and time periods It was therefore acceptable to use the average number of platoons *per operation* as representative of each day's output

[17]Each mechanized infantry platoon here consisted of four M113A1 APCs and two M113-based TOW carriers making six vehicles in all. The reader should note the caveat reported in footnote 2 of this section.

[18]This was necessary to reduce the effect of stochastic outlyers, which tended to be important at the higher attrition rates.
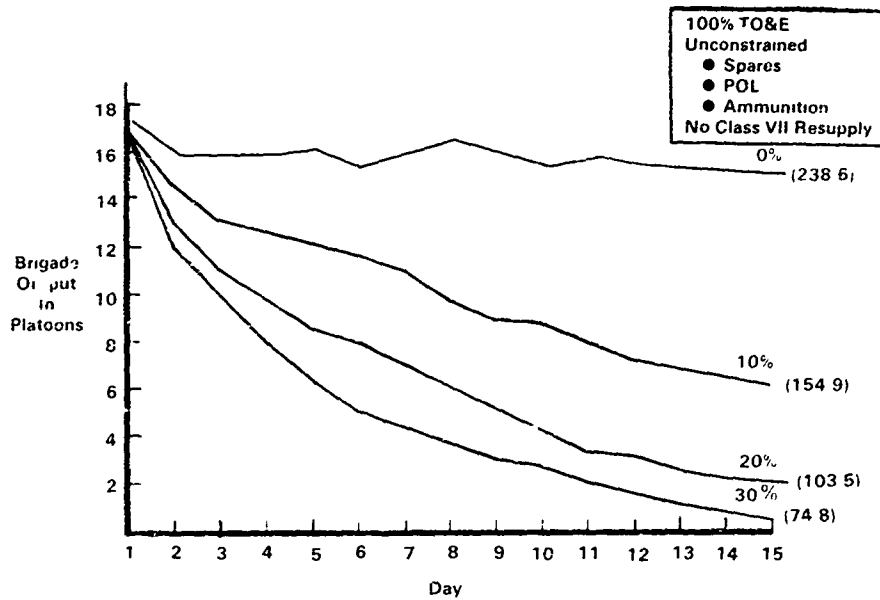
Fig. 3—Active defense SOC daily output for base case armor components
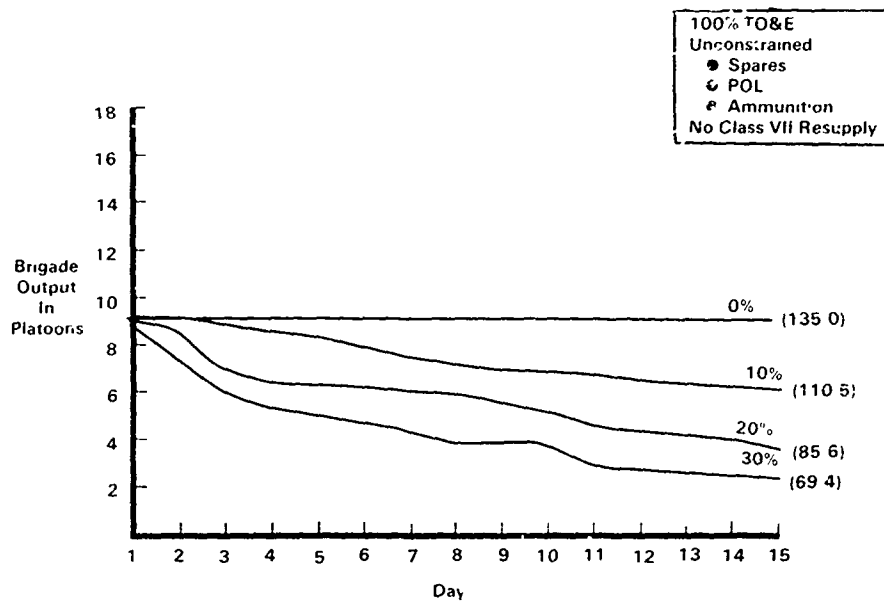
Fig. 4—Active defense SOC daily output for base case
mechanized infantry components

to generate 30 tanks (six platoons) from an initial stock of 36 (or 83.3 percent), but only 18 APCs (three platoons) from an initial stock of 23 (or 78.3 percent). In short, the mechanized infantry companies are somewhat more robust than their tank counterparts in the provision of organic backup vehicles. Naturally, as soon as combat losses and mechanical failures take their toll, no backup vehicles go unused.

The base case with replacement of major end items is analyzed in App. G.

The SHORTPARTS Case

Figures 5 and 6 show the corresponding output curves for the case in which parts are limited to those in the "constructed" PLLs/ASL, i.e., actual spares from representative units. The curves show a significant decrease in daily output and cumulative output for the armor components of the brigade when compared to the base case. A smaller decrease is evident for the mechanized infantry components. From these curves we calculated the readiness and sustainability index, Eq. (2), as a function of the number of days of operations.

To obtain the index, we divided the cumulative output (for each brigade component and a given attrition rate) after T days for the SHORTPARTS brigade by that of the base case brigade. Figure 7 shows the results of the calculation when the (M60A1) gross attrition rate was set at 20 percent per day. As the figure shows, this brigade produces 66 percent of the armor output of the base case brigade over 15 days, but 92 percent of the armor output over the first two days when performing the active defense SOC; the brigade's mechanized compo-
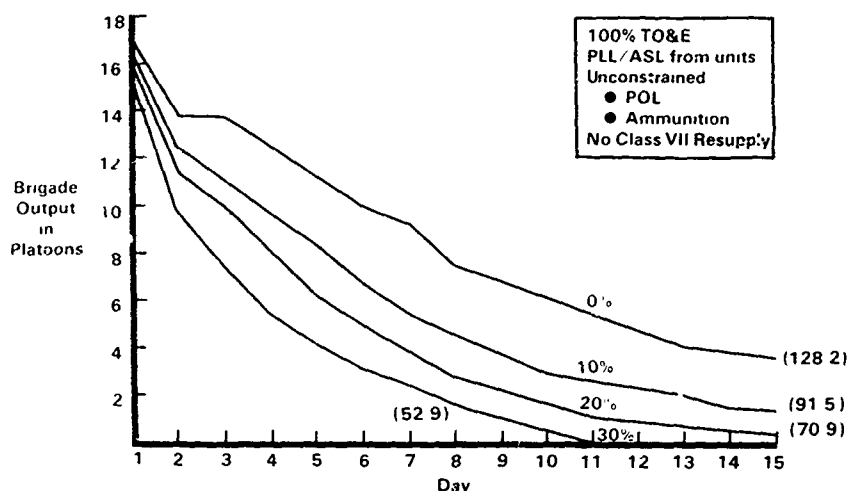
Fig. 5—Active defense SOC daily output for armor components
with constructed PLL/ASL
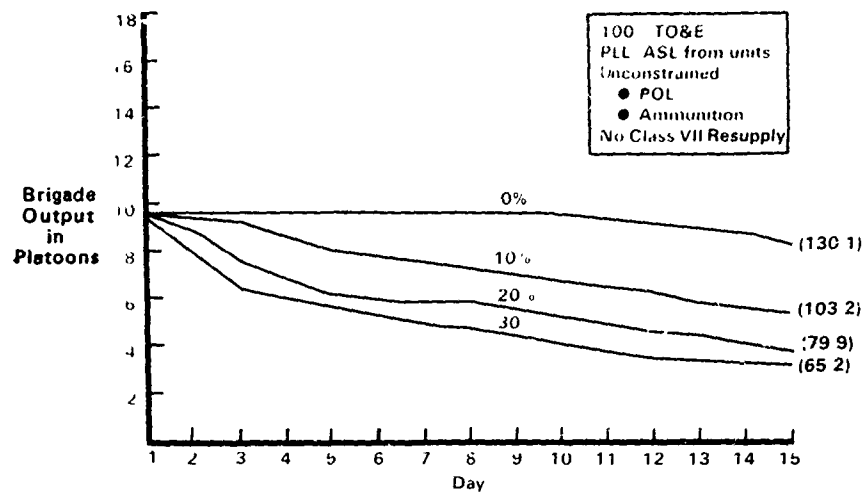
Fig. 6—Active defense SOC daily output for mechanized infantry
components with constructed PLL/ASL
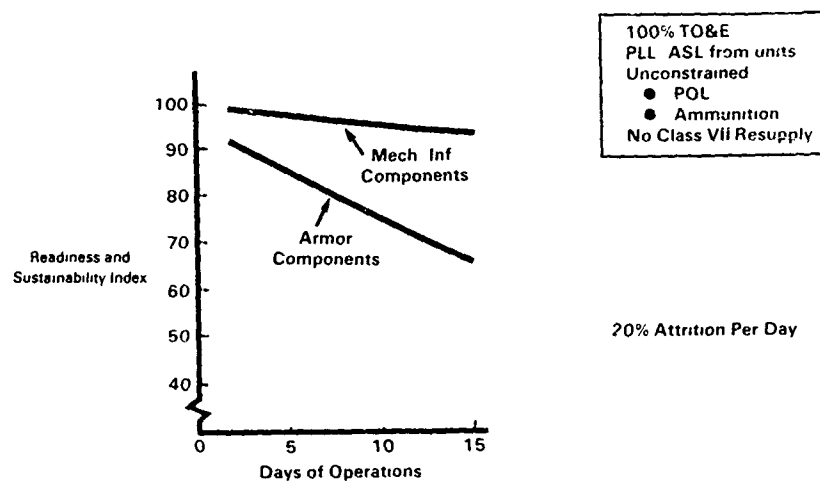
Fig. 7—Active defense SOC readiness and sustainability index
with constructed PLL/ASL

nents produce 93 percent of the output of the base case brigade's mechanized infantry over 15 days, and 99 percent over the first two days.[19] In simplest terms, the longer the SHORTPARTS brigade has to engage in active defense operations, the lower its output relative to that of the base case brigade, or if one prefers, the higher its forgone output.

We investigated what would happen to brigade output if that part of the ASL at the DISCOM were unavailable throughout the simulation. This could occur if those parts were destroyed by enemy action or if the supply links to the brigade were disrupted. In Fig. 8, we have reproduced the readiness and sustainability indexes of Fig. 7 (labeled *With DISCOM*), and have added the indexes for the brigade *sans* DISCOM. As the figure shows, the brigade's armor components produce about 10 percent less output than previously over 15 days of operations, while the mechanized infantry components lose about 5 percent additional output. Over shorter periods the losses are smaller in percentage terms. Roughly the same percentage losses in output were found to hold across the full range of attrition rates.
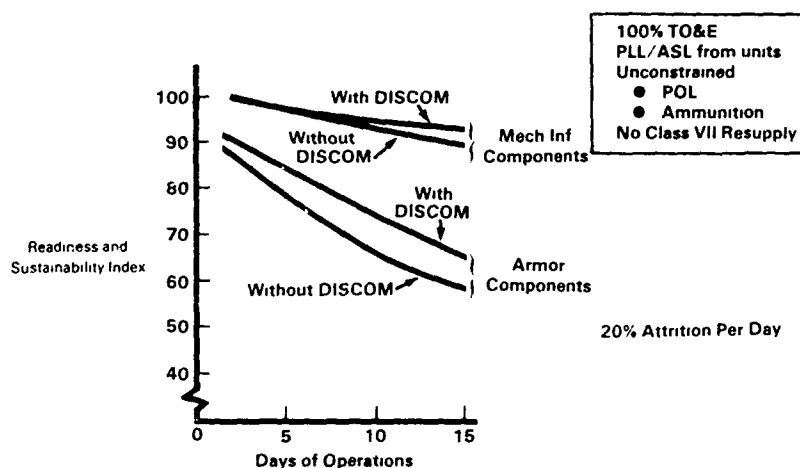
Fig. 8—Active defense SOC readiness and sustainability index with
constructed PLL/ASL with and without a DISCOM

The SHORTMAN Case

When we ran the SHORTMAN case, the daily output of the brigade was similar to that in the base case, and the cumulative output was only slightly reduced from that of the base case. We concluded that given the unlimited, instantaneous access to spares, a situation not likely to be encountered by many brigades, the reductions in manpower did not appreciably affect brigade output.

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[19]The readiness index for the armor components varied with the attrition rate, but for the Mechanized Infantry components, it did not vary significantly. See App. H for an analysis of how different attrition rates affected readiness

The SHORTSKILL Case

The SHORTSKILL case produced quantitatively different results from the SHORTMAN case. As Fig. 9 shows, a readiness and sustainability penalty is paid when maintenance personnel take longer than the CMAC average (the base case) to complete CMAC tasks even when spares are unconstrained. At low attrition rates. 0 and 10 percent per day (not shown), a flat curve of readiness and sustainability versus days of operations resulted for the armor components of the brigade, but at higher attrition rates, 20 and 30 percent per day (only 20 percent shown), the readiness and sustainability index improved slightly as days of operations increased.[20] Tanks awaiting maintenance and battle damage repair could not be sent out on operations (and could therefore not be killed). Output lost early in the simulation was simply made up later, high attrition having made this catch-up feasible.[21] These results suggest that for very short, intense periods of active defense operations which require rapid turnaround of down vehicles, a shortage of skills, even with unconstrained availability of spares, may be very serious.
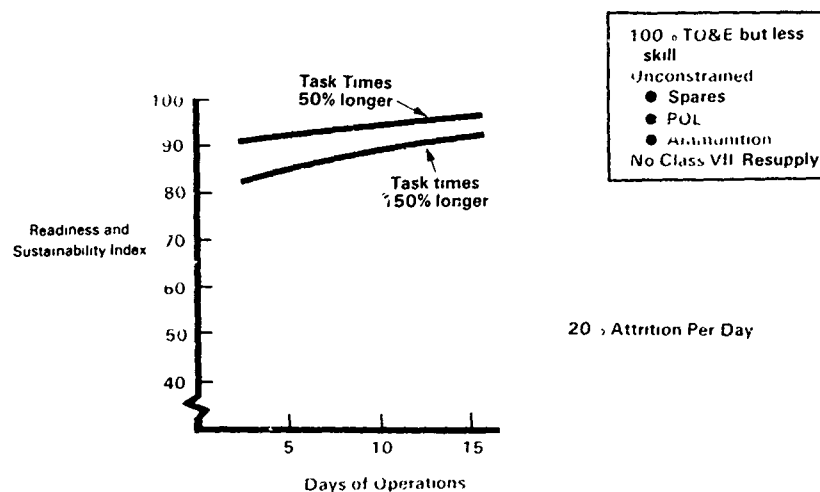
Fig. 9—Active defense SOC readiness and sustainability index for
armor components with longer task times

Another perspective on the SHORTSKILL case is provided in Fig. 10. Instead of days of operations, the readiness and sustainability index is shown as a function of a normalized measure of skill, with 1.0 indicating the CMAC standard, i.e., the base case. Lower numbers indicate lower skill, for example, 0.50 means a mechanic takes twice as long, and 0.25, four times as long as the CMAC standard to complete a task.

