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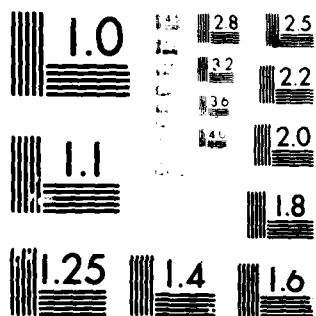
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↙ This is a report of the initial work on a project to develop a method of assessing the relationship between the resources available to and relative readiness of Army maneuver and firepower units. A concept is presented which differentiates between the current method of reporting on the status of resources available to tank battalions (AR 220-1) and an alternative which presents estimates of the capability of a battalion to generate ready platoons trained, equipped and provisioned for specific operations. This concept highlights the difference between available resources (inputs) and a unit's Specific Operational Capability (SOC) to perform an OPLAN defined mission (output). The concept is evaluated in a simulation term AURA (Armored Unit Readiness Assessor) and the results provide examples of how readiness is effected by tasking and attrition assumptions. The report also raises issues concerning the purposes for readiness assessment and the tasks remaining to further evaluate readiness assessment methods for Army Units. ↘

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RESOURCE READINESS OF ARMORED UNITS

Robert Shishko, Robert W. Paulson

A Rand Note

prepared for the

OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE/
MANPOWER, RESERVE AFFAIRS AND LOGISTICS



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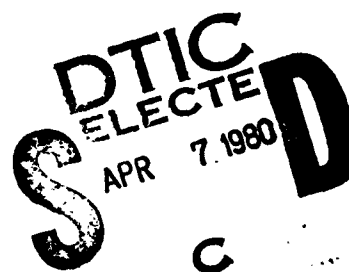
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PREFACE

This note 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 79-IV-2, Quantifying the Effect of Resource Levels on the Readiness of Ground Forces.

Manpower issues are assuming an ever greater importance in defense planning and budgeting. Broad strategies and specific solutions for dealing with present and future defense manpower problems include the development of new methodologies for examining broad classes of manpower problems, as well as specific problem-oriented research. In addition to providing analysis of current and future manpower issues, this studies program should contribute to a better general understanding of the manpower problems confronting the Department of Defense.

This note should be of interest to those concerned with readiness and resource management for general purpose forces.

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SUMMARY

This note examines how managers and the OSD decisionmaking staff can relate the readiness status of force structure units to resource flow decisions. The suggestions and findings are based on observations concerning, first, the meaning of *readiness* and, second, the relationship between a unit's readiness and the flow of resources to it. The specific task is to ascertain the relationship between readiness status and resources for a typical armored battalion.

READINESS DEFINITIONS AND MEASUREMENT

The JCS defines operational readiness as "the capability of a unit, shop, weapon system, or equipment to perform the missions or functions for which it is organized and designed."¹

This and other definitions emphasize the capability of an operating unit to deliver a *product or service over some period of time*. But more than a list of resources available and their current (static) condition is required. At a minimum, a readiness measure must be output related and take into account the timeliness with which a unit can respond, how long it can continue to operate, and under what circumstances it is expected to operate. Although these ideas are not new, the current Army Regulation AR220-1 (15 June 1978) *Unit Status Reporting (USR)*, which establishes a system for reporting the readiness status of selected active and reserve units, does not appear to be responsive to them.

The deficiencies discussed here apply to the FORSTAT in general and therefore affect all the Services. First, the Army's current readiness reporting system cannot be reconciled with currently expressed definitions of readiness, which emphasize output measurement. AR220-1 emphasizes the quantification of inputs and intermediate

¹Joint Chiefs of Staff, *Joint Reporting Structure, Force Status and Identity Report (FORSTAT)*, JCS Publication No. 6, Washington, D.C., June 1974.

products--in particular, operationally ready (OR) weapon systems. Second, there are several problems associated with measuring a *force's* readiness rather than a *unit's*. Third, current Army readiness reporting systems do not appear to be responsive to the needs of resource managers. Finally, the current readiness measures lack specificity in the kinds of military actions the unit can undertake, for what regions it is equipped to fight, how long it is capable of performing its mission, and so on. In particular, the C-ratings do not refer to any particular opplan. A unit that may be ready to perform its mission under one opplan may be unprepared to perform its mission under another. The current readiness reporting system does not ask: "Ready for what?"

CONCEPTUALIZING ARMORED UNIT READINESS

To construct a measure of readiness for armored units, we believe one must deal with four questions:

- What is the precise unit of output of the armored unit?
- Under what circumstances is the unit's output being measured?
- What time period, e.g., 7 days, 30 days, is to be used in measuring the output?
- When can the unit begin producing output after mobilization?

Output

The problem of defining 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. In peacetime, armored 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. It is useful to think of a unit's output as described by a vector of that unit's ability to perform *conceptual operations* of several specific types.

This concept of output measures the unit's ability to marshal its resources to carry out a conceptual operation. The adequacy of this unit to defeat the enemy or to hold territory is a consideration apart from the definition of output. Clearly, this measure is one-sided--

that is, it does not measure 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*. Capability and readiness are, however, closely related: In the simplest scheme, capability is a function of readiness, the effectiveness of individual weapon systems attainable in the field, the number of units, and the efficacy of doctrine.

We have used the term *specific operational capability* (SOC) to describe each type of conceptual operation used in the above definition of output. A SOC is determined by a usage profile and special conditions of employment, both of which are described by the circumstances in which the unit is expected to fight. Each SOC should be related to an oplan insofar as the quantitative specification of the SOC's time-dependent assumptions is concerned. Each SOC should also identify the operation-essential subsystems and training requirements. For example, if a SOC calls for night operations by armored units, the unit should have the appropriate numbers and types of night-sight devices and crews trained in their use.

Tanks are employed in mass, with platoons generally being the smallest maneuver unit. We chose as our output measure the number of *platoon-sized units* that could be marshalled for a given SOC.

Circumstances

The circumstances under which an armored unit is expected to fight must be assessed *before* one can determine readiness. In particular, to assess the readiness of armored units in a given oplan, one must specify the *time dependent assumptions* concerning:

- attrition (temporary and permanent)
- consumption rates (all resources)
- maintenance task lengths under realistic conditions
- movement rates (distances and times)
- resupply schedules and quantities (all resources)
- management of maintenance work loads
- diurnal cycles (operations, resupply, maintenance)

- personnel fatigue and efficiency
- unit rotation and reconstitution
- other pertinent factors

Some of these will be SOC-specific, while some will be oplan-specific. Other assumptions will have to be made on the basis of policy decisions or military judgment.

Conceptually a unit's readiness measure must specify the time period over which the output is to be measured. In order to measure readiness for an oplan, the mobilization and deployment criteria must be specified.

A Readiness Index

Once these variables have been quantified, we believe that an index of readiness, R_{ij}^k , for the k^{th} unit for the i^{th} SOC of oplan j can be defined as

$$R_{ij}^k = \frac{Q_{ij}^k(m, T, \tau)}{Q_{ij}^o(m, T, \tau)} \quad (\text{S.1})$$

where Q_{ij}^k is the cumulative output of the k^{th} unit for the i^{th} SOC of oplan j produced from starting date τ and time period T . Q_{ij}^o is the identical quantity for a *reference unit*. The readiness index for the k^{th} unit is thus its output *relative* to some reference unit.

ARMORED UNIT READINESS ASSESSOR (AURA)

In the absence of a readily available Army model for evaluating the relationship of resources to output for armored units, we adapted a Rand model under development--TSAR (Theatre Simulation of Airbase Resources)--which was funded under Project Air Force. We used the name AURA (Armored Unit Readiness Assessor) to describe the adaptation of TSAR to armored units. TSAR/AURA is a Monte Carlo event simulation model that combines user-specified battle demands with unit resources to calculate the number of tank platoons that can be generated for a

specific operation. 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. It 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 problem, none of the conceptual work described above is model-specific. In operationalizing the readiness index, we would be happy to use another tool that performs the same calculations as TSAR/AURA.

APPLICATION OF AURA TO AN M60A1 ARMORED BATTALION

We applied TSAR/AURA to an armored battalion that is equipped with 54 M60A1 tanks. We made a number of assumptions and imposed a number of ground rules. Our simulation strategy was first to run cases in which manpower levels and spares were varied and second to run cases in which POL and ammunition were varied. The base case consisted of a full TO&E armored battalion with *unconstrained* POL, ammunition, and spares.

Following the base case, we ran two cases in which maintenance manpower and crews were reduced (hereafter referred to as the *C-2 in manpower* and *C-3 in manpower* cases, respectively). Consumables were left unconstrained. Next we restored the manpower to the full TO&E level, but gave the battalion the PLL of an actual unit, which considerably reduced the battalion's access to spares. The PLL used in the simulation reflected the actual status of the M60A1 parts stockage for the 2nd Battalion, 67th Armored Regiment, 2nd Armored Division as of 13 November 1978.