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[20]The readiness curve for the mechanized infantry components was uniformly high and was little affected by either attrition rate or days of operations.
[21]This is true for the SHORTPARTS as well, but early forgone output could only be partially made up because of the ultimate shortage of parts.
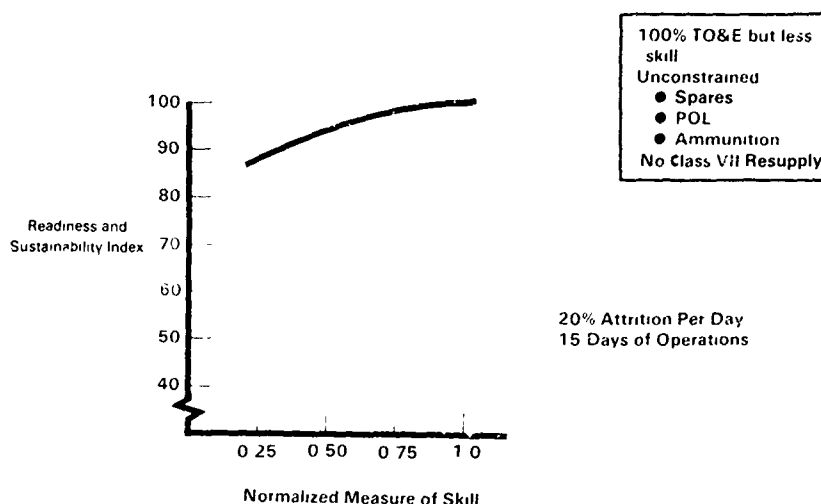
Fig. 10—Active defense SOC readiness and sustainability index for
armor components with lower skill levels

The EUROCOMBO Case

The EUROCOMBO case combines a number of resource constraints and conditions: The brigade was at full TO&E strength, but maintenance task times were 50 percent longer than the CMAC standard. The brigade had unconstrained access to POL and ammunition, but had only the constructed PLLs/ASL. The brigade was resupplied with major end items according to the previously described schedule. Figure 11 shows the readiness and sustainability indexes for this brigade. A comparison with the SHORTPARTS case suggests that the timely replacement of major end items allows the brigade to produce substantially more output (about 20 percent more for the armor components) than otherwise over 15 days of operations.

SIMULATION RESULTS: ATTACK SOC

In the attack SOC, the brigade's task forces are massed early in the day and conduct an assault and pursuit over long distances; recovery, replenishment, and reconstitution are done overnight, and the brigade repeats the same operation the next day. Figures 12 and 13 show the daily output curves for the armor and mechanized infantry components of the base case brigade in the attack SOC. The percentage above each of the four curves is again the gross (M60A1) attrition rate used in that run times the number of operations per day, in this case, one. As before, the numbers in parentheses represent cumulative output of the brigade over 15 days of operations; this cumulative output is the denominator of the readiness and sustainability index for the attack SOC.
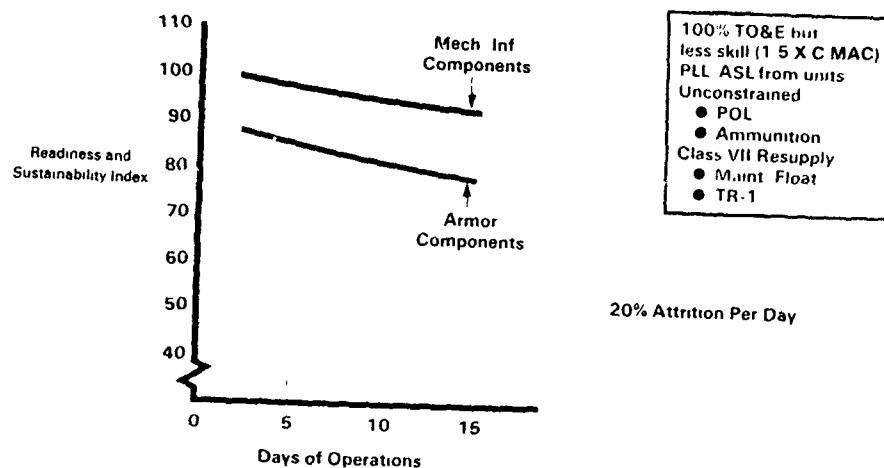
Fig. 11—Active defense SOC readiness and sustainability index for
European combination
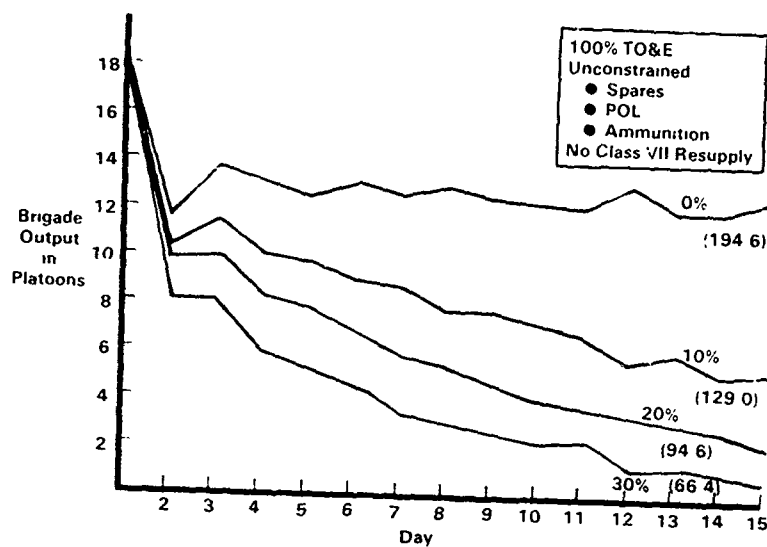
Fig. 12—Attack SOC daily output for base case armor components
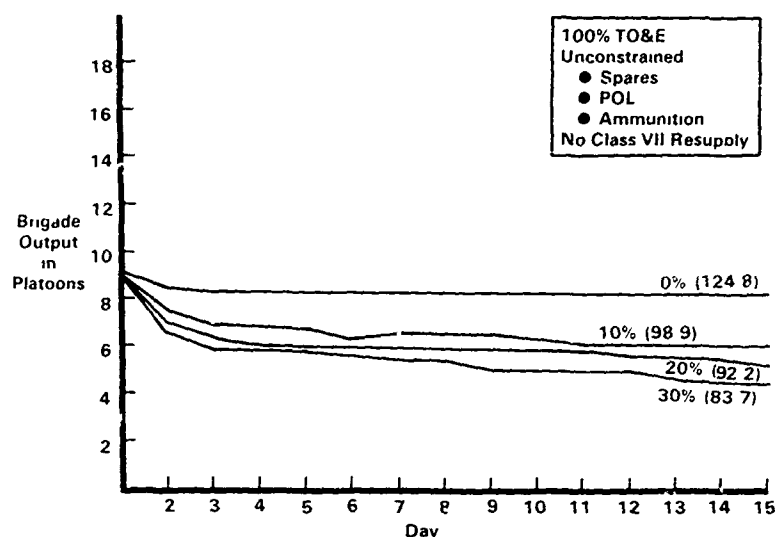
Fig. 13—Attack SOC daily output for base case mechanized
infantry components

A Summary of Remaining Cases

Figure 14 shows the readiness and sustainability index for the SHORTPARTS case in the attack SOC. The brigade's armor components can produce about 75 percent of the base case brigade's armor output over 15 days of operations, while the mechanized infantry components can produce about 90 percent of the base case brigade's mechanized infantry output.

As in the active defense SOC, no significant decline in output, and consequently in the readiness and sustainability index, was found when manpower was reduced to the SHORTMAN level.

The effect of longer task times on the brigade's output in the attack SOC was tested in the SHORTSKILL case. At *all* attrition rates the readiness and sustainability index for both armor and mechanized infantry components remained roughly constant as days of operations increased, so the effect observed in the active defense SOC did not reappear in the attack SOC.

In the EUROCOMBO case, the readiness and sustainability index was qualitatively similar, though quantitatively different from, that of the active defense SOC. Because important insights can be obtained, we focus next on a direct comparison of the attack and active defense SOCs for identical brigades, i.e., with resources held constant.

SIMULATION RESULTS: ATTACK AND ACTIVE DEFENSE SOCS

In Fig. 15 we have reproduced the readiness and sustainability indexes for the armor components of the SHORTPARTS brigade for both SOCs at the 20 percent per day attrition. These curves were taken from Figs. 7 and 14. Before any conclusions are drawn, one caution must be stated. It may not be correct to compare the readiness levels for these two SOCs at
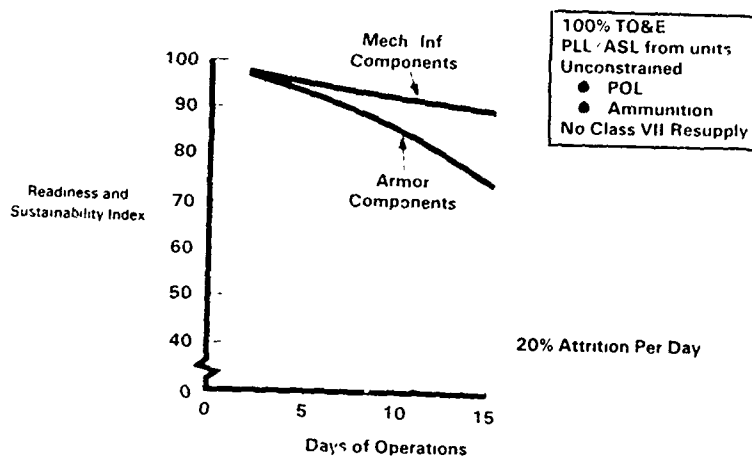
Fig. 14—Attack SOC readiness and sustainability index with constructed PLL/ASL
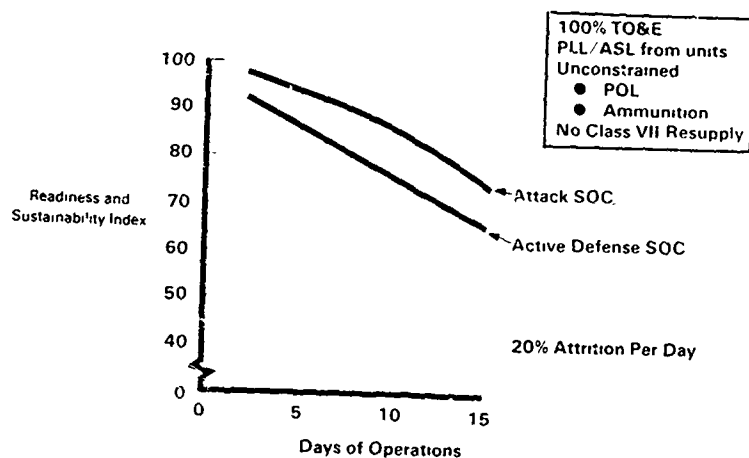
Fig. 15—Armor components readiness and sustainability indexes with constructed PLL/ASL

the *same* attrition rate per day. Certainly there is no a priori reason why an attrition rate appropriate for evaluating attack SOC readiness and sustainability would also be appropriate for evaluating active defense SOC readiness and sustainability. Two different attrition rates seem more reasonable, if only because attrition itself may be more *manageable* when a unit has the initiative, i.e., is conducting an attack. However, when the readiness and sustainability levels of the SHORTPARTS brigade are compared at the same attrition rate, in this case 20 percent per day, the brigade's armor components were not equally prepared for both SOCs.

The explanation gets at the heart of the readiness and sustainability measurement problem Readiness and sustainability depend on *what the unit must do in combat*. Relative to a reference combined arms brigade with unconstrained resource , the SHORTPARTS brigade loses proportionately more output when it must conduct one kind of operation than when it must conduct another. The decreased access to spares faced by the brigade causes it to suffer proportionately more forgone output when the time between operations is shorter, as is the case in the active defense SOC relative to the attack SOC. This lack of reconstitution and replenishment time is felt primarily because even the responsive supply system postulated for the brigade is unable to provide parts (when they exist) in a timely fashion, and secondarily because even the brigade's highly competent mechanics cannot cannibalize fast enough. These capabilities, then, only partially substitute for the brigade's scarcest resource—instantaneously available spares. In the attack SOC, these other capabilities—supply system responsiveness and rapid cannibalization—substitute more fully. As a general rule, a combined arms brigade's resource readiness and sustainability index will be higher for those SOCs *that demand relatively less of the brigade's scarcest resources*.