We next ran the case in which the maintenance manpower and crews were reduced to the C-3 in manpower level *and* spares were constrained to those found in the 2nd Battalion, 67th Armored Regiment PLL. In these cases, POL and ammunition were always left unconstrained.

In a separate set of runs, we simulated the effect of POL and ammunition shortages. Manpower was set at the full TO&E level and spares were unconstrained, but in one case we gave the battalion a stock of ammunition equal to an average daily consumption rate of 667 rounds, and in another case we gave the battalion a stock of POL equal to an average daily consumption rate of 1350 gallons.

At high attrition rates the TSAR/AURA simulation suggests that *for the attack SOC* support resources--spares and manpower--are less important than having OR tanks and crews available at the start. At low attrition rates the simulation suggests that *for the attack SOC* these support resources are very important and are interactive because spares can substitute for manpower.

The reason that the readiness index improves as the attrition rate increases can be explained by reference to the fact that the cumulative output of the well-provisioned base case battalion falls dramatically as the attrition rate increases. The cumulative output of the poorly provisioned battalion also falls as the attrition rate increases, but not nearly so much *in percentage terms* as the base case battalion.

NEED FOR FUTURE RESEARCH

Because we feel more work is needed, we would not recommend policy actions be taken on the basis of the results at this time. There is a definite need to model a combined arms brigade including the DS/GS infrastructure. It would then be possible to test the robustness of our results for a variety of SOC's and alternative time-dependent assumptions. It is also important to validate the data processed by the TSAR/AURA simulation model.

The uses of readiness measures generally fall into two classes: near-term management and longer term resource requirements. Each may require rather different kinds of readiness information, but both are likely to rely on a detailed understanding of the relationship of inputs to outputs.

Using the readiness concepts proposed in this paper, a unit could be rated by its ability to perform various specific operational capabilities under various plans. The unit's ability to mobilize and deploy

could also be rated. The usefulness of this kind of information depends on the ability of Army decisionmakers to move resources across units in response to readiness deficiencies.

The longer term uses of readiness measurement systems include (1) the computation of resource requirements for a force over a set of oplans, (2) the evaluation of new weapon systems, particularly with regard to capital-labor tradeoffs, and (3) the evaluation of alternative force structures. Each of these uses requires a great deal of hard thinking about what information is needed, who will use it, and how.

The kinds of information suggested for the near-term management questions are not sufficient for the computation of requirements because of the problem aggregating over SOC's and oplans and then "rolling up" requirements to the theatre or world-wide level. Evaluating various capital-labor tradeoffs for proposed weapon systems fits easily into the readiness framework because such tradeoffs should be looked at in terms of present value cost for *equal output resource combinations*. The force structuring issue is also closely allied with readiness measurement. In each of these uses, a necessary building block is the ability to translate resources into output, and it was toward this objective that this research was conducted.

ACKNOWLEDGMENTS

In conducting this study on resource readiness for armored units, we made a deliberate effort to draw upon the readiness and armor expertise of individuals across the Army's major commands (MACOMs). Our study benefited greatly from our discussions with many people in the following organizations:

- HQDA
 - DCSOPS/Operations and Readiness
 - DCSPER/Personnel Readiness
 - DCSLOG/Readiness
- TFMO (Tank Forces Management Office)
- CAA (Concepts Analysis Agency)
- HQ TRADOC
 - DCS Combat Developments
 - DCS Training
- LOGC (Logistics Center)
- Fort Knox
 - Directorate of Combat Developments
 - Directorate of Training Developments
- Fort Leavenworth
 - Combined Arms Center and Development Activity
- HQ FORSCOM
 - DCSOPS/Readiness
 - DCSPER/Personnel Readiness
 - DCSLOG/Equipment Readiness
- Fort Hood
 - HQ III Corps
 - XIII COSCOM
 - 1st Cavalry Division
 - 2nd Armored Division
 - TRADOC Combined Arms Test Agency.

We are especially grateful to Lieutenant Colonels William Warnock and Richard Henrickson, DA/DCSOPS (Readiness Division), who as our main points of contact did so much to make these visits possible. We also thank Major General John C. Faith, DA/DCSOPS, Director of the Readiness Division, for his support during the study.

This study could not have been done were it not for the assistance of Rand colleagues Don Emerson, who developed the TSAR computer model, and Milt Kamins, who adapted the model to our problem. We also thank Steve Drezner and C. Robert Roll, Jr. for their comments. Any remaining errors are our responsibility.

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I. THE READINESS 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 of forces already in the field. Because major investment programs and manpower policy changes affect readiness 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. This paper examines how managers and the OSD decisionmaking staff can relate the readiness status of force structure units to resource flow decisions. The suggestions and findings that follow are based on our observations concerning, first, the meaning of *readiness* and, second, the relationship between readiness and the flow of resources to a unit. Although these two issues have been extensively studied by others, no resolution has yet been found.

Our specific task is to ascertain the relationship between readiness status and resources for a typical armored battalion. One reason for this choice was the number and importance of armored units in the Army. A second reason was that if a methodology could be demonstrated for a maneuver/firepower unit, then the methodology could probably be adapted to other types of general purpose units as well.

READINESS 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) *Force Status and Identity Report (FORSTAT)*, which defines operational readiness as "the capability of a unit, shop, weapon system, or equipment to perform the missions or functions for which it is organized and designed."¹

¹Joint Chiefs of Staff, *Joint Reporting Structure, Force Status and Identity Report (FORSTAT)*, JCS Publication No. 6, Washington, D.C., June 1974.

General David Jones, now Chairman of the Joint Chiefs of Staff, elaborated further on this concept of readiness during the USAF Readiness Year.

From my point of view, our state of readiness certainly determines how rapidly and with what effect peacetime configured forces can be brought to bear upon various crises or conflict situations. It also includes *how long* and *to what degree* our forces can be employed. It embodies the capability to successfully *accomplish tasks within a specified time* with current resources and management systems.¹ (Emphasis added.)

This definition is consistent with the less rigorous interpretation found in the *DoD Materiel Readiness Report* (February 1978).

Readiness: The capability of some specified force structure (or subset thereof) to do something, somewhere with some amount of advance notification, and to continue doing it for some period of time.

These definitions of readiness emphasize the capability of an operating unit to deliver a *product or service over some period of time*. 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 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 (15 June 1978) *Unit Status Reporting (USR)*, which establishes a system for reporting the readiness status of selected active and reserve units, is not responsive to them.

¹U.S. Congress, *Department of Defense Appropriations for FY78, Statement of the Chief of Staff of the Air Force*, House Committee on Appropriations, 95th Congress, 1st Session, Washington, D.C., February 1977.

UNIT STATUS REPORTING (AR220-1)

The stated purpose of AR220-1 is to satisfy:

(a) the requirements of the Army portions of JCS Publication 6 *Force Status and Identity Report (FORSTAT)*, which is used to assess combat readiness, and (b) additional needs of the Department of the Army for readiness information.

These additional requirements are further defined to include the following objectives:

- Provide the readiness status of U.S. Army units to the National Command Authorities (NCA), the Joint Chiefs of Staff (JCS), Headquarters, Department of the Army (DA), and Commanders at all levels.
- Provide DA with indicators that: (a) identify problems which degrade unit status, (b) assist the Department of the Army and intermediate commands to allocate resources, (c) identify the differences between current personnel/equipment assets in units and full wartime requirements, and (d) determine Army-wide readiness conditions and trends.

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 conditioned 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 four 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 mission.

Table 1
RATING CRITERIA

	C-1	C-2	C-3	C-4
<u>Personnel:</u> <u>Strength</u>	Operating strength not less than 95% of full MTOE.	Operating strength not less than 85% of full MTOE.	Operating strength not less than 75% of full MTOE.	Operating strength less than 75% of full MTOE.
MOS	Not less than 86% of full MTOE strength are personnel in the operating strength who are qualified to perform the duties of the position to which assigned.	Not less than 77% of full MTOE strength are personnel in the operating strength who are qualified to perform the duties of the position to which assigned.	Not less than 68% of full MTOE strength are personnel in the operating strength who are qualified to perform the duties of the position to which assigned.	Less than 68% of full MTOE strength are personnel in the operating strength who are qualified to perform the duties of the position to which assigned.
Senior Grade	86% of E5 and above assigned.	77% of E5 and above assigned.	68% of E5 and above assigned.	Less than 68% of E5 and above assigned.
<u>Equipment</u> <u>On Hand</u>	Not less than 90% of full MTOE reportable lines at or above 90% fill and pacing item (PI) at or above 90% fill.	Not less than 90% of full MTOE reportable lines at or above 80% fill and pacing item (PI) at or above 80% fill.	Not less than 90% of full MTOE reportable lines at or above 70% fill and pacing item (PI) at or above 70% fill.	Less than 90% of full MTOE reportable lines at less than 70% fill and pacing item (PI) at or less than 70% fill.
<u>Equipment</u> <u>Status</u>	Average OR rate equals or exceeds 90%.	Average OR rate equals or exceeds 80%.	Average OR rate equals or exceeds 70%.	Over 30% of reportable equipment inoperable. PI OR rate less than 70%.
	PI OR Rate must be 90%.	PI OR Rate between 80 and 90%.	PI OR Rate between 70 and 80%.	
<u>Training:</u> Div, Bde/ Regt, or Bn/Sqdn.	0-2 weeks required to attain a fully trained status.	3-4 weeks required to attain a fully trained status.	5-6 weeks required to attain a fully trained status.	7 plus weeks required to attain fully trained status.
Company/ btry or below.	0-1 weeks required to fully trained status.	2 weeks required to fully trained status.	3-4 weeks required to fully trained status.	5 plus weeks required to attain a fully trained status.