That this phenomenon is widespread is reinforced by Fig. 16, which shows the armor component readiness indexes for both SOCs for the EUROCOMBO case. Here, the longer task times and resupply of major end items to sustain the brigade further aggravates the brigade's lack of timely spares when performing the two SOCs.
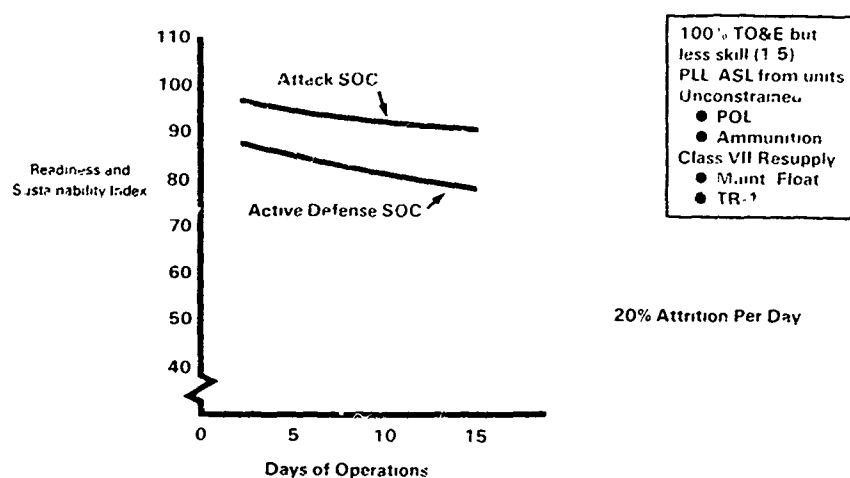
Fig. 16—Armor components readiness and sustainability indexes
for European combination

IV. IMPLICATIONS FOR RESOURCE, READINESS, AND SUSTAINABILITY MANAGEMENT

On a conceptual level, this report provides a way of thinking about readiness and sustainability for Army maneuver units that is output-related and time-conscious—that is, takes into account when, for how long, and under what circumstances a unit must fight. On the practical side, the report demonstrates how one particular model, AURA, can be used to implement these readiness and sustainability concepts. In the process AURA successfully dealt with a combined arms organization, and proved sensitive enough to evaluate the readiness contribution of various support echelons and marginal as well as major changes in resources. We believe this work to be a step toward being able to measure systematically the contribution of various resources to readiness and sustainability.

There are a number of ways the present work could be used. These can be roughly classified as (1) analysis of readiness and sustainability initiatives, (2) readiness and sustainability reporting, and (3) resource requirements determination. We shall deal with each of these briefly.

ANALYSIS OF READINESS AND SUSTAINABILITY INITIATIVES

As a hypothetical example of how the concepts and tools presented here could be used, we analyzed three alternative readiness and sustainability improvements that could be applied to the armor component of combined arms brigades in USAREUR—our EUROCOMBO case. The three alternatives were (1) adding 15 M60A1 tanks (1/2 TR-1 push package) to the stream of replacements already scheduled for the brigade (to be distributed proportionately to quantities in Table D-3), (2) equipping the brigade with a MERPL,[1] and (3) upgrading the brigade's maintenance personnel so that all could attain the CMAC standard task times.

Using AURA, an estimate was made of the percentage change that each alternative would generate in the readiness and sustainability indexes of the brigade's armor components. The percentage change in the readiness and sustainability index is exactly equal to the percentage change in *output* for reasons described in Sec. III under the heading, "The Mathematics of Readiness and Sustainability Indexes." Only the 15-day readiness and sustainability index at a daily attrition rate of 20 percent was analyzed. The results are shown in Table 4. Each alternative raises both readiness and sustainability indexes, but the increase is substantially different for each improvement. Further, each resource has a differential effect on readiness and sustainability depending on the SOC. This is perhaps best illustrated by noting that alternatives (2) and (3) have a stronger effect on output under the active defense SOC, while alternative (1) tends to favor the attack SOC.

These alternatives have both initial and continuing costs. For example equipping the brigade with a MERPL involves substantial initial investment costs covering not only the spares themselves but the mobile storage capacity as well (assuming that it is sensible to provide full mobility), plus the recurring manpower costs to move and manage the additional

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[1] Mission Essential Repair Parts List We estimated that a brigade equipped this way would produce between 90 and 95 percent of the armor output of the base case brigade

Table 4

READINESS AND SUSTAINABILITY IMPROVEMENT BY SOC[a]

SOC	Percentage Change in Readiness Index for Armor Components of Brigade		
	Add one-half TR-J pkg. per brigade	Equip brigade with MERPL	Upgrade "skills" to CMAC standard
SOC 1 (Active Defense)	+10%	+42%	+5%
SOC 2 (Attack)	+12%	+24%	+2%

[a]Attrition per day = 20%; 15 days of operations.

parts and costs incurred because of handling losses and stockage deterioration. We did not make cost estimates for this study, so no rational choice among the three readiness and sustainability improvement alternatives is possible; nor was recommending any particular improvements our objective. However, we believe it is within the state of the art to make such cost estimates, and that opens up an exciting possibility. A resource manager can *tailor* readiness and sustainability improvements according to the desired level of readiness and sustainability for each type of output (SOC) and to the relative marginal cost of each such improvement. Properly used, such analyses can provide stronger justification of certain budget requests.

Other examples of analytic use of the readiness and sustainability measure proposed in this report could be (1) the validation of certain logistics planning factors, (2) POM[2] justification of the proposed M88A1 buy, (3) evaluation of the AMSAA[3] proposed combat PLL/ASL, and (4) evaluation of alternative combat service support organizations for Army 88 studies. Naturally, the design of experiments using AURA in the analytic mode would have to be carefully planned.

READINESS REPORTING

Aside from the analytic uses described above, some near-term management questions that might be addressed in a readiness and sustainability framework include (1) the allocation and distribution of existing resources, (2) the selection of units to perform specific operations during periods of crisis (crisis management), and (3) the evaluation of system and manager effectiveness. The top of Fig. 17 illustrates an example of currently reported data from the FORSTAT system as it appears in the FORSCOM *Blue Book*. The hypothetical 2nd

[2]Program Objective Memorandum
[3]Army Material System Analysis Activity

DAMPL 31602   Xth ARMORED DIVISION
ALO 1   ORGANIC BATTALIONS

UNIT	OVER ALL	STR	MOS	SGD	EOH	EOH PI	ES	ES PI	TNG	TNG WKS	AUTH	OP STR	%	DEPL	%
MANEUVER 2/9 AR ⋮ FIRE SPT SUPPORT	2(1)	1	1	2(1)	1	1	2	2	2	3	560	524	94	507	91

UNIT	OPLAN SOC 1	9999 SOC 2		OPLAN SOC1	XXXX SOC2	SOC3		MPLAN SOC	XXXX		DPLAN SOC1	XXXX SOC2
MANEUVER 2/99 AR ⋮ FIRE SPT SUPPORT	1(2)	3(2)		1	1	2		3(5)			3(5)	4(5 4)

(1) = MOS (2) = POL (3) = AMMUNITION (4) = SPARES (5) = TRAINING

Fig. 17—Current and possible readiness reports

Battalion, 99th Armored Regiment, is rated C-2 overall. The number in parentheses indicates that the unit was C-1 at the time of the last report. The unit is currently C-1 in personnel strength. MOS fill, equipment on hand, and pacing items on hand; but it is C-2 in senior grade fill, equipment status, pacing item status, and training.[4] The commanding officer of the 2nd Battalion subjectively estimates that it would require three weeks of training to make the unit "combat ready."

The bottom of Fig. 17 illustrates the kind of readiness and sustainability information that could supplement existing readiness reports. The same unit could be rated by its ability to perform various specific operational capabilities under various oplans. The unit's ability to mobilize and deploy could also be rated. In this illustration, the 2nd Battalion, 99th Armored Regiment, is C-1 in SOC 1 for *Oplan 9999*, but is only C-3 in SOC 2.[5] The number in parentheses indicates that this unit was C-2 in SOC 1 at the time of the last report. The numbers in brackets indicate what resource is holding the unit at C-3; in this example, a POL (or POL moving capacity) constraint is responsible. Similarly, other oplans and associated SOCs could be rated.[6] The usefulness of this kind of information depends, of course, on the

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[4] See Table 1 for the criteria for each category.

[5] It might be advisable to use something other than a C-rating since it might be confused with the measurement of readiness by inputs A Rand colleague has suggested that we call them D-ratings.

[6] One practical feature of this supplementary readiness and sustainability report is that it requires only information that is already reported under AR220-1 or information that is already available (and machine readable) from battalion and division-level management systems Using quantitative data on manpower and equipment reported monthly, together with individual PLLs/ASLs, a theatre or DA-level readiness organization would compute the indexes. These would then be available to higher-level commanders The only additional requirement on battalion and company commanders would be a relatively straightforward quantitative assessment of maintenance personnel skills; an average rating by "shop" will suffice Rather than being an additional burden, this quantitative assessment (in terms of CMAC standard task times) would allow these commanders to systematically "tell it like it is" and to avoid some time-consuming verbal descriptions of personnel strengths and weaknesses

ability of Army decisionmakers to move resources across units in response to readiness and sustainability deficiencies.

Congress now requires DoD to make *projections* of material readiness; soon, projections of manpower readiness will be required as well. Ultimately the logic of combining the two projections into an output-related readiness and sustainability measure will be compelling. The kind of readiness and sustainability report just described could also be used in a prospective mode as well as a current statement of readiness and sustainability.

RESOURCE REQUIREMENTS DETERMINATION

In the above use of this report's concepts, actual or projected resources are used as inputs into a model like AURA to determine current or prospective readiness and sustainability. The process, however, can be conceptually reversed: First, one could determine by combat simulation or other means desired levels of readiness and sustainability (by SOC) for units in a given oplan, and second, using a model that relates inputs to outputs, one could calculate the minimum-cost combination of resources that achieves the desired readiness and sustainability levels. The resultant vector of resources represents requirements.[7] The practical problems of performing the needed calculations, particularly those of aggregating over SOCs and oplans and then "rolling up" requirements to the theatre or world-wide level, cannot be taken lightly, but are by no means insurmountable.

Establishing requirements is but one step in developing a set of resource requests during the annual DoD programming cycle. Current readiness measures are not very useful to OSD and DA planners and programmers in that process. We believe that the output-related readiness and sustainability measure proposed here could be used to construct a more "balanced" resource program than current methods permit because all resources would be treated consistently—that is, the value of each resource would depend on its contribution to a *common* objective function, readiness and sustainability. With such an objective function, which should ultimately include all training dimensions, *budget, policy, and operations issues* could be addressed in a common framework.

IMPLEMENTATION

Implementation of these readiness and sustainability concepts to their fullest potential requires, in our opinion, two preconditions. The first is a step-by-step effort to complete the necessary research building blocks; the second is early involvement of potential DA users.

The research completed to date has involved the application of AURA to the maneuver units of heavy divisions in a European conventional conflict. It remains to develop consistent SOCs for the combat support units—artillery, air defense artillery (ADA), combat aviation and engineers—and to simulate these units in a combined arms context.[8] It also remains to apply AURA to light infantry, airborne, and air-assault divisions, and to consider other than

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[7]In a very real sense, this is what is currently done in CEM (Concepts Evaluation Model) for a limited set of resources. The process fails to recognize input substitution, however, and assumes that resources not treated will be available as needed

[8]Preliminary discussions with USAREUR brigade and battalion commanders in November 1980 suggested that battle tasking for artillery, ADA, and combat aviation units could be modeled

European-type conflicts. How unit training can be included in this framework is another important issue that deserves hard thinking.[9]

It seems clear that continued DA cooperation in conducting the above research is necessary, but beyond that, full implementation must involve all Army major commands (MACOMs) and staff activities. As a first step, AURA can be transferred to the DA staff. This can be accomplished rather quickly as its parent model TSAR, described in App. C, is already running on in-house Pentagon computers. Some of the uses described earlier could be tested as operational experience is gained.[10] In the longer run, other MACOMs could become not only users of AURA, but contributors as well. For example, FORSCOM and USAREUR might work with TRADOC to develop appropriate SOCs; DARCOM might make periodic improvements to the maintenance data base, perhaps as a result of actual field tests.

In any case, early DA exposure to the readiness and sustainability concepts and tools presented here seems warranted.

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[9]USAREUR's move toward event-oriented training would seem to suggest a complementary approach.
[10]AURA-type models may be able to make an important contribution to the annual Total Army Analysis (TAA), OMNIBUS, and Total Logistics Readiness/Sustainability (TLR/S) exercises.

Appendix A

ATTACK AND ACTIVE DEFENSE SOCS

The attack SOC usage profile, shown in Fig. A-1, is conducted by *each* of the brigade's tank-heavy task forces. Each task force moves to an assembly area at 0600 hours, penetrates enemy lines, seizes an objective several kilometers away, and consolidates its position. The hour shown for each completed task in the schematic represents *expected value*. The time to exploit was made a random variable drawn from a uniform distribution of one to seven hours. The consumption rates shown in Table A-1 represent the typical expenditure of ammunition and fuel by a tank and an armored personnel carrier. Cross-leveling, the practice of distributing remaining resources evenly among units at the end of the operation, would even out any variations. We obtained these consumption rates in discussions with brigade and battalion commanders in FORSCOM and USAREUR.
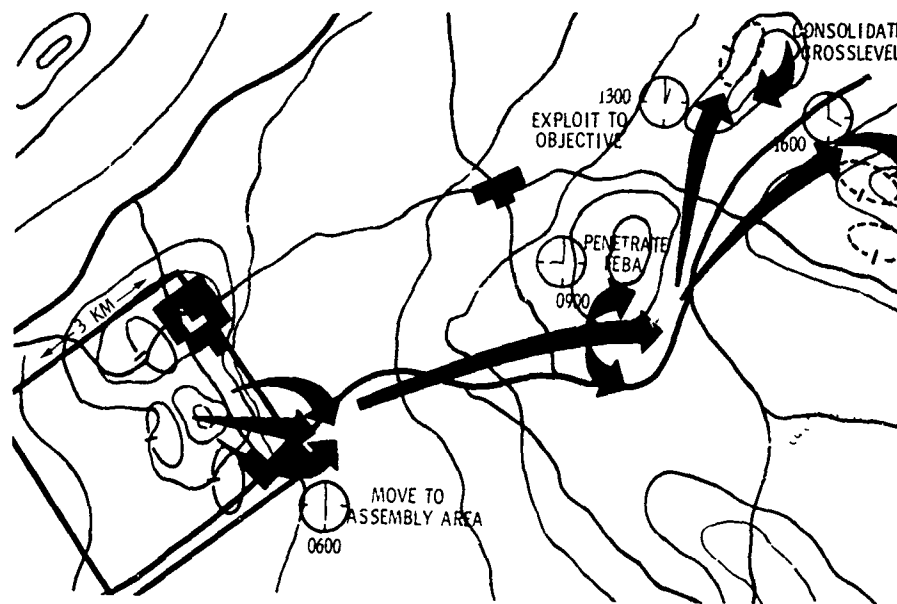
Fig. A-1—The attack SOC usage profile

In this usage profile, the fuel consumed during the operation and subsequent recycling is about 28 percent of the full fuel load of the M60A1 tank and about 30 percent of that of the M113A1 personnel carrier. (These fuel-consumption figures were obtained from the 1st Cavalry Division, Ft. Hood, Texas.) About 60 percent of the tank's 105mm ammunition load is fired during the operation.

The active defense SOC usage profile calls for three operations by each of the brigade's

Table A-1

ATTACK SOC CONSUMPTION RATES

MISSION COMPONENT	DISTANCE (KM)	TIME (HRS)	ENGINE TIME (HRS)	FUEL (GAL KM)/(GAL hR)	FUEL (GAL)	105MM	30 CAL	50 CAL
MOVEMENT TO ASSEMBLY AREA								
M60A1	10	20	20	1 3	13 0	0	0	0
M113A1				2 /	2 7			0
PENETRATION ROLL FLANKS								
M60A1	4	1 0	1 0	2 25	9 0	24	500	200
M113A1				4	1 6			400
EXPLOIT TO OBJECTIVE								
M60A1	40	4 0	4 0	1 3	52 0	16	500	100
M113A1				27	10 8			300
CONSOLIDATE								
M60A1	*	1 0	1 0	1 3	1 3	0	50u	0
M113A1				27	27		-	300
CROSS LEVEL								
M60A1	-	2 0	2 0	5 0	10 0	0	0	0
M113A1				1 5	3 0			0
RECYCLE								
M60A1	-	14 0	4 0	5 0	20 0	0	0	0
M113A1				1 5	6 0		-	0
TOTAL								
M60A1	55	24 0	14 0		105 3	40	1500	300
M113A1					24 4			1000

three task forces in a 24-hour period. Over that time each task force engages in three positional defense battles, two rearward redeployments, and one hasty counterattack. The sequence of events is shown in Figs. A-2 through A-4.

Starting at 0600, the task force defends an initial set of battle positions (BP1) against an enemy force, and then withdraws about 6 kms to a second set of prepared battle positions (BP2) where the task force is replenished and reconstituted. This redeployment is completed at approximately 0820. At 1300 (Fig. A-3), the task force is again attacked by another enemy force, presumably a second-echelon regiment.

The task force defends BP2, and then launches a hasty counterattack, recovering some of the terrain it gave up in the morning. At 2000 (Fig. A-4), the task force is again assaulted, and after defending its battle positions, withdraws to BP2. Operations end for the day at approximately 2220 with a net loss of 6 kms. Average time between operations is approximately 4.7 hours during the day, and 7.7 hours overnight.

Consumption rates for each operation in the active defense SOC are shown in Table A-2. Multiplying the fuel and ammunition figures by three to reflect a daily rate reveals that slightly less fuel and significantly more 105mm ammunition is used in the active defense SOC than in the attack SOC. At these consumption rates, over the three operations each day, the typical M60A1 shoots all of its on-board main gun ammunition.
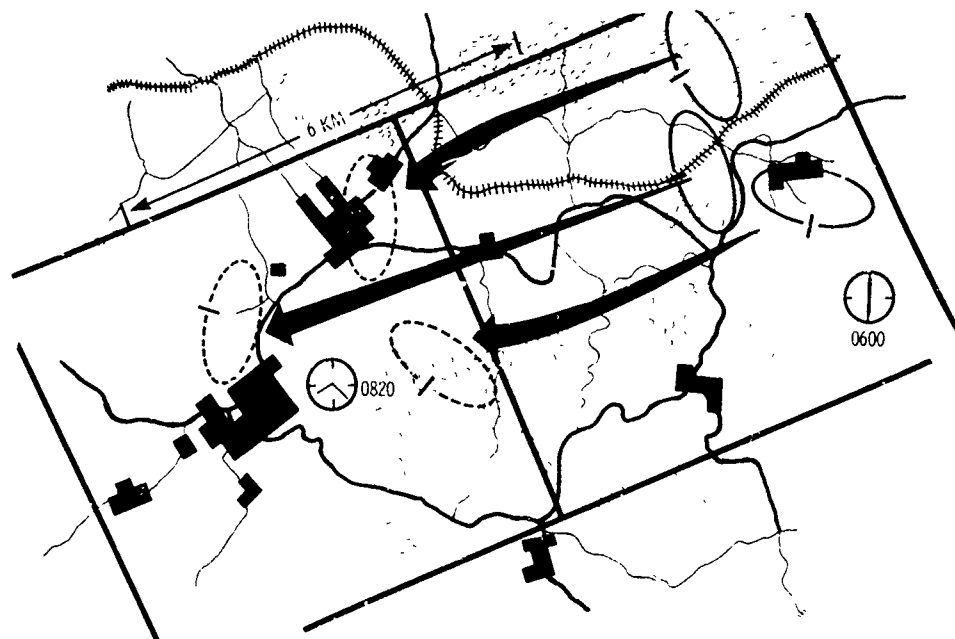
Fig. A-2—Active defense SOC, phase I
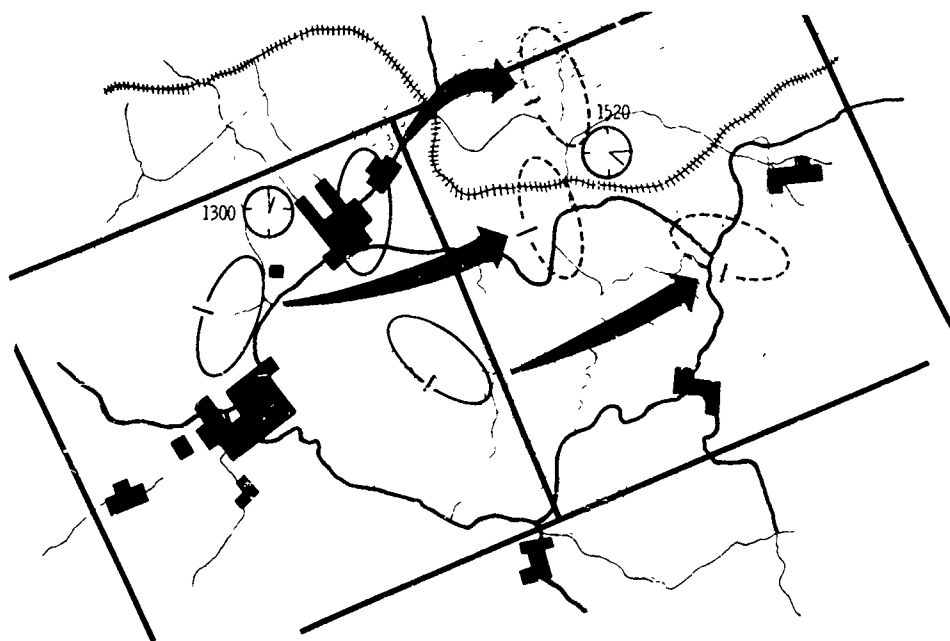
Fig. A-3—Active defense SOC, phase II
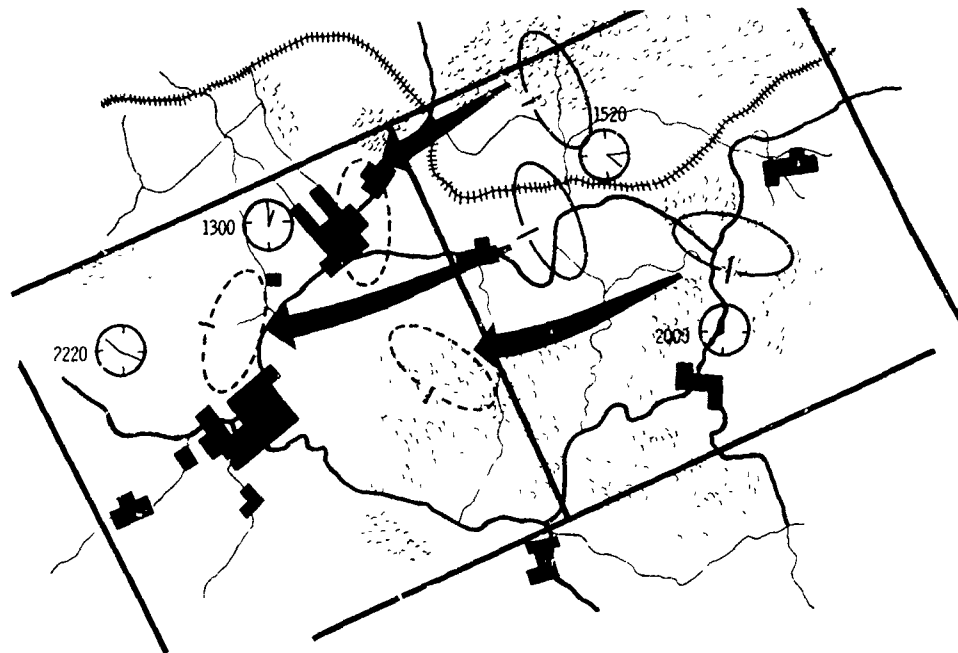
Fig. A-4—Active defense SOC, phase III

Table A-2

ACTIVE DEFENSE SOC CONSUMPTION RATES

MISSION COMPONENT	DISTANCE (KM)	TIME (HRS)	ENGINE TIME (HRS)	FUEL (GAL/KM) (GAL/HR)	FUEL (GAL)	AMMUNITION (RDS) 105MM	30 CAL	50 CAL
DEFEND BP 1								
M60A1	3	15	15	2.25	675	21	500	200
M113A1				4	12	-	-	330
RELOCATE TO BP 2								
M60A1	10	05	05	13	130	0	500	100
M113A1				.27	27	-	-	0
DEPLOY/CROSSLEVEL								
M60A1		03	03	50	15	0	0	0
M113A1				15	45	-	-	0
RECYCLE								
M60A1	-	47	235	50	1175	0	0	0
M113A1				15	35	-	-	0
TOTAL								
M60A1	13	70	465		320	21	1000	300
M113A1					785	-	-	330

Appendix B

SPECIFIC OPERATIONAL CAPABILITIES AND UNIT TRAINING

An SOC is defined by a usage profile and special conditions of employment: The usage profile specifies the quantitative dimensions of the SOC while the special conditions of employment specify the SOC-essential equipment and training.

NUMBER OF DISTINGUISHABLE SOCS

Table B-1 illustrates three SOCs that might be of interest to, say, USAREUR planners. The particular attack SOC in this illustration is described by the attack usage profile used in App. A and the combination of special conditions listed. Those special conditions indicate that the unit must be prepared to engage in continuous operations (day and night), in a CBR environment, in open terrain only, but with possible water obstacles. The active defense SOC is described by its usage profile along with the same special conditions of employment. In the particular delay SOC illustrated in Table B-1, the unit must be prepared for continuous operations in a CBR environment in urban terrain only.

Table B-1

THREE HYPOTHETICAL SOCs

Special Conditions of Employment	Usage Profile		
	Attack	Active Defense	Delay
Continuous operations	Yes	Yes	Yes
Chemical, biological, radiological environment (CBR)	Yes	Yes	Yes
Intense ECM environment	No	No	No
Urban terrain	No	No	Yes
River ferding	Yes	Yes	No

The advantage of this specificity is precisely that each SOC can be associated with *training events,* and with specialized *operation essential equipment*—night-sight devices, CBR air filtration kits, and so on. If training funds are highly constrained, then not every unit can maintain proficiency in every aspect of combined arms combat. The SOC taxonomy allows a more precise indication of circumstances for which the unit has been trained and prepared.

The disadvantage of this specificity is that the number of distinguishable SOCs can increase rapidly. Even with only three usage profiles and five special conditions of employment as shown in Table B-1, there are 96 distinguishable SOCs. In general,

$$
\begin{pmatrix} \text{Number of} \\ \text{distinguishable SOCs} \end{pmatrix} = \begin{pmatrix} \text{Number of} \\ \text{usage profiles} \end{pmatrix} 2^{\begin{pmatrix} \text{Number of} \\ \text{special conditions} \end{pmatrix}} . \quad \text{(B-1)}
$$

In Eq. (B-1), the term 2^x represents the number of yes-no combinations with x special conditions of employment. With five such conditions, there are 32 SOCs with the attack usage profile, 32 SOCs with the active defense usage profile, and so on. We believe, however, that most of these SOCs collapse into a significant few, and of these, many would be covered by the same Army Training and Evaluation Program (ARTEP). As ARTEPs are now designed, most basic battalion level operations are included in the evaluation program. If SOCs could be specifically related to a unit's General Defense Plan (GDP) and expected alternatives, specific highly likely operations and maneuvers could be identified. These operations could be stressed and planned to an event-oriented combined arms training program. Once resource requirements (fuel, training ammunition, maneuver time, etc.) could be assigned to such event-oriented training, training budgets for various levels and areas of proficiency might be developed. A unit's ability to accomplish a range of SOCs under various training budget constraints could be forecast and levels of training readiness for a given unit could be planned.