Source: AR220-1, 15 June 1978, Appendix F, p. F-1.

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 the FORSTAT in general and therefore affect all the Services. Our purpose here is to bring some of these to light in the context of our definition of readiness and approach to readiness measurements.

First, the Army's current readiness reporting system as embodied in AR220-1 is not reconcilable to currently expressed definitions of readiness. Although those definitions emphasize output measurement, AR220-1 emphasizes the quantification of inputs and intermediate products--in particular, operationally ready (OR) 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. 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 status of a unit may be dependent upon decisions and conditions that are beyond the ability of the unit to control.

Unit status is essentially the end product of managerial effort at all levels, Army-wide. Therefore, attributing readiness conditions solely to the leadership and managerial efforts of the reporting unit commanders ignores limitations

Table 2
TABLE OF ORGANIZATION AND EQUIPMENT MISSION STATEMENTS

Mission Statement	Type of Unit	T0&E
To close with and destroy enemy forces using fire, maneuver, and shock effect	Tank Co ACS, ACR	17-27H
	Tank Bn, Armor	17-35H
	Inf or Mech Inf	
	Tank Co, Tank Bn Armor; Mech Inf	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	17-55H
	Armored Cav Troop ACR	17-57H
	Armored Cav Troop Sep Light	17-117H
	Inf Brigade	
	Armored Cav Sqdn Arm & Inf Div Armored Cav Troop ACS	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	17-205H
	Air Cavalry Troop ACS	17-207H
	Air Cavalry Sqdn, Airborne Div	17-275H
	Cav Troop ACS, Airborne Div	17-277H
	Air Cav Troop ACC	17-278H
	Air Cav Troop ACC, Air Mobile D Cav Troop ACS, Air Mobile Dac	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	17-385H
	Attack Helicopter Co AHB, ACCB	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	17-58H
	Air Cav Troop Armored Cav Sqdn	17-108H
	Armor or Inf Div	
	Air Cav Troop Armored Cav Sqdn Inf Div	17-208H

which exist within the system The report is . . . not designed to provide an evaluation of commanders The goal is to achieve a rating equal to ALO (Authorized Level of Organization) in personnel and equipment and to train to the highest level possible with resources available to the unit. Terms such as Ready, Not Ready, Incapable of Performing Mission, and Deployable have meaning to war planners, but are meaningless as descriptors of unit achievement [and status].¹

Force readiness is not merely a composite of unit readiness. 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 armored units does not have sufficient guidance from current measures to *project* the effect of varying resource levels on output. A battalion is not even required under AR220-1 to report on the status of various battalion assets that contribute significantly to battalion output and sustainability--for example, the battalion's prescribed load list (PLL).

Finally, the current readiness measures lack specificity in the kinds of military actions the unit can undertake, 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?"

PREVIOUS STUDIES ON READINESS RELATED PROBLEMS

The issues of measuring readiness and the interaction between resources and output for armored units are long-standing ones. In

¹AR220-1, *Unit Status Reporting*, 15 June 1978, p. 2.

Appendix A we identify and briefly review some recent studies on armored organizations, operations, and readiness. Most of these studies dealt with the status of resources or of intermediate products such as operationally ready (OR) tanks. Only a few touched upon the operational context of mobilization, deployment, and employment, or on the measurement of output or readiness in a specific operational context. It is in this latter area that we concentrated our efforts.

PLAN OF THE REPORT

With the preceding material on readiness measurement issues as background, the remainder of this report is organized as follows: In Section II we conceptualize a readiness index based on output under specific conditions of employment and deployment. In Section III, we describe the particular tool we used, the TSAR/AURA simulation model, to relate inputs (resources) to our measure of output. In Section IV, we present the results of applying the TSAR/AURA model to a single armored battalion. Section V discusses some policy and research implications of our results for resource and readiness managers.

II. CONCEPTUALIZING ARMORED UNIT READINESS

PROPERTIES OF A READINESS MEASURE

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 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 the conditions under which the unit must perform its mission change or whenever the time period over which the unit's product or service is measured changes.

Earlier we said that an *ideal* readiness measure should be output-related and time-conscious. We can describe what we mean more precisely. To construct a measure of readiness for armored units, we believe one must deal with four questions.

- What is the precise unit of output of the armored unit?
- Under what circumstances is the unit's output being measured?
- What time period, e.g., 7 days, 30 days, is to be used in measuring the output?
- When can the unit begin producing output after mobilization?

We will deal with each of these questions in turn.

Output

The problem of defining 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). Army maneuver units are designed to be used as a part of a combined arms team. In this respect, the readiness assessment problem for maneuver units 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 armored units perform

a wide variety of battlefield assignments is not necessarily a handicap so long as the analyst is specific about which element of the output vector is being measured.

In peacetime, armored 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. In other words, an operation is a sequence of tasks performed in accordance with tactical doctrine and the best judgment of the unit commander. An operation is completed when the objective is seized (on attack) or when a new position is established (on active defense). When these operations are linked--that is, replicated singly or in "packages"--they form 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.

Distinction Between Readiness and Capability. 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*. Capability and readiness are, however, closely related: In the simplest scheme, capability is a function of readiness, the effectiveness of individual weapon systems attainable in the field, the number of units, and the efficacy of doctrine.

Specific Operational Capabilities. We have used the term *specific operational capability* (SOC) to describe each type of conceptual operation used in the above definition of output. A SOC is determined by a usage profile and special conditions of employment. A condition of employment is considered special *only if* it mandates the use of special equipment or requires special training. In general, both the usage

profile and special conditions will vary depending on the general scenario of employment. For example, one would expect distances, terrain, and weather during combat operations in the Middle East to be rather different from those in Central Europe and those in CENTAG to be different from those in NORTHAG (although clearly less so). Each SOC should be related to an oplan insofar as the quantitative specification of the SOC's time-dependent assumptions is concerned. Each SOC should also identify the operation-essential subsystems and training requirements. For example, if a SOC calls for night operations by armored 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 SOC's for armored units are discussed below.

Mass. Tanks are employed in mass, with platoons generally being the smallest maneuver unit. Our output measure could be specified for platoon-sized units, company-sized units, and so on. The output would, in general, not be scaled in a linear fashion because the relationships underlying large scale combat are not linear.

Circumstances

The circumstances under which an armored unit is expected to fight must be assessed *before* one can determine readiness. Put differently, before we can determine unit readiness, we must ask: "Ready for what?" Armored units that are ready to support operations in the Middle East may be inadequate to support operations in Central Europe. Reasons may include a lack of specific training, insufficient material resources to support the volume of fire needed in Central Europe, or the need for specialized equipment to engage Soviet armored forces. Because each unit is designed to generate a product that contributes to some oplan, a readiness measure must be responsive to the employment and logistic concepts of that plan.

Currently, oplans for Europe provide detailed information on deployment schedules, logistics, and opposing forces. These data, however, are generally not sufficient to assess readiness and must be supplemented not only with planning data from such sources as the *Army*

Planning Factors Data Book, but from a wide variety of single-focus studies as well.

In particular, to assess the readiness of armored units in a given oplan, one must specify the *time-dependent assumptions* concerning:

- attrition (temporary and permanent)
- consumption rates (all resources)
- maintenance task lengths under realistic conditions
- movement rates (distances and times)
- resupply schedules and quantities (all resources)
- management of maintenance work loads
- diurnal cycles (operations, resupply, maintenance)
- personnel fatigue and efficiency
- unit rotation and reconstitution
- other pertinent factors.

Some of these will be SOC-specific; some will be oplan-specific. Other assumptions will have to be made on the basis of policy decisions or military judgment.

The forthcoming revision of the *Unit Status Reporting* (AR220-1) recognizes that readiness must be oplan-related. In that revision, POMCUS 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.