Appendix C

ARMY UNIT READINESS ASSESSOR (AURA)

The AURA (Army Unit Readiness Assessor) model is a derivative version of a Rand model that is now coming into use by its sponsor, the U.S. Air Force. The original model, called TSAR (Theatre Simulation of Airbase Resources), was adapted to handle the special requirements of combined arms units. TSAR/AURA simulates a system of interdependent theatre-wide units/bases supported by an intratheatre resource management system. By capturing the interdependencies among resources, TSAR/AURA permits decisionmakers to examine the implications of alternative resource levels on mission output levels for combat units, and to assess a broad range of policy options that may affect resource allocation decisions on a theatre-wide basis. TSAR/AURA also allows examination of the effects of attrition, replenishment, and higher-echelon repair on continued operations.

Although the TSAR/AURA simulation model is a versatile and powerful tool for the readiness and sustainability problem, none of the conceptual work described in Section II is model-specific. In operationalizing the readiness and sustainability index, we would be happy to use another tool that performs the same calculations as TSAR/AURA.

TSAR/AURA ARCHITECTURE

Eleven classes of resources are treated in the simulation including weapons, crews, support personnel, tools, support equipment, spares, munitions, POL, and organizational facilities. Each of these broad classes of resources may be divided into many individual types with some limitations.[1] Spare parts may be specified by the user, or, if ordered, the model will compute a parts list according to standard algorithms.[2]

TSAR/AURA is a Monte Carlo event simulation model that has been designed for analyzing the interactions between resources and the capability of units to generate operations in a rapidly evolving wartime environment. On-weapon maintenance tasks, part repair tasks, munitions and POL replenishment, and facilities repair tasks are simulated for several units simultaneously. The model is readily adaptable to problems across a broad range of complexity. When specific features are not needed in a particular problem, they simply are not used. Thus, the model permits the analyst to represent either a single unit, a set of independent units, or a set of interdependent units without any adjustment or modification of the program. Similarly, if the user does not wish to examine the effects of unit losses, or of shortages of facilities, maintenance personnel, tools, spare parts, munitions, or fuel, no special precautions are needed as the model adapts automatically to all such problem representations.

TSAR/AURA has also been designed with an analytic structure that permits examination of a wide variety of potential improvements in unit resource allocation and organization in a common context. New maintenance doctrines, modified manning levels, increased stock

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[1]Only nine types of crews and weapons systems and one type of facility and POL are currently permitted in any particular simulation

[2]In other words, the model will generate a PLL (Prescribed Load List) and ASL (Authorized Stockage List) With a credible battle damage generator, the model could be used to create a War Reserve Spares Kit (WRSK).

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levels for parts and equipment, and a variety of concepts for theatre-wide resource management can be examined with the model in terms of their effects on the system's ability to generate missions.

An important objective in the original design formulation was to achieve a sufficiently high speed of operation that the extensive sequence of runs so frequently necessary in research and analysis would be economically practical. Adaptation of existing models was rejected because of the prohibitive costs of modifying these programs and using them on a regular basis for problems of the size that were contemplated. The resulting custom-designed program, written in the widely available FORTRAN language, achieves a substantially higher speed by virtue of more efficient processing and by taking advantage of the recent dramatic increases in the size of the core storage of modern computers. The current formulation makes no intermediate use of auxiliary high-speed storage units (e.g., disks, tapes) except for storing the initial conditions for multiple trials.

In the model, specified numbers of weapon systems of various types (e.g., tanks, armored personnel carriers) can be assigned to each unit. The weapons of a given type of army unit may be supported by a common pool of resources (e.g., personnel, spares), or the systems may be organized into two or three subgroups each supported by its own set of resources. Thus, the model offers a natural way of treating the Army's multi-echelon support organizations—general support (GS), direct support (DS), organization, and unit.

OPERATIONS

The systems are readied for operations and massed for employment in response to a set of user-supplied operation requirements, differentiated by unit, weapon type, operation length, and priority. If a unit is not specified, the operation demands are allocated to the unit next best able to fulfill the operation. Operations may be scheduled or organized for continuous or contingency action as required by the user. Returning weapons not destroyed, both damaged and serviceable, may still have unexpended munitions and may have unscheduled or scheduled maintenance task requirements. The inputs that govern such probabilities for maintenance work other than battle damage repairs—the break rates—may be either a fixed rate per operation or varied daily by work center (shop) or weapon type as a function of the operations rate or other user-specified activity function (e.g., miles driven, rounds fired, days on the line). If a weapon system is damaged or destroyed, a replacement can be resupplied immediately or resupplied after a delay approximating wartime replacement conditions.

The next assignment for each unit is selected as the previous operation tasks are completed. The selection takes into account the known requirements for the next operation and the unit's remaining capability to meet the requirement. It also depends on the unit's ability to generate weapons configured for the next operation. All maintenance and replenishment tasks not essential for the next operation may be deferred and the available resources concentrated on required tasks. If a weapon is not required for the next operation, it may be reassigned or reconfigured for a more appropriate operation.

MAINTENANCE AND SPARES

On-weapon maintenance tasks may require a number of specialists, specialized equipment, and a spare part; each task is either a single set of such requirements—a simple

task—or it may be a network of tasks, each with its own demand for personnel and equipment. When resources are limited, those weapons most likely to be readied first (given on-hand resources) may be given priority.

If a required part is not available, (1) the broken one that is removed may be repaired within the unit, (2) the appropriate part may be cannibalized from another weapon, (3) a part may be obtained by lateral resupply from a specified subset of units, or (4) the part may be ordered from a central source within the theatre. If a part cannot be repaired in the unit— that is, is Not Reparable This Station (NRTS)—it may be sent to a neighboring unit or to a centralized facility in the theatre designated to perform intermediate maintenance. If a part cannot be repaired within the theatre, a replacement may be requested from a depot in CONUS.

Each maintenance task and parts repair job is accomplished by the personnel and equipment associated with a particular work center, or *shop*. The user may group the resources and tasks into as many as 25 different shops, exclusive of those associated with the scheduled pre- and post-operation maintenance tasks. Because each shop may be assigned several different types of personnel and equipment, those engaged in on-equipment and off-equipment tasks may be the same or different depending upon how the user wishes to define the unit's maintenance policies.

The user is given substantial flexibility in defining the rules by which maintenance tasks are processed. The user may permit the activities of certain groups of shops to proceed simultaneously or may require that the activities of several such groups of shops proceed in a specified order. The user may also control these prescriptions for simultaneous and sequential operations separately for each weapon type at each base. Furthermore, for groups of shops that may proceed simultaneously, certain exceptions may be specified in the form of lists of activities that are incompatible with each task. These features permit alternative work load management doctrines to be examined for their influence on operation generation capabilities. Work speed-up and other procedures to shorten on-equipment, pre-operation, and off-equipment activities also may be specified.

Scheduled pre-operation tasks are also associated with the shop structure. These tasks involve weapon refueling and the loading of munitions. The likelihood that the munitions are left over from the previous operation can be specified independently for each type of munition. After operation assignment, weapon configuration is checked, and, if necessary, the system is reconfigured; this may involve one or two separate tasks, each of which may require personnel and equipment. The loading of the operation-dependent munitions also may involve one or two separate tasks, each with its distinct requirements.

Several features are included that permit the user to simulate various "work-around" procedures that can alleviate resource constraints. One such feature permits the user to specify alternative resource requirements for any unscheduled on-equipment task, parts repair job, or weapons loading job; for example, one might specify that a three-man crew could do a normal four-man job in 50 percent more time. Similarly, if munitions shortages do not permit the normal, or preferred, munitions to be loaded for an operation, several alternative loadings may be specified. A third "work-around" feature permits the user to designate certain types of personnel as having been cross-trained so that they may replace or assist certain other specialists. This personnel substitutability feature is operative only for specified units and on specified on-equipment tasks, or munitions loading tasks.

DISTRIBUTION AND TRANSPORTATION

In addition to simulating a set of units, the user also may specify a centralized theatre distribution center or a centralized theatre repair facility at which some or all intermediate maintenance is conducted. The centralized distribution facility can receive spare parts from CONUS and either retain them until demanded by a unit or transship (some or all) to the unit with the earliest projected requirement. Such a facility can also be used to direct the lateral shipment of parts and other resources from one unit to another. The repair facility, such as a GS Corps Support Command (COSCOM) Center, has maintenance personnel, equipment, and spare parts. Parts are shipped to and from the COSCOM from the operating units and are processed in the manner prescribed by the user's choice of theatre management rules to govern these operations.

The simplest rules for Corps Support Command or Division Support Command (DISCOM) operation prescribe that faulty parts are repaired in the order in which they arrive and that they are returned to the sender. The user may also invoke a variety of more complex management algorithms, not only for selecting what to repair and how to dispose of parts when they have been repaired, but for reallocating personnel, equipment, and parts among the several operating units. Repair priorities can be based on existing and projected demands and on the relative importance of parts for the various missions. Shipment priorities are related to the current and projected demands, on-base reparables, and enroute serviceables. When central stocks are insufficient to meet a unit's demand, another unit can be directed to ship the required part, if both the requesting unit and the donor unit meet certain conditions concerning the importance of the demand and the availability of stock.

Daily estimates can be prepared of each unit's capabilities for generating different kinds of operations with different types of weapons (tanks). These estimates provide the basis for various unit management decisions. One application is in selecting which unit is to be assigned an operation for which no unit has been specified. These data can also be used to support assignment decisions when weapons must be diverted and when weapons are transferred from unit to unit.

THEATRE MANAGEMENT

The theatre-wide management of the various resources is supported by a user-specified scheduled transportation system that may be subjected to delays, cancellations, and losses. The model also permits the user to represent a theatre-wide reporting system to provide the central management authority with periodic resource status reports from the several operating units; these reports may be delayed, incomplete, or lost.

When these transportation and communication systems are coupled with the sets of rules for distributing and redistributing resources among the operating units, various concepts of theatre resource management may be represented and examined in the context of realistic transportation and communication imperfections. In its current formulation, the model already includes certain alternatives for the theatre management rules and has been designed to facilitate additions or modifications.

Appendix D

SUPPORTING MATERIAL

Table D-1

SIMULATED BRIGADE EQUIPMENT

Vehicle	Organization		
	Battalion Task Force	FAST	Brigade Total[a]
M60A1 Tank	36		108
M113A1 APC	17 } 23		51[b] } 69
M113 TOW Carrier	6 }		18 }
M88 Recovery Vehicle	4	2	14
M578 Recovery Vehicle	2	2	8

[a]Brigade contains three battalion task forces.

[b]This includes the 48 M113A1s in the three Rifle Companies (TO&E 7-47-02) plus three from the Headquarters and Headquarters Company (TO&E 7-46-02). Excluded are the mortar carriers, evacuation APCs, and scout APCs.

Table D-2

SIMULATED BRIGADE MANPOWER

Type or MOS	Organization					
	Battalion Task Force					
	Armor Company (2)	Mech Inf Company (1)	DS Contact Team	Total Task Force	FAST	Brigade Total[a]
M60A1 Crewmen	158 (about 40 crews)					472 (118 crews)
M113A1 or TOW Carrier Crewmen		79 (about 26 crews)				237 (79 crews)
63C	28	14	9	51	39	192
63F	10	5		15	4	49
45B					2	2
45K	1		3	4	11	23
45L	12			12	4	40
62B					4	4
36H			1	1	1	4
44B			1	1	1	4
52D			1	1	1	4

[a]Brigade contains three battalion task forces.

Table D-3

MAJOR END ITEM REPLACEMENTS

Day	Quantity	
	M60A1	M113A1
3	7[a]	2[a]
6	5	--[b]
8	5	--
10	5	--
12	5	--
14	5	--

[a]Represents typical brigade share of division maintenance float items for USAREUR divisions.

[b]Currently no (M113) APCs are held as PWRM.

Table D-4

CLASS III (POL) SUPPLY/DEMAND ESTIMATES
(DIESEL FUEL REQUIREMENTS)

Demand (Daily)

| Vehicle | SOC[a] Estimate | | | | | |
| | Active Defense | | | Attack | | |
	Eng Hrs	Dist	Gallons	Eng Hrs	Dist	Gallons
M60A1	14	39	99	14	55	105.3
M113A1	14	39	23.6	14	55	24.4

Task Force Totals	No of Veh	Gal/Day	Total	No of Veh	Gal/Day	Total
M60A1	36	99	3,564	36	105.3	3,790
M113A1	23	23.6	543	23	24.4	561
Total			4,107			4,351

[a]Rates based on Ft. Hood Consumption Factors—28 February 1979.