Sustainability

The time over which one chooses to measure readiness brings in sustainability. A unit that may be ready 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 measure must specify the time period (and average rate) 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 measurement. For example, one might want to assess the readiness of a battalion to operate for 15 days using its own and brigade support assets, but one would probably want to assess the readiness of a division to operate for 60 days using organic and theatre support assets.¹

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, the analyst must specify when the unit is expected to begin operations.²

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 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 a SOC, an oplan, DA policy, or explicit DA assumption, it is possible to define a readiness index. Let $q_{ij}^k(t;m)$

¹The reason is straightforward. A division might be continuously engaged for 60 days, but an individual battalion within it probably would not be.

²AR220-1 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 24 hours.

be the rate of output with mass m for the i^{th} SOC under the j^{th} opplan of the k^{th} 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 i^{th} SOC under the j^{th} opplan by the k^{th} unit produced between τ and $\tau + T$ is given by

$$Q_{ij}^k(m, T, \tau) = \int_{\tau}^{\tau+T} q_{ij}^k(t; m) dt. \quad (1)$$

The rate of output of the k^{th} unit is a function of the resources consumed by the unit. Let $x_1^k(t)$, $x_2^k(t)$, ..., $x_n^k(t)$ be that set of resources--manpower, equipment, spares, POL, munitions, and so on--consumed by the k^{th} unit. Then the left-hand side of Eq. (1) is more aptly written as

$$Q_{ij}^k(m, T, \tau) = Q_{ij}^k(x_1^k, x_2^k, \dots, x_n^k; m, T, \tau).$$

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

$$R_{ij}^k = \frac{Q_{ij}^k(x_1^k, x_2^k, \dots, x_n^k; m, T, \tau)}{Q_{ij}^o(x_1^o, x_2^o, \dots, x_n^o; m, T, \tau)}. \quad (2)$$

In other words, a simple readiness index for the k^{th} unit is its output *relative* to a reference unit. The idea of standardizing on the output of a reference unit is that we believe commanders will have a greater appreciation for the readiness 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 have "a feel for." For example, one might choose a unit with its full TO&E

complement of manpower and equipment, unconstrained ammunition, POL resupply, 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. Alternatively, the reference unit could be defined not with unconstrained spares, but with a PLL or ASL defined by the MERPL.¹

As a readiness index, Eq. (2) does not take into account two further considerations. First, for a particular SOC, the *utility of output* at time t might grow faster or slower than the *output itself*. Second, within a particular opplan, 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 index for the k^{th} unit as

$$R_{ij}^k = \frac{\int_{\tau}^{\tau+T} U_{ij}[q_{ij}^k(t, m), t] dt}{\int_{\tau}^{\tau+T} U_{ij}[q_{ij}^0(t, m), t] dt}, \quad (3)$$

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

Advantages of Proposed Index

The readiness 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, the units might not be. As a

¹MERPL stands for Mission Essential Repair Part List.

result, the proposed index permits the management of resources to achieve various readiness 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 level when relative scarcities change.

Relationship of Readiness and Resource Requirements

Resource requirements are theoretically related to readiness because the same relationship of inputs to output used to compute the readiness index, Eq. (2) or Eq. (3), should be used to compute resource requirements. Such a computation would involve, say, maximizing Q_{ij}^k subject to a budget constraint. Although this procedure would lead to an optimal mix of resources for the unit, it is an oversimplification of the problem. The output measure refers only to a specific operational capability (SOC) in a particular oplan. The problem remains of aggregating over SOC's and oplans for the individual unit, and then "rolling up" resource requirements to the theatre or world-wide level. Because resource requirements must take into account the distribution and redistribution of many assets through many "pipelines," they cannot be treated superficially. Once these problems are overcome, however, the link between readiness measurement and requirements should be operationally as well as theoretically established.

SPECIFIC OPERATIONAL CAPABILITIES FOR ARMORED UNITS

Earlier we stated that a SOC is defined by a usage profile and special conditions of employment. We intend here to elaborate on these concepts for armored units. A usage profile specifies the quantitative dimensions of the SOC; the special conditions of employment specify the SOC-essential equipment and training.

Number of Distinguishable SOC's

Table 3 illustrates three SOC's that might be of interest to, say, USAREUR planners. The particular attack SOC in this illustration is described by the attack usage profile (to be illustrated later) and the combination of special conditions listed. Those special conditions

Table 3
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 fording	Yes	Yes	No

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 3, the unit must be prepared for continuous operations in a CBR environment in urban terrain only.

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 armor 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 SOC's can increase rapidly. Even with only three usage profiles and five special conditions of employment as shown in Table 3,

there are 96 distinguishable SOC's. In general,

$$\text{Number of distinguishable SOC's} = \left(\text{Number of usage profiles} \right) 2^{\left(\text{Number of special conditions} \right)}.$$

(3)

In Eq. (3), the term 2^x represents the number of yes-no combinations with x special conditions of employment. With five such conditions, there are 32 SOC's with the attack usage profile, 32 SOC's with the active defense usage profile, and so on. We believe, however, that most of these SOC's collapse into a significant few, and of these, many would be covered by the same Army Training and Evaluation Program (ARTEP).

The Attack SOC Usage Profile

An attack SOC usage profile for an M60A1 armored battalion is illustrated in Fig. 1 and Table 4. The attack SOC depicted in Fig. 1 resembles a FRAG order: The battalion is to move to an assembly area beginning at 6:00 a.m., penetrate enemy lines, seize an objective several kilometers away, and consolidate its position. The time to complete each task is shown in Fig. 1 and represents the *expected value*. The consumption rates shown in Table 4 represent the typical expenditure of ammunition and fuel by an individual tank; crossleveling at the end of the operation would even out any variations.

In this usage profile, although the objective is only 15 kilometers behind the FEBA, tactical maneuvers by the typical tank result in 40 kilometers of movement. The fuel consumed during the operation and subsequent recycling is about 28 percent of the full fuel load.¹ Note also that about 50 percent of the tank's 105mm ammunition load is fired by the crew during the operation.

¹The figures for fuel consumption per kilometer or per hour represent the best information we could obtain from the 1st Cavalry Division, Ft. Hood, Texas.