FM 101-10-1 Estimate
(Table 3-21 Factors p. 3-37)

Defense
$\left\{\begin{array}{l}\text{M60A1--Battalion:}\\[2mm]\dfrac{36}{54}\times\underset{\text{Gal/Km}}{46.3}\times\underset{\text{Dist}}{39}=1{,}203.8\\[4mm]\text{M113A1--Battalion:}\\[2mm]\dfrac{23}{79}\times\underset{\text{Gal/Km}}{16}\times\underset{\text{Dist}}{39}=\underline{181.6}\end{array}\right.$

Total $\qquad$ 1,385.4

Attack
$\left\{\begin{array}{l}\text{M60A1--Battalion:}\\[2mm]\dfrac{36}{54}\times\underset{\text{Gal/Km}}{46.3}\times\underset{\text{Dist}}{55}=1{,}681\\[4mm]\text{M113A1--Battalion:}\\[2mm]\dfrac{23}{79}\times\underset{\text{Gal/Km}}{16}\times\underset{\text{Dist}}{55}=\underline{256}\end{array}\right.$

$\qquad$ 1,937

Supply (Movement Capacity)

| | Task Force Goers (2500 gallons) assigned | | | | | |
	No	Avg Avail	Avail No	Trips/Day	Capacity	Gallons Moved
Defense SOC	3	.83	2	3	2,500	15,000 gal
Attack SOC	3	.83	2	2	2,500	10,000 gal

Table D-5

Class V (Ammunition) Daily Requirements

Defense SOC Daily Estimates

Task Force Requirements						
		Number of Tanks	Number of Rounds	Wt/Rnd[a] (lbs)	Total Wt (lbs)	
M60A1	105mm	36	63	62.78	= 142,385	
	50 cal	36	900	.345	= 11,178	
	7.62mm	36	3,000	.093	= 10,044	
					163,607	
M113A1	50 cal	23	1,000	.345	= 7,935	
					171,542	= 85.77 Tons

[a]Wt/Round from FM 101-10-1, Table 3-27.

FM 101-10-1 Estimates

	Task Force Veh/ Division Veh		Tons/Day		
M60A1 (Defense)	$\frac{36}{324}$	×	793.3	= 88.14 Tons	
M113A1	$\frac{23}{1,050}$	×	54.2	= 1.19	
				89.33 Tons	

Lift Capacity						
	Type	Task Force Quantity	Avail	Trips/Day		
Goers	5 Tons	6	.83	2	= 49.8	Tons
	8 Tons	5	.83	2	= 66.4	
					116.2	Tons
Trucks	2.5 Tons	21	.83	2	= 87.15	Tons

203.35 Tons

Appendix E

BATTLE DAMAGE AND RECOVERY
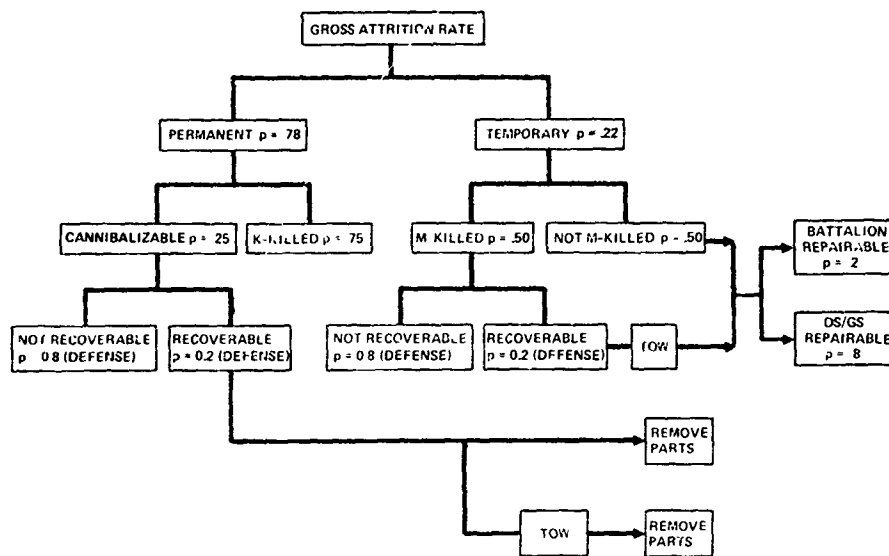
Fig. E-1—Attrition, battle damage and recovery assumptions (M60A1 active defense)
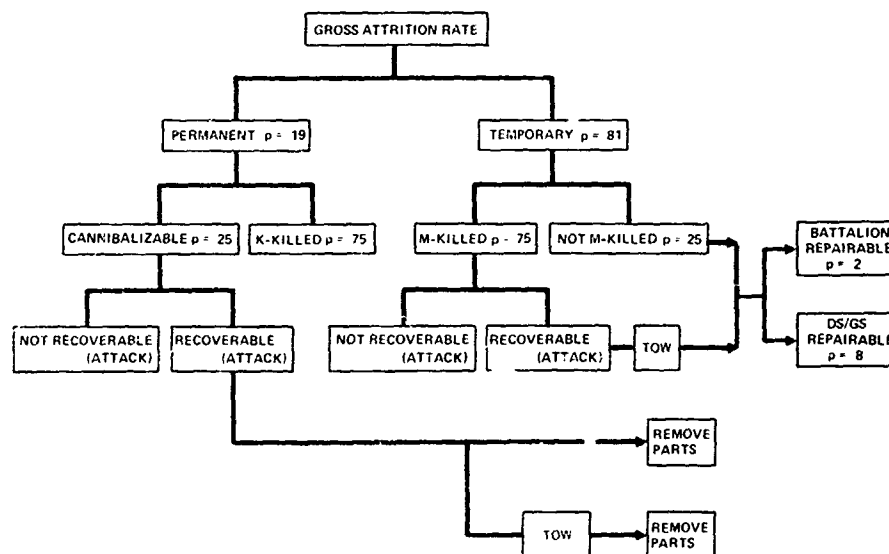
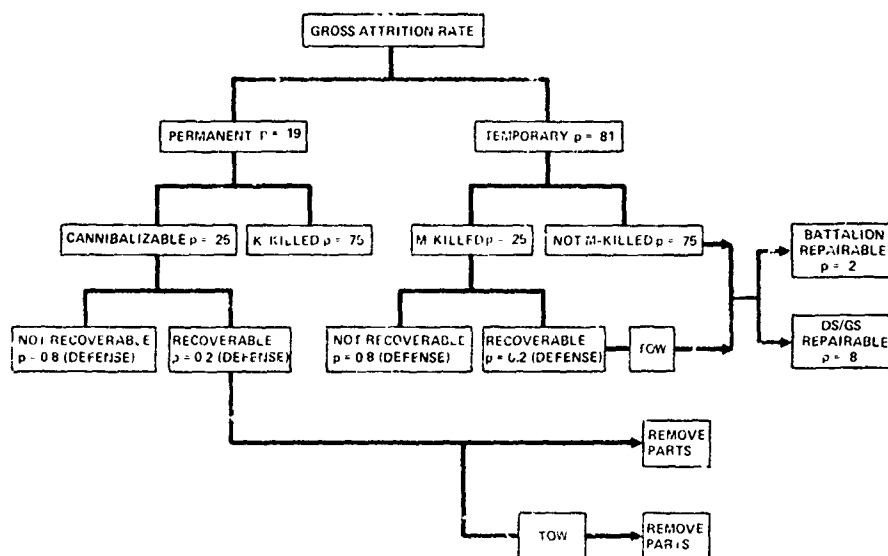Fig. E-2—Attrition, battle damage and recovery assumptions (M113A1 attack)

Fig. E-3—Attrition, battle damage and recovery assumptions
(M113A1 active defense)

Table E-1

BATTLE REPAIR TIMES

Expected Repair Flow Times

Vehicle	Organizational (Bn)	Direct Support (FAST)
M60A1	12 Hours	48 Hours with p = 0.8 24 Hours with p = 0.2
M113A1	6 Hours	48 Hours

Note: Flow times are expected values depending on the
availability of required skills. Manhours may
exceed flow time hours depending on total repair
requirements.

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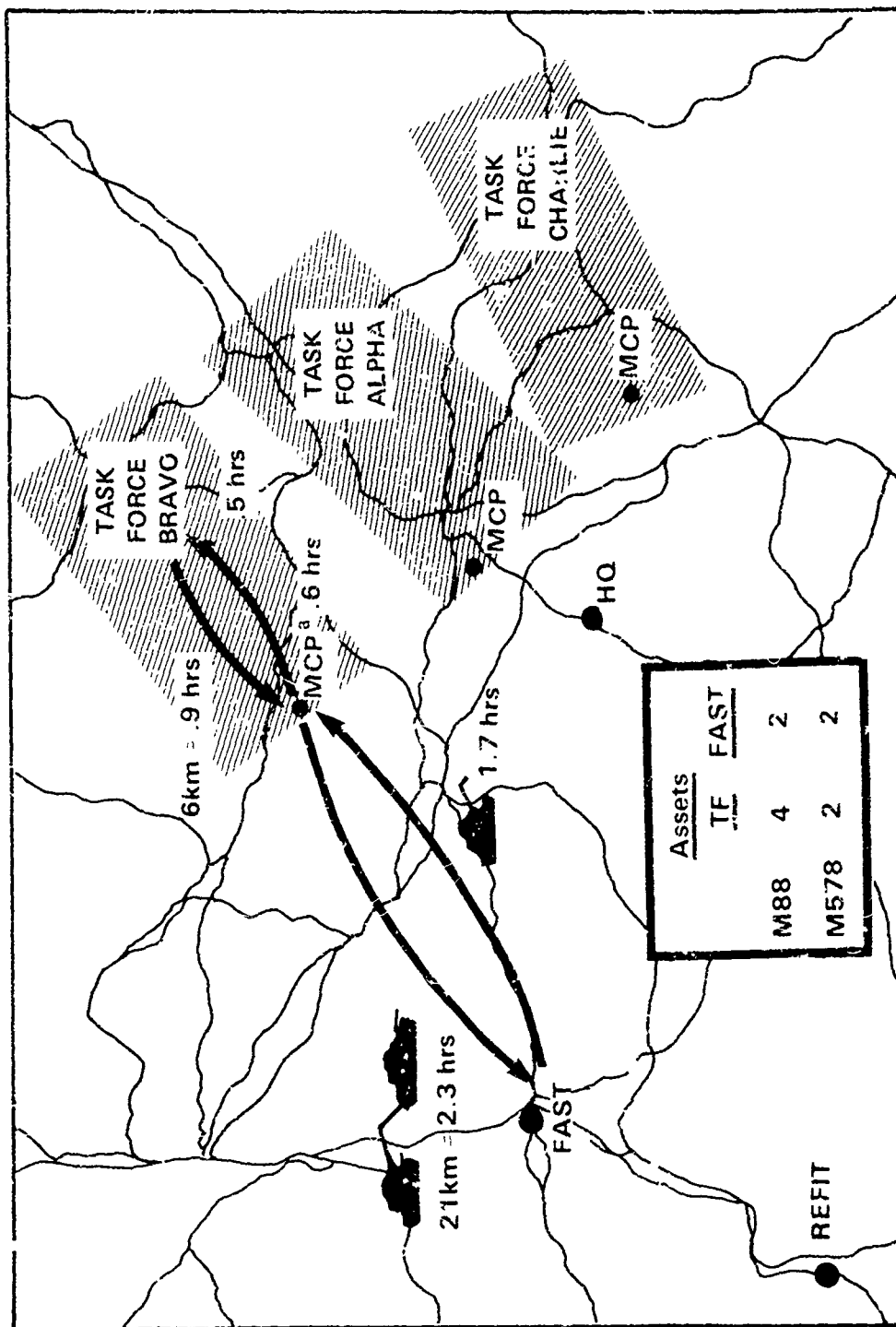
Fig. E-4—Repair support

Appendix F

PARTS DISTRIBUTION
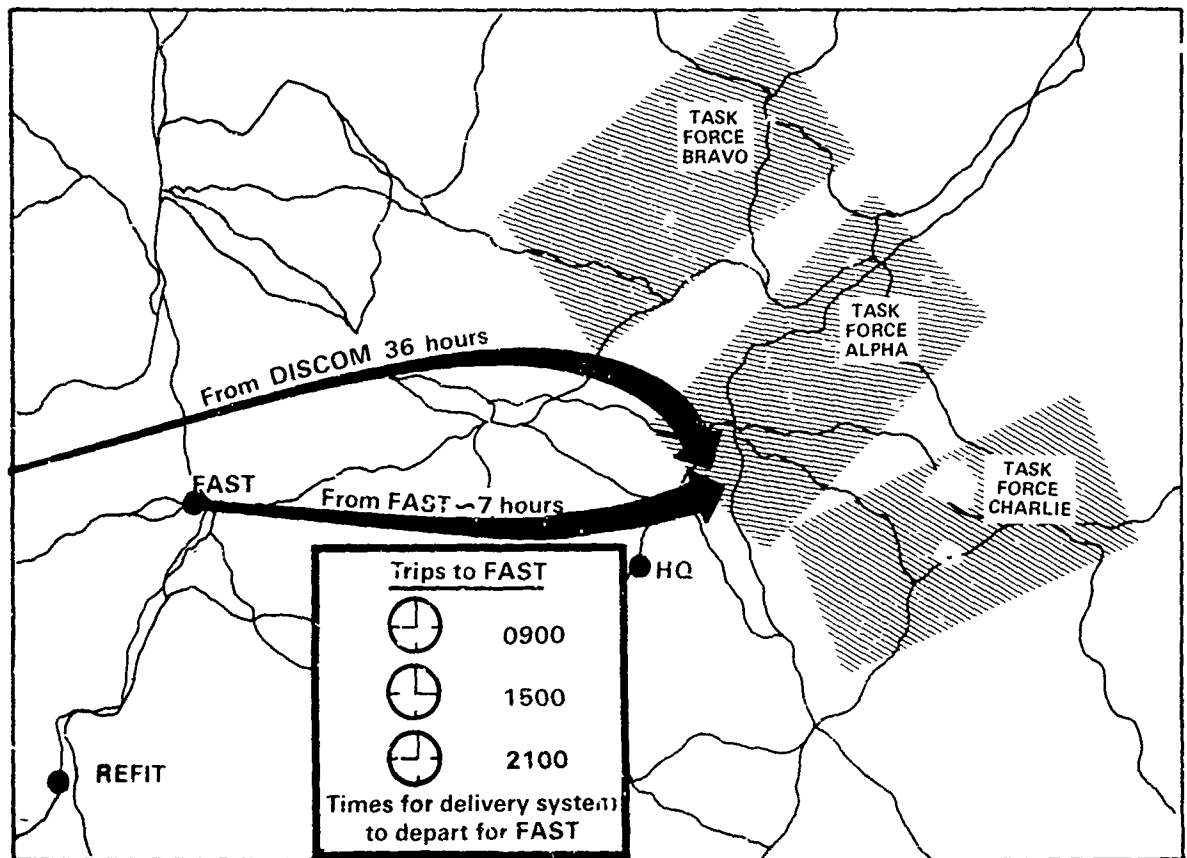
Fig. F-1—Parts distribution

Appendix G

SIMULATION RESULTS FOR BASE CASE WITH REPLACEMENT

The base case brigade with end item replacement can be used as an alternative reference unit by which to calculate the denominator of the readiness and sustainability index, Eq. (2).[1] By itself, the base case with replacement permits analysis of the effect of major end item resupply on the sustainability of the base case brigade. Figure G-1 shows the daily output of the base case brigade's armor components with major end item replacement for the active defense SOC.
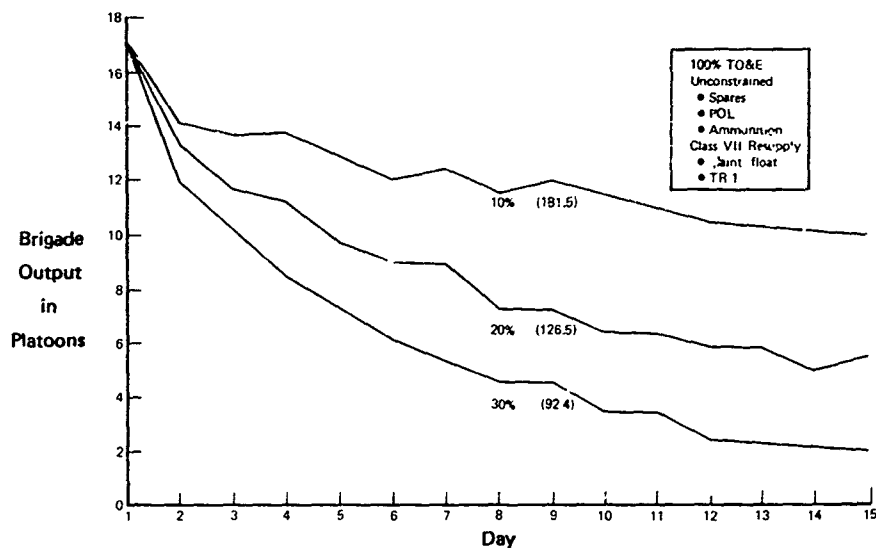
Fig. G-1—Active defense SOC daily output for base case armor components with replacement

At identical attrition rates per day, the resupplied base case brigade produces considerably more armor output over 15 days of operations than the base case without replacement. This is shown clearly in the readiness and sustainability index shown in Fig. G-2 for 20 percent attrition per day. Over shorter periods, before all replacements arrive, the readiness and sustainability index is correspondingly less.

These results could be reasonably predicted; the resupply of major end items provides 32 tanks, or about 30 percent more armor than the brigade has initially. These tanks are available *on average* for about two-thirds of the 15-day period of operations, given the slight front

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[1]To convert to this denominator, one must divide the readiness and sustainability indexes in the text by those shown in Figs. G-2 or G-4, depending on the SOC.
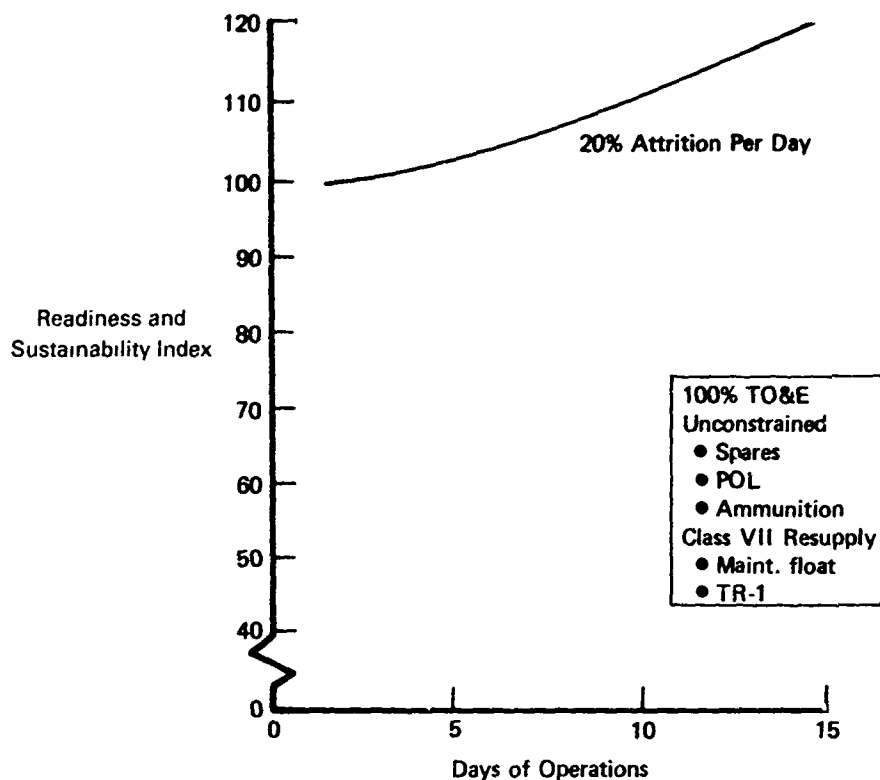
Fig. G-2—Active defense SOC readiness and sustainability index
for base case armor components with replacement

weighting of the replacement schedule. One could thus expect about a 20 percent increase in output and the index. Only a slight variation was found with respect to the attrition rate per day. As attrition does not alter the above analysis, this too was expected.

For the base case brigade's mechanized infantry components, the output with replacement is virtually indistinguishable from the base case brigade without replacement because only two APCs, or about 3 percent of the brigade's initial stock, are added (see Table D-3). These are available for about 80 percent of the 15-day period of operations. Consequently, the readiness and sustainability index is about 2 percent higher with replacement than without.

Figures G-3 and G-4 show the same information as above for the attack SOC. The specifics of the attack SOC alter the above results, but only marginally.
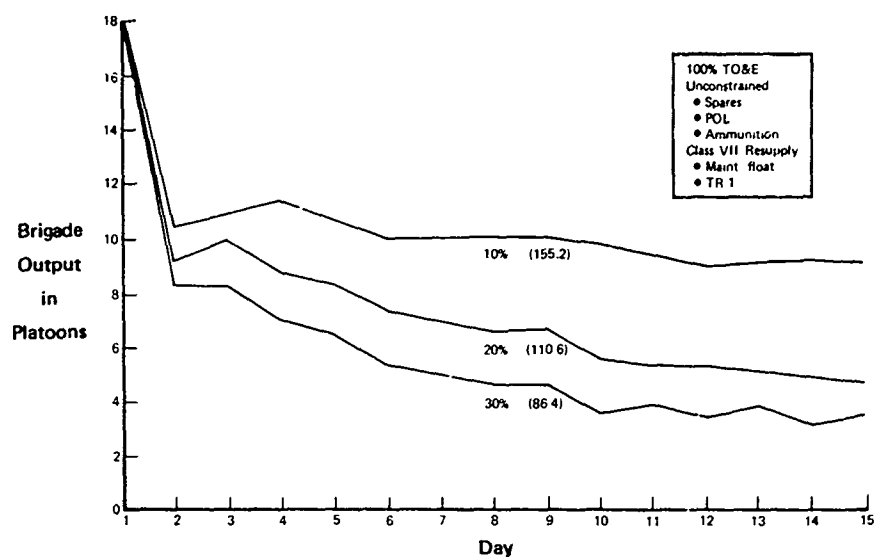
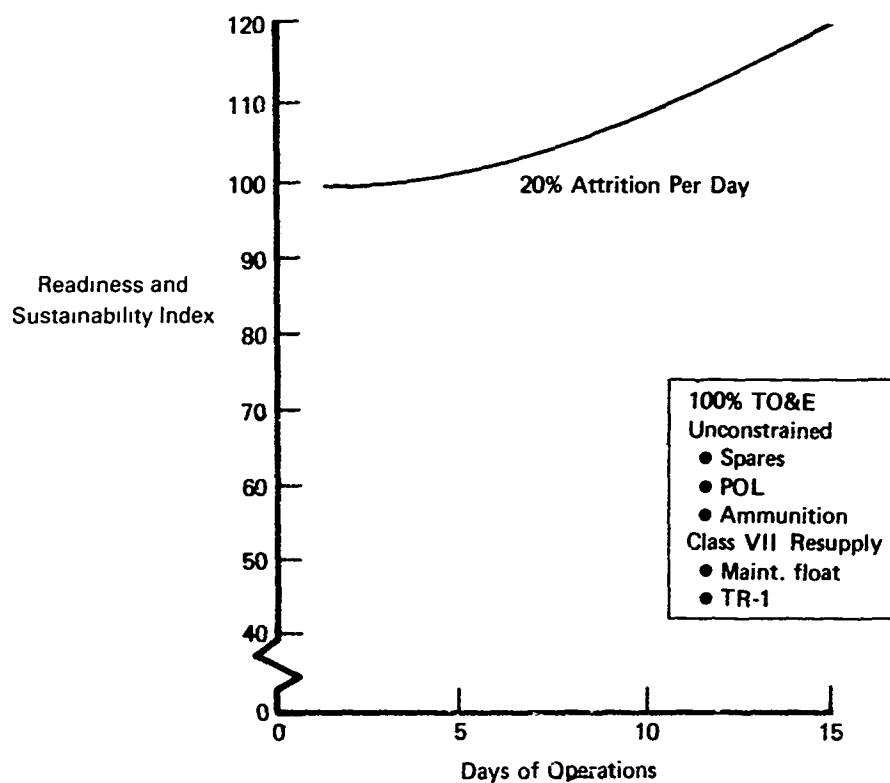Fig. G-3—Attack SOC daily output for base case armor
components with replacement

Fig. G-4—Attack SOC readiness and sustainability index for base case armor
components with replacement

Appendix H

SIMULATION RESULTS AT ALTERNATIVE ATTRITION RATES

The effect of different attrition rates on the readiness and sustainability index is systematic and can be explained by relatively straightforward principles. The implications for resource requirements planning are, however, profound. In Fig. H-1, we have reproduced the readiness and sustainability index in text Fig. 7 for the SHORTPARTS brigade at 20 percent attrition per day, and we have added the index for the three other daily attrition rates we used in our simulations. For any period of operations, the higher the daily attrition rate, the greater the resource readiness and sustainability index for the SHORTPARTS brigade. To some, this may seem unusual, but it is precisely what one should expect to see.

First, the readiness and sustainability index does not measure capability, but only the ability to generate output *relative* to a base case unit performing the same SOC and suffering
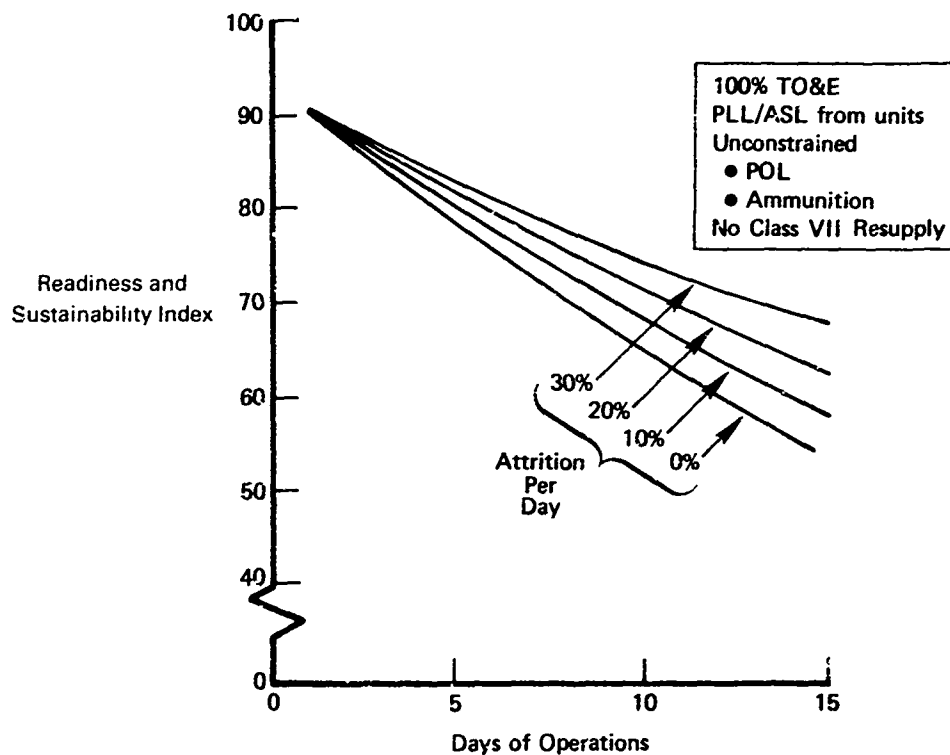

Fig. H-1—Active defense SOC readiness and sustainability index for armor components with constructed PLL/ASL

the same at.rition. A higher daily attrition rate per se does not imply lower unit capability, because that can be determined only in a two-sided engagement—that is, by reference to battle outcome. It could very well be true that capability was higher at the 30 percent per day attrition rate than at lower rates if the brigade defeated, say, a first echelon division.

Second, the daily attrition rate used in readiness and sustainability measurement should be the same as the one used in resource requirements determination. In effect, the choice of the daily attrition rate for readiness and sustainability measurement is not really open as it should have already been fixed in the planning process. The family of curves in Fig. H-1 represents only the parametric variation of the daily attrition rate, which is necessary as there is *no* agreed upon rate (or rates) to be used in analysis.