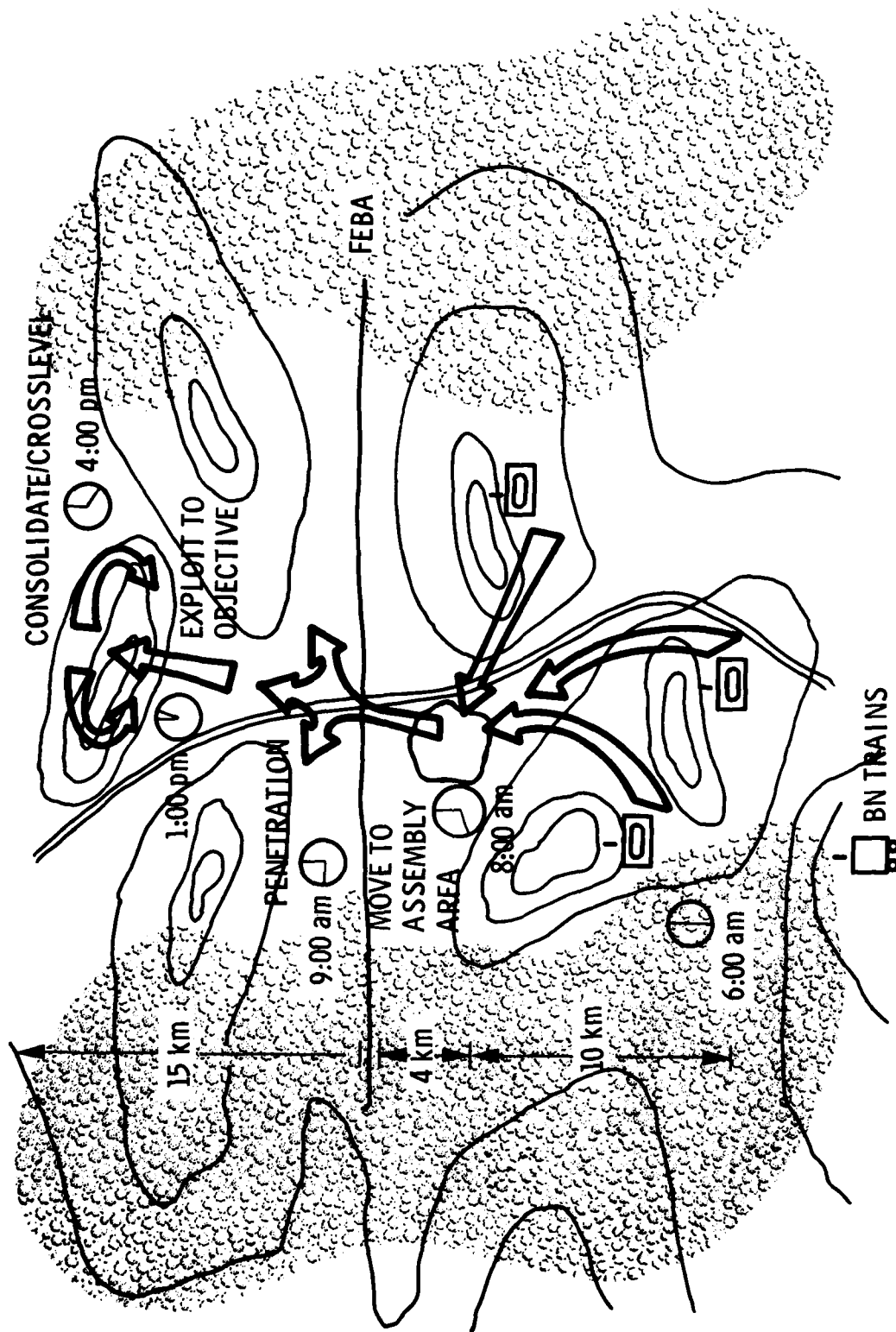


Fig. 1--ATTACK SOC MISSION DURATION

Table 4
ATTACK SOC CONSUMPTION RATES

MISSION COMPONENT	DISTANCE (KM)	AVERAGE		ENGINE TIME (HRS)	FUEL (GAL/KM) (GAL/HR)	FUEL (GAL)	AMMUNITION (RDS)		
		SPEED (KM/HR)	TIME (HRS)				105MM	30 CAL	50 CAL
MOVEMENT TO ASSEMBLY AREA	10	20	2.0	2.0	1.30	13.0	0	0	0
PENETRATION ASSAULT ROLL FLANKS	4	4	1.0	1.0	2.25	9.0	20	500	200
EXPLOIT TO OBJECTIVE	40	10	4.0	4.0	1.30	52.0	12	500	100
CONSOLIDATE	1	4	1.0	1.0	1.30	1.3	0	500	0
CROSSLEVEL	0	0	2.0	2.0	5.0	10.0	0	0	0
RECYCLE				4.0	5.0	20.0			
TOTAL	55		10.0	14.0		105.3	32	1500	300

III. ARMORED UNIT READINESS ASSESSOR (AURA)

In the absence of a readily available Army model for evaluating the relationship of resources to output for armored units, we adapted a Rand model under development. This model, called TSAR (Theatre Simulation of Airbase Resources), was funded under Project Air Force. We used the name AURA (Armored Unit Readiness Assessor) to describe the adaptation of TSAR to armored 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.

In our simulation we have used only the modules that apply to the battalion echelon and below. We have not dealt with the interactions of a battalion team with brigade, division, and corps support levels in this initial simulation of unit resource interactions. Subsequent simulations will develop the model's capabilities to examine combined arms and support structure outputs.

Although the TSAR/AURA simulation model is a versatile and powerful tool for the readiness problem, none of the conceptual work described in Section II is model-specific. In operationalizing the readiness 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 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

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

²In 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).

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 Repairable 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 repairables, 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.

IV. APPLICATION OF AURA TO AN M60A1 ARMORED BATTALION

SCOPE, SOURCES OF DATA, AND ASSUMPTIONS

In our simulations we made a number of assumptions and imposed a number of groundrules that require exposition. First, and most important, the simulation involved only battalion-level resources--that is, we limited ourselves to determining what output an armored battalion with 54 M60A1 tanks could potentially produce using its own resources only. This is equivalent to the assumption that maintenance support from higher echelons would not be available in time to support the battalion's operations.

Second, with respect to maintenance, we assumed that maintenance task times and frequencies for the M60A1 were those in the M60A1 Contingency Maintenance Allocation Chart (CMAC) as published in FM42-9-1.¹ 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. For each failure, we determined whether the tank would be immobilized and would consequently need to be towed by the battalion's M-88s or M-578s. Appendix B describes the shops or work centers in the simulation, the number of separate tasks each shop can perform, MOSs assigned to each shop, and the basis for the failure probabilities.

If a part was not available from the battalion's PLL, maintenance personnel were instructed to cannibalize, *first*, an unserviceable tank with "holes" and *second*, an unserviceable tank 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.²

¹These 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.

²As one general officer we spoke with said, "The first time a part is pulled, it's broken pulling it out. The second time it's pulled out okay, but it's broken putting it in. The third time everything works fine."

Third, we assumed that the battalion's TO&E equipment was fully "mission capable" at the start of the simulation, which we allowed to run for 15 days.

Fourth, we chose to simulate the attack SOC described at the conclusion of Section II. The duration of the attack SOC is provided in Fig. 1 and the consumption rates in Table 4. Because of the duration of the attack SOC, the battalion had to be prepared to fight and recycle in darkness. The attack SOC usage profile calls for the battalion to mass at a specified time. We chose the platoon as the unit of mass so daily output for this SOC is just the number of five-tank platoons that could be massed at the designated time.¹ We chose the platoon because it is the smallest organized unit. Appendix C provides further justification of this choice.

Finally, we parametrically varied the overall (gross) attrition rate using 0 percent, 10 percent, 20 percent, and 30 percent per operation to test the sensitivity of our results to this variable. Because the attrition rate is an important variable, we provide more detail below on why we chose the 0 to 30 percent range and how the gross attrition rate was apportioned over the alternative outcomes.

One final comment is needed. Although TSAR/AURA does not model the enemy explicitly, it does model the effect of enemy actions. In particular, enemy actions cause the battalion to lose *resources* and *time*. In our simulation the resources lost were restricted to those tanks (and crews) that were destroyed or damaged during an operation. No enemy attacks on the battalion trains or maintenance areas were permitted; hence no maintenance personnel, or stocks of spares, POL, or ammunition were lost to enemy action. The time it takes the battalion to take the objective was made a random variable to simulate lighter or heavier than expected enemy resistance. Although Fig. 1 shows an expected elapsed time from penetration to objective of four hours, the simulation value for this time on a given operation was drawn from a uniform distribution between one and seven hours.

¹The simulation allowed each company to send out one four-tank platoon if it could not make a full five-tank platoon. The simulation also allowed a platoon to be sent out up to one hour after the battalion was supposed to mass.

Gross Attrition Rate

In choosing a range of gross attrition rates per operation, we sought guidance from comparable rates used in major DA models, in particular the Concepts Evaluation Model (CEM) used in the annual Omnibus and Total Army Analysis (TAA) exercises. CEM computes combat losses for a number of major Army weapon systems, including the M60A1 tank. A useful way to depict these combat losses is to compute the fraction of on-line items¹ that are destroyed or damaged on each day. Figure 2 shows the daily combat loss (CL) rate for the M60A1 from the CEM baseline European scenario. The daily CL rate peaks at the beginning of the third week of the war; at that point, about *one-half* of the on-line M60A1s are being lost each day.

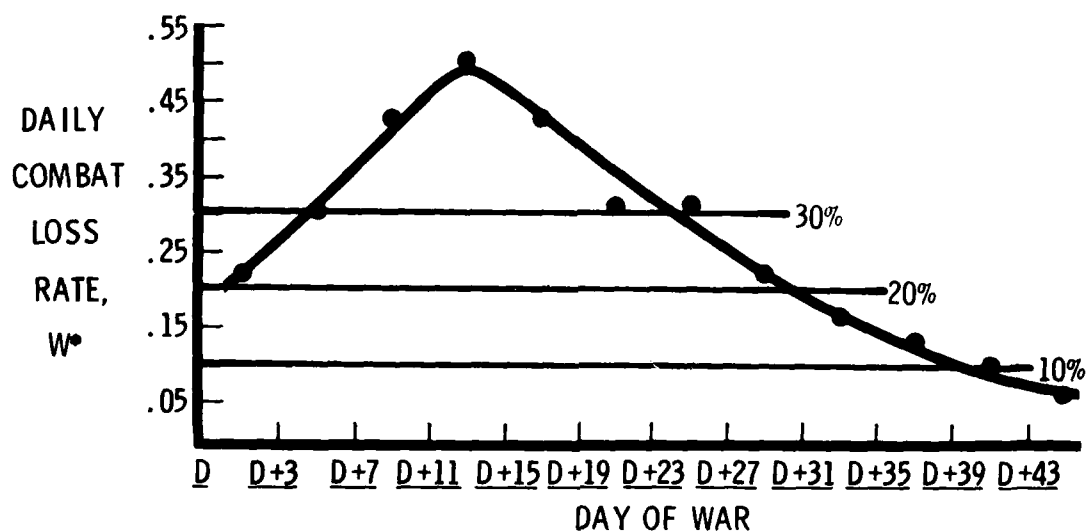


Fig. 2--M60A1 COMBAT LOSS RATE FROM CEM BASELINE SCENARIO

¹On-line items include both engaged and non-engaged items that are in the field. Theatre reserve items and items undergoing major repair and maintenance are not regarded as on-line.

The CL rate in CEM is an endogenous variable and results from all combat losses incurred by all USAREUR forces. The CL rates do not reflect a particular combat mode but rather a changing amalgam of four modes--attack, defense, delay, and inactive. Thus, we did not have an attack CL rate from which we could scale the gross attrition rate for the attack SOC. Furthermore, the CL rate attrition measure is different from that needed in our simulation. TSAR/AURA requires an attrition rate per operation--that is, an attrition probability per tank per operation. Fortunately, the two attrition measures are related as shown in Eq. (4).¹

$$\text{Daily CL rate} = (\text{Attrition rate})(\text{Operations per day}) . \quad (4)$$

Because in the attack SOC we simulated, the battalion conducts only one operation each day, the attrition rate and the associated battalion CL rate are identical. As shown in Fig. 2, the attrition rates we chose--from 0 percent, for a no-attrition baseline, to 30 percent--cover all but the peak loss period of the CEM simulation.²

Battle Damage Probabilities and Repair Times

Each gross attrition rate was divided according to the conditional probabilities shown in Fig. 3. 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 kills used in the simulation came from the same CEM baseline European scenario mentioned above in connection with the CL rates. Unlike the CL rates, however, that ratio is remarkably stable over the first 45 days of the war.

¹In continuous time $w(t) = a(t)s(t)$, where $w(t)$ is the instantaneous CL rate, $a(t)$ is the instantaneous attrition rate, and $s(t)$ is the instantaneous operations rate.

²Historical personnel loss rates are typically higher on attack than on defense, which may account for the peak period if the same is true for equipment losses. For more information, see U.S. Department of the Army, *Staff Officers Field Manual, Organizational, Technical and Logistics Data*, FM101-10-1, July 1976, Tables 5-8 through 5-11, pp. 5-8, 5-9.

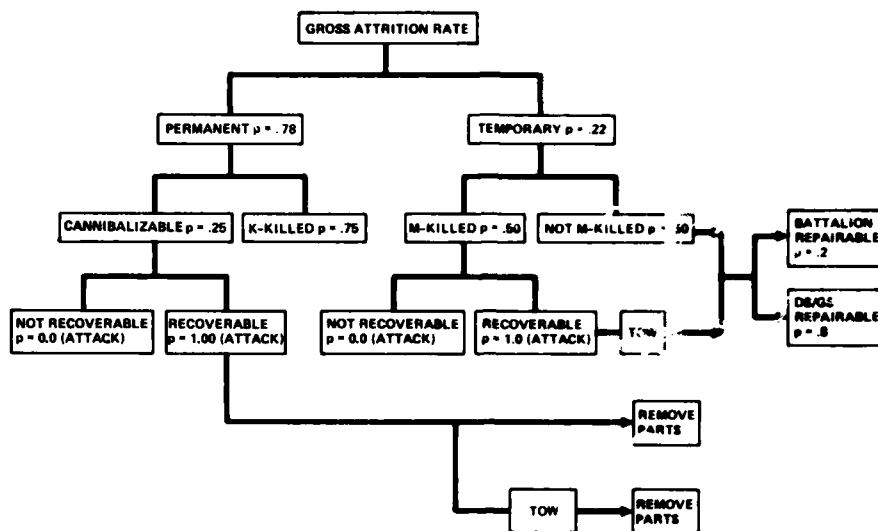


Fig. 3--ATTRITION AND BATTLE DAMAGE PROBABILITIES

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* all such M-killed tanks were recoverable because the FEBA was presumably moving forward, thus leaving M-killed tanks in friendly territory.¹

We further assumed that of all the temporarily killed M60A1s that returned to the battalion maintenance area, only 20 percent were repairable with battalion resources only; the remaining 80 percent we assumed

¹The same optimistic recovery assumption was made for tanks that could be cannibalized.

required some form of DS/GS support. The battalion level repair of a battle-damaged M60A1 required a variety of maintenance skills--track vehicle mechanics, turret mechanics, and welders--and took an *average* of 8.75 hours elapsed time to complete.¹ These percentages and elapsed times are consistent with recent tests at the Army Ordnance Center.²

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. 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 *net* lethality of today's antitank weapons.

Training

The simulations we ran can best be described as *neutral* with respect to training in the sense that in all runs the performance of maintenance personnel and weapon crews was assumed equal. The training factor did not compound the effects of resource constraints. However, the *level* of training was not arbitrary. Maintenance personnel had to be proficient enough to perform the operation-essential maintenance tasks within the average times specified in the M60A1 CMAC; tank crews had to be proficient enough to complete each task in the attack SOC, which could be likened to the completion of a similarly constructed Level 1 ARTEP.

Different types of training deficiencies could be modeled in TSAR/AURA; for example, CMAC task times could be made much longer. Another type of training deficiency where only some of the personnel in each MOS were qualified is equivalent to having manpower shortages in those MOSs.

¹Actual elapsed time in the simulation ranged from five to ten hours.

²U.S. Department of the Army, *CODAM Final Project Report*, U.S. Army Ordnance and Chemical Center and School, Aberdeen Proving Ground, Maryland, 1979 (unpublished).

A Comment on These Assumptions

Although the limitations we placed on the simulation and the assumptions we made have important effects on the results, had more accurate inputs been available, the TSAR/AURA simulation could have handled a wide variety of alternative assumptions without difficulty.

SIMULATION COMPLEXITY AND STRATEGY

Using the CMAC for the M60A1, we entered 224 separate battalion-level maintenance tasks into the TSAR/AURA maintenance jobs "library." These tasks collectively required 175 identifiable parts or kits. Maintenance took place in 23 separate work centers or shops and required seven distinguishable types of maintenance personnel. In addition to the 54 tanks, TSAR/AURA kept track of battalion's M-88 and M-578 armored recovery vehicles (ARV).

Manpower

TSAR/AURA kept track of and controlled over 300 maintenance personnel and crewmen when we simulated a full TO&E armored battalion.¹ The individuals not modeled by TSAR/AURA were either officers or personnel in the Combat Support Company or Headquarters Company who were in the battalion's scout platoon, mortar sections, or transportation sections. These personnel were not directly connected with the M60A1 weapon system.

Simulation Cases

Our simulation strategy was to run cases in which first manpower levels and spares were varied and second, POL and ammunition were varied. Table 5 shows the cases that were simulated. The base case, which we used later to calculate the readiness index, Eq. (2), consisted of a full TO&E armored battalion with *unconstrained* POL, ammunition, and spares. By unconstrained, we mean that the battalion held a stockpile of each consumable sufficient to cover all their resource requirements

¹A full TO&E armored battalion contains 533 individuals. See Appendix B for further information.

Table 5
ATTACK SOC SIMULATION CASES FOR ARMORED BATTALION

Cases		Resources				
Number ^a	Name	POL	Ammunition	Spares	Manpower	End Items
1-4	Base	u	u	u	100% TO&E	No Replacement
5-8	C-2 in Manpower	u	u	u	83% Maintenance Manpower 77% Crews	No Replacement
9-12	C-3 in Manpower	u	u	u	70% Maintenance Manpower 77% Crews	No Replacement
13-16	Major Parts Shortage	u	u	2/67Δ PLL ^b	100% TO&E	No Replacement
17-20	C-3 in Manpower and Parts Shortage	u	u	2/67Δ PLL	70% Maintenance Manpower 77% Crews	No Replacement
21-24	Ammunition Constrained	u	667 Rds/Day	u	100% TO&E	No Replacement
25-28	POL Constrained	1350 Gals/Day	u	u	100% TO&E	No Replacement

^aEach set of resources was run four times, using each of the four gross attrition rates.

^b2/67Δ = 2nd Battalion, 67th Armored Regiment.

u = Unconstrained.

at the attack SOC consumption rates. In all cases including the base case, no end items (tanks) were replaced during the 15-day simulation.

Following the base case, we ran two cases in which maintenance manpower and crews were reduced (hereafter referred to as the *C-2 in manpower* and *C-3 in manpower* cases). Consumables were left unconstrained. Next we restored the manpower to the full TO&E level, but gave the battalion the PLL of an actual unit, which considerably reduced its access to spares. The PLL used in the simulation reflected the actual status of the M60A1 parts stockage for the 2nd Battalion, 67th Armored Regiment, 2nd Armored Division, as of 13 November 1978.¹

We next ran the case in which the maintenance manpower and crews were reduced to the C-3 in manpower level *and* spares were constrained to those found in the 2nd Battalion, 67th Armored Regiment PLL. In these cases, POL and ammunition were always left unconstrained.

In a separate set of runs, we simulated the effect of POL and ammunition shortages. Manpower was set at the full TO&E level and spares were unconstrained; but in one case we gave the battalion a stock of ammunition equal to an average daily consumption rate of 667 rounds, and in another case we gave the battalion a stock of POL equal to an average daily consumption rate of 1350 gallons.