The reason why the readiness and sustainability index increases as the daily attrition rate increases is that at the higher rate, the less the resource shortage—parts in the case of Fig. H-1—matters. In the SHORTPARTS case, at the higher daily attrition rates the existing spares go further as there are fewer tanks/APCs on average to support. Further, as the work load decreases rapidly over time, maintenance personnel have more opportunity to cannibalize and can thereby mitigate the shortage of parts; at the same time more battle-destroyed vehicles are available for parts removal. As a general principle, one would expect resource shortages to affect output less severely when the number of vehicles to be supported is smaller on average over time.[1] Secondarily, one would expect more resources to be released and available to substitute for any particular set of resource shortages at higher daily attrition rates. Output does not suffer as much relative to the base case at these higher rates.

In Figs. H-2 and H-3, we show the readiness and sustainability index as a function of the daily attrition rate used in the simulation for the armor and mechanized infantry components of the SHORTPARTS brigade for the active defense SOC. Figures H-4 and H-5 show the same for the attack SOC.

Figure H-6 shows the readiness and sustainability index for the EUROCOMBO case armor components for both SOCs as a function of the attrition. The earlier conclusion in the text that the indexes are substantially different from one another for these two SOCs holds across a wide range of daily attrition rates. No convergence of these curves was found in our simulations.

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[1]This is easily observed in cases when there are no substitutes as, for example, with POL and ammunition. See our Note, *Resource Readiness of Armored Units*, N-1299-MRAL, especially pp. 43-44.
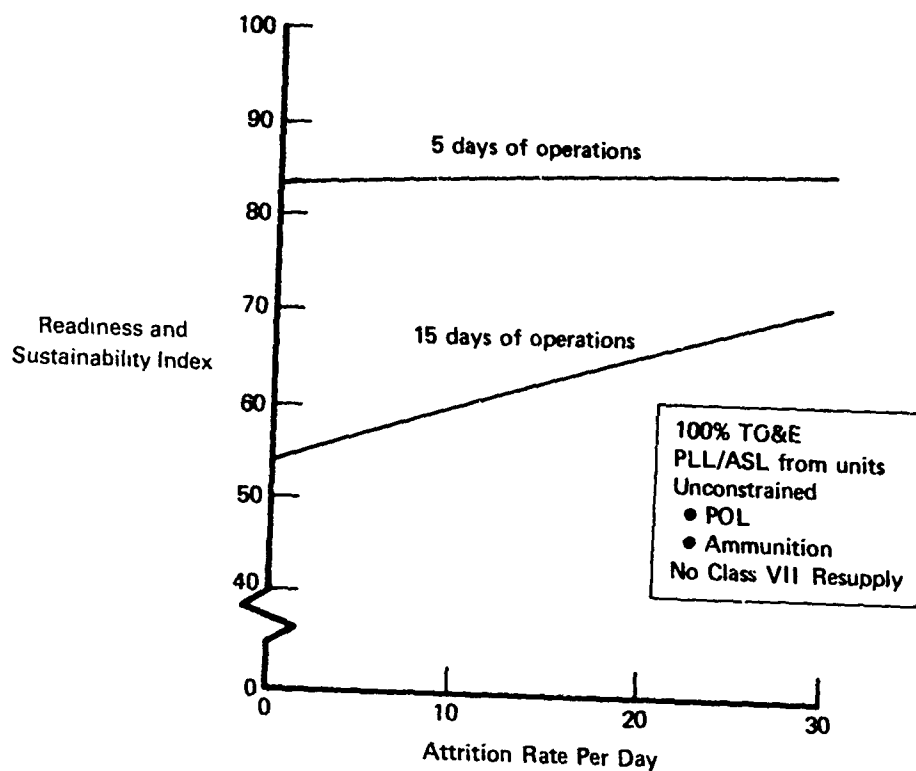
Fig. H-2—Active defense SOC readiness and sustainability index for armor
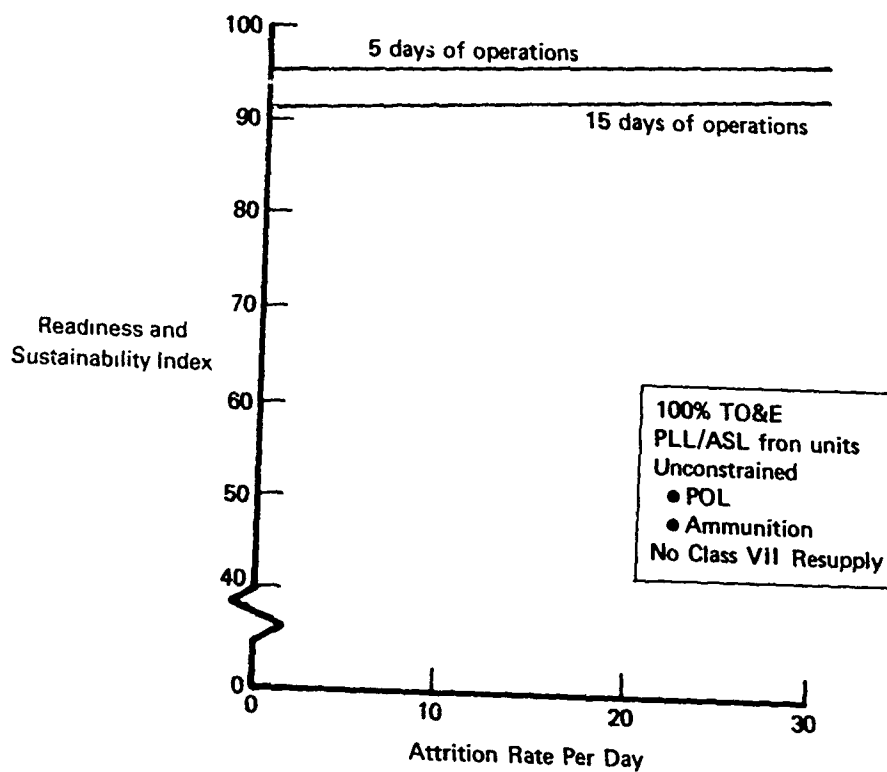components with constructed PLL/ASL

Fig. H-3—Active defense SOC readiness and sustainability index for mechanized
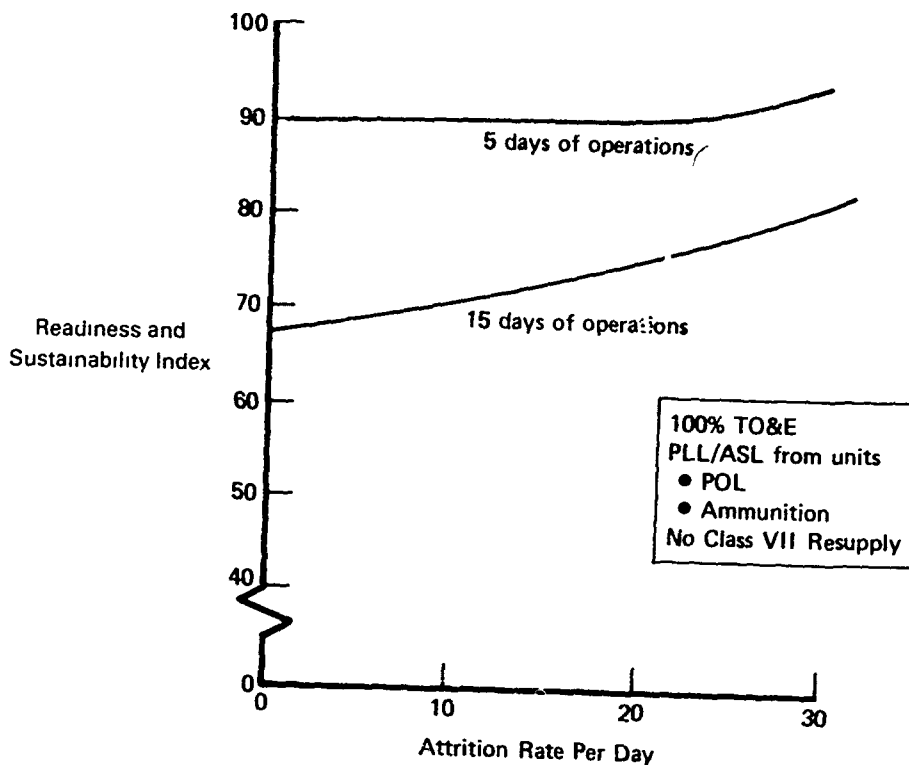infantry components with constructed PLL/ASL

60

Fig. H-4—Attack SOC readiness and sustainability index for armor
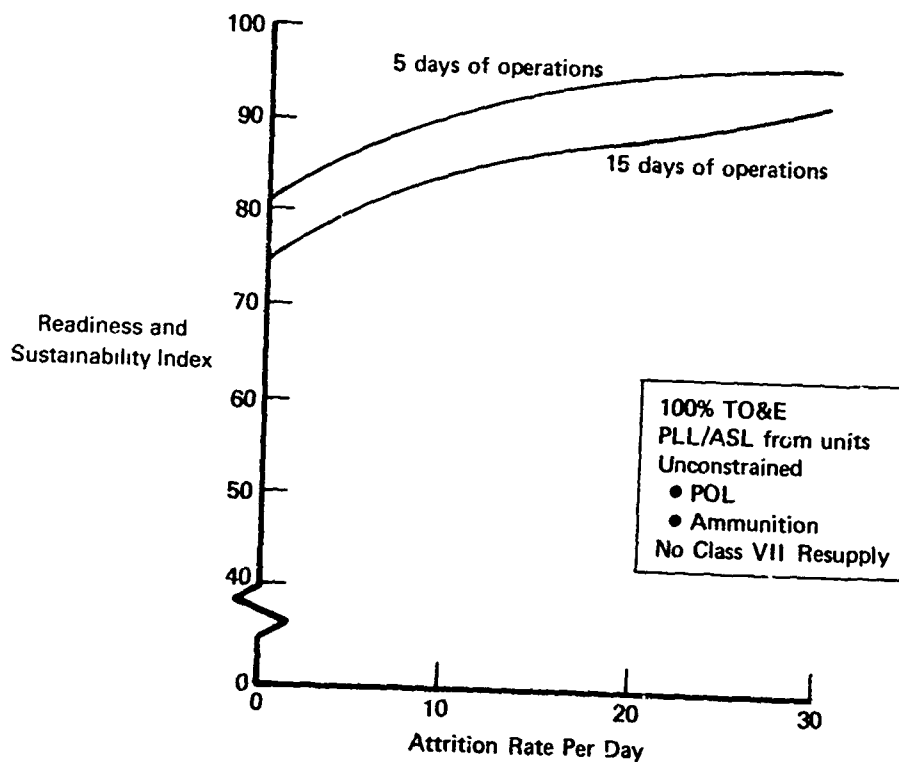components with constructed PLL/ASL

Fig. H-5—Attack SOC readiness and sustainability index for mechanized
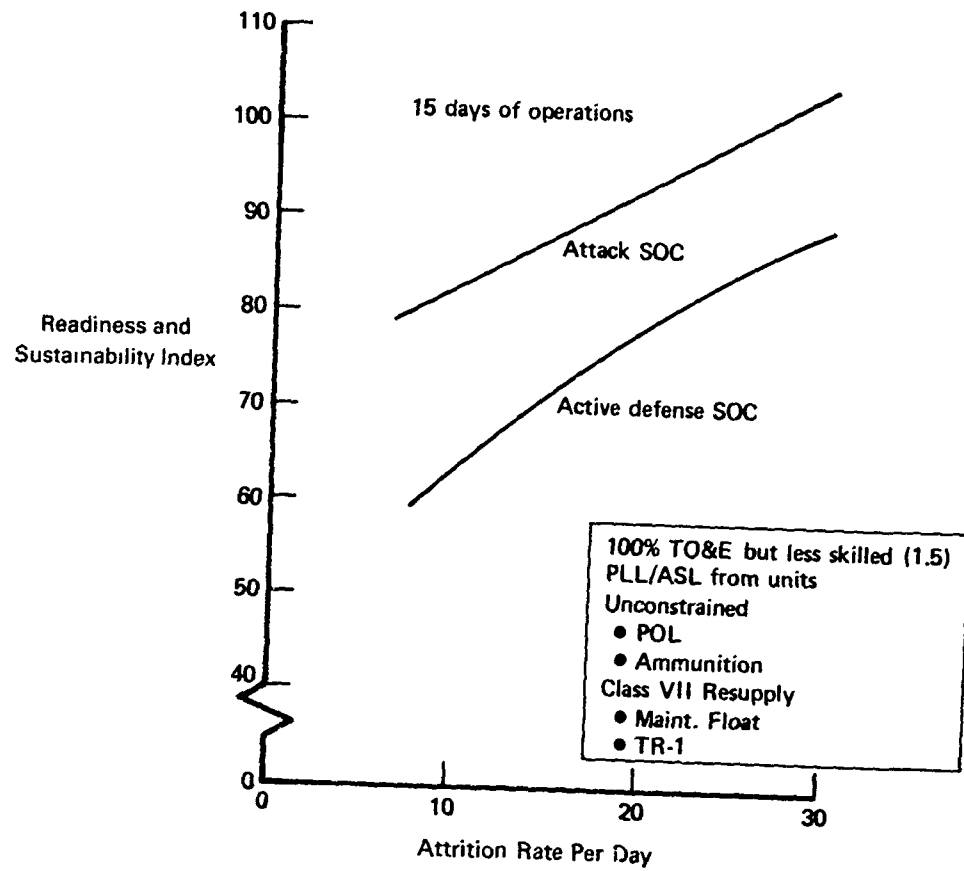infantry components with constructed PLL/ASL

Fig. H-6—Readiness and sustainability indexes for European combination
armor components

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