SIMULATION RESULTS: MANPOWER AND SPARES INTERACTIONS

Recall that the attack SOC calls for the entire battalion to be massed at a particular time each day for an assault on successive objectives. Output for the battalion according to the readiness definition is the number of platoons that can be so massed *given the resources available to the battalion*. Fig. 4 shows the output--the number of "platoon attacks" that can be mounted each day of the simulation--for the base case. The percentage above each of the four curves is the gross attrition rate used in that run. The number in

¹The entire PLL consisted of 296 line items with a nominal value of \$41,810.86. However, our requirement to limit the parts made available in the simulation to only those in the CMAC resulted in the loading of only 37 out of a possible 94 M60A1 line items in the 2nd Battalion's PLL. The total value of the 37 line items was \$17,584.

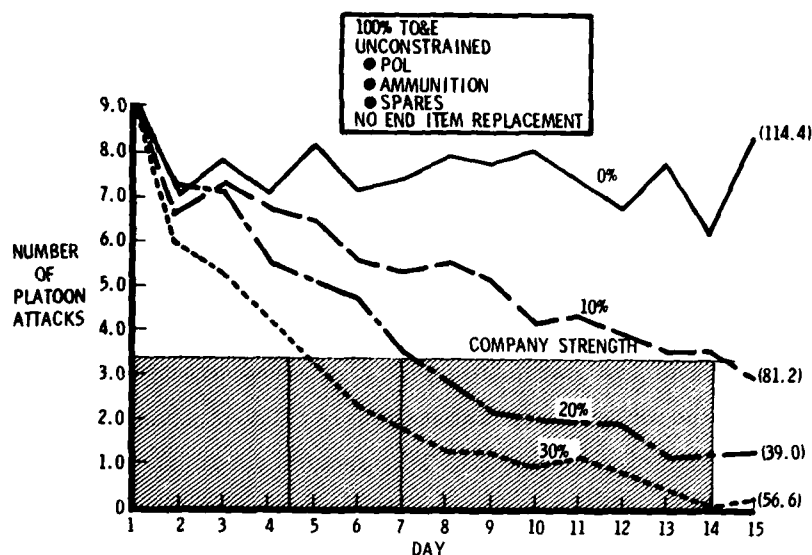


Fig. 4--DAILY OUTPUT FOR BASE CASE

parentheses at the end of each curve is the *cumulative* output over the 15 days of the simulation, which was used in our readiness index. The curves were based on the average daily output of five independent trials. Appendix D provides the numerical detail including standard deviations.

The zero percent curve shows the output potential resulting from the *inherent reliability of the pre-RISE M60A1*. At any positive rate of attrition, the battalion gradually decreases in strength and output. As a benchmark we recorded in the figure when the battalion reaches company strength. At a gross attrition rate of 30 percent, not unreasonable for a Central European scenario, the battalion is reduced to company strength in four to five days (96 to 108 hours).¹

¹This is remarkably consistent with the U.S. Army Ordnance Center cannibalization study which showed the typical battalion can last about 89 hours. For more detail, see U.S. Department of the Army, *Collection, Classification, Cannibalization, and Field Expedients*, U.S. Army Ordnance and Chemical Center and School, August 1975.

When we ran the reduced manpower levels (C-2 in manpower and C-3 in manpower), the daily output of the battalion was similar to that in the base case, and the cumulative output was only slightly reduced from that of the base case (see Appendix D for numerical details). We concluded that given the unlimited, instantaneous access to spares, a situation not likely to be encountered by many battalions, the reductions in manpower did not appreciably affect battalion output.

Figure 5 shows the daily output of the battalion for the four gross attrition rates when the battalion was manned at the full TO&E level, but had the PLL of the 2nd Battalion, 67th Armored Regiment. Daily output and cumulative output are substantially lower than that for the base case at low attrition rates (0, 10 percent), but at high attrition rates (20, 30 percent), daily and cumulative output are only moderately less than that for the base case. We concluded that at high attrition rates, the battalion was able to conduct an effective cannibalization program. First, with high attrition the number of tanks that might need work decreases over time, releasing maintenance personnel to do cannibalization. Second, there are more damaged tanks from which parts can be removed.

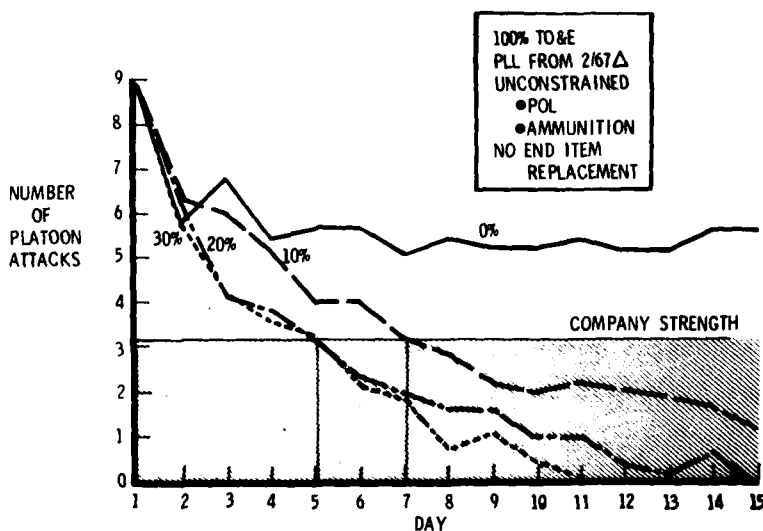


Fig. 5--DAILY OUTPUT FOR PARTS SHORTAGE CASE

The last case we ran with manpower and spares varied is depicted in Fig. 6. In this case, manpower was reduced to the C-3 in manpower level, and the 2nd Battalion, 67th Armored Regiment PLL represented the spares available to the battalion. This case contains the two resource constraints that were investigated separately up to this point. As the figure shows, daily and cumulative output are substantially lower than that for the base case at low attrition rates and are moderately lower even at the 30 percent attrition rate. One reason for this, we concluded, was that the battalion does not have sufficient manpower to take maximum advantage of cannibalization.

Effects of Resource Constraints on Output

Because it is difficult to directly compare the different resource sets in Figs. 4, 5, and 6, we have reproduced the daily output of the battalion at the 20 percent rate of attrition for each of those sets. As Fig. 7 shows, the base case and the C-3 in manpower case are similar, although the base case results in slightly greater output as would be

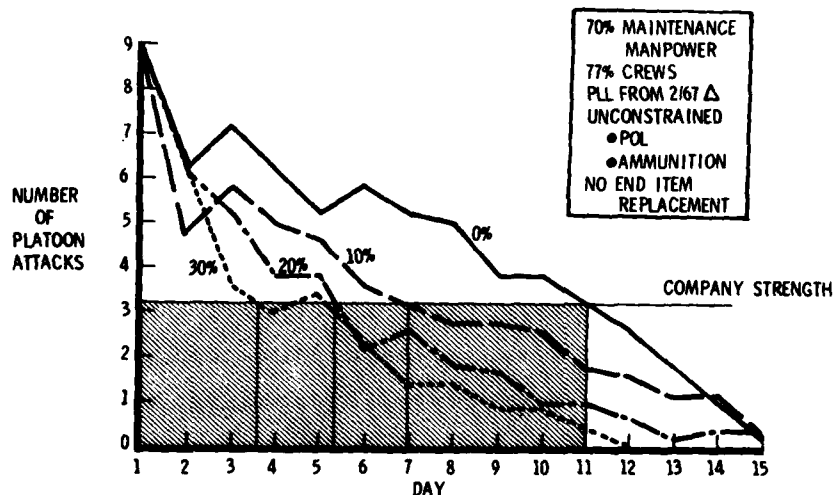


Fig. 6--DAILY OUTPUT FOR MANPOWER AND PARTS SHORTAGE CASE

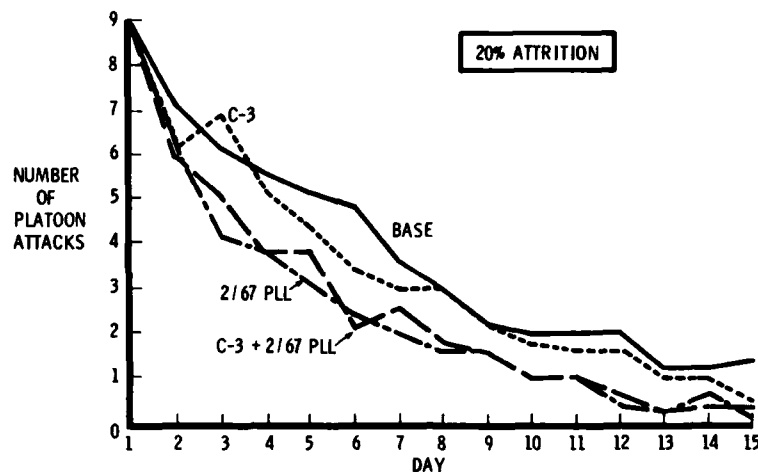


Fig. 7--DAILY OUTPUT FOR FOUR CASES AT 20 PERCENT ATTRITION

expected. The parts shortage case (labeled 2/67 PLL) and the parts shortage plus C-3 in manpower case (labeled C-3 + 2/67 PLL) show a marked decrease in daily output.

The effect of the parts shortage is vividly displayed when cumulative output over 15 days is compared. For the four attrition rates, Fig. 8 shows the cumulative output for the base, the C-2 in manpower, the C-3 in manpower, and the parts shortage plus C-3 in manpower cases. The percentages shown near the bar graphs are the attrition rates. The pattern is almost predictable: First, the attrition rate exerts a powerful effect on the aggregate level of output of the battalion. Second, at low attrition rates, cumulative output decreases slightly or remains about the same as manpower is reduced, but it collapses when the parts shortage is added as well. Third, at high attrition rates and as manpower is reduced, cumulative output decreases slightly or remains about the same, but it declines relatively less when the parts shortage is included.

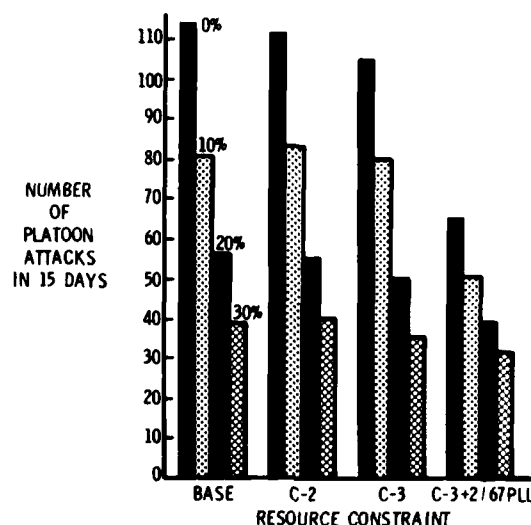


Fig. 8--CUMULATIVE OUTPUT FOR FOUR RESOURCE SETS

Effect of Resource Constraints on Material Condition

As previously mentioned, TSAR/AURA keeps track of the material condition of each tank in the battalion. In Figs. 9 and 10, we show the number of tanks remaining after 15 days and the number of tanks available for combat after 15 days for the same four resource sets as in Fig. 8. The percentages shown near the bar graphs are the respective attrition rates. At a 0 percent attrition rate, the battalion always has its 54 tanks. As the attrition rate increases, the number of tanks remaining decreases for a given resource set.

Across resource sets, however, there is another story. For a given attrition rate, the number of tanks remaining stays about the same as manpower is reduced, but when the parts shortage is added, the number of tanks remaining increases dramatically. The reason for this result is that with the manpower and parts shortage embodied in the fourth resource set, fewer tanks are massed each day for the attack SOC, and therefore fewer tanks are "killed." Of the surviving tanks, some are likely to be NORS and hence unavailable. As Fig. 10 shows, the number of available tanks also decreases as the attrition rate increases for

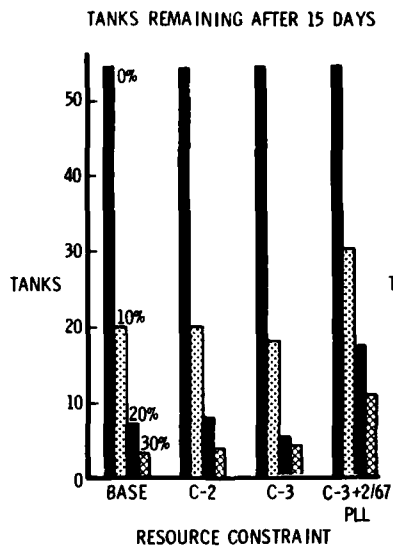


Fig. 9--TANKS REMAINING
FOR FOUR RESOURCE SETS

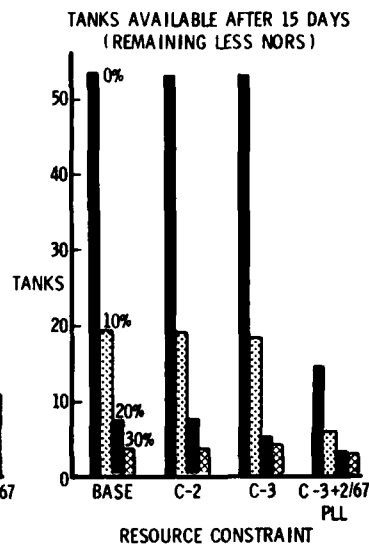


Fig. 10--TANKS AVAILABLE
FOR FOUR RESOURCE SETS

a given resource set. For a given attrition rate, the number of available tanks stays about the same as manpower is reduced, but falls when the parts shortage is included. The relative decline is more severe at the lower attrition rates. In summary, although more tanks remain with the manpower and parts shortage, only a few of these are available for combat.

SIMULATION RESULTS: POL AND AMMUNITION

The simulation results with respect to POL and ammunition shortages can be summarized by reference to Fig. 11. Cumulative output as a function of the attrition rate is shown for three cases: the base case, a case in which the battalion held a stockpile of 10,000 rounds of 105 mm ammunition (equivalent to 667 rounds per day), and a case in which the battalion held a stockpile of 20,000 gallons of fuel (equivalent to 1350 gallons per day). In these latter runs, manpower was at the full TO&E level, while other consumables--spares and POL in the first one, and spares and ammunition in the second--were unconstrained. In other

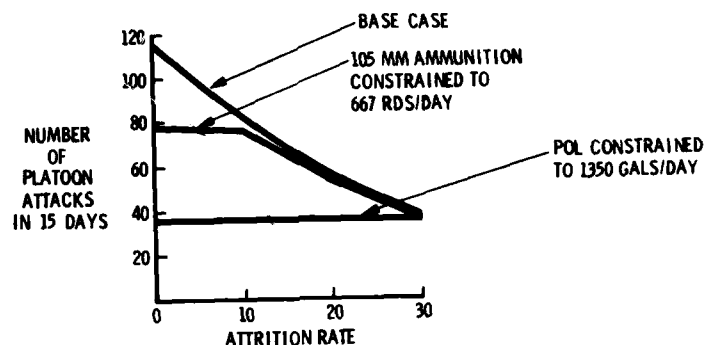


Fig. 11--CUMULATIVE OUTPUT: AMMUNITION AND POL SHORTAGES

words, these latter runs were exactly like the base case, except for either an ammunition or POL constraint.

In the constrained ammunition case, the battalion produces about as much cumulative output as in the base case from a 30 percent down to a 10 percent attrition rate. Below 10 percent, however, the battalion is incapable of producing any more output. At these lower attrition rates, more tanks survive, requiring more ammunition. Although there are available tanks, there is no ammunition to put on them.

In the constrained POL case, only at a 30 percent attrition rate is the stock of fuel sufficient to cover all the tanks that the battalion's other resources can put out. Below 30 percent, the battalion has available tanks but no POL with which to fuel them. Cumulative output never rises higher than that produced at a 30 percent attrition rate. The POL shortage simulated here is obviously quite severe.

THE READINESS INDEX

Using the data from which the curves in Figs. 4 through 6 were constructed, it is possible to compute the readiness index based on Eq. (2) (see Appendix D for the numerical detail to make this calculation). Two examples are depicted in Figs. 12 and 13. In these figures, we have

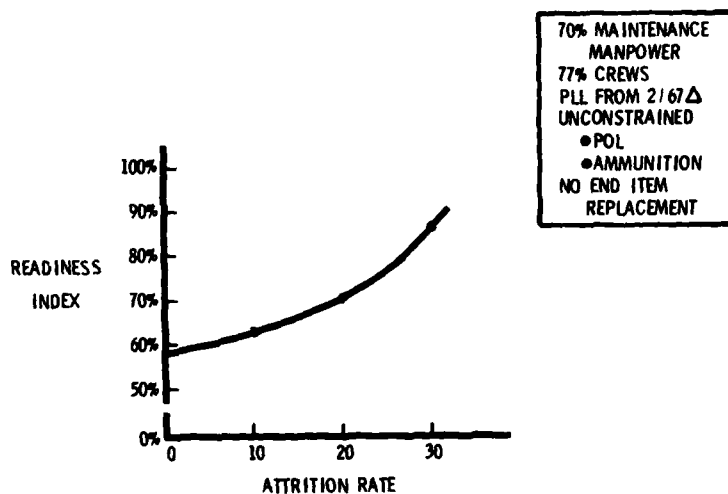


Fig. 12--READINESS INDEX FOR MANPOWER AND PARTS SHORTAGE CASE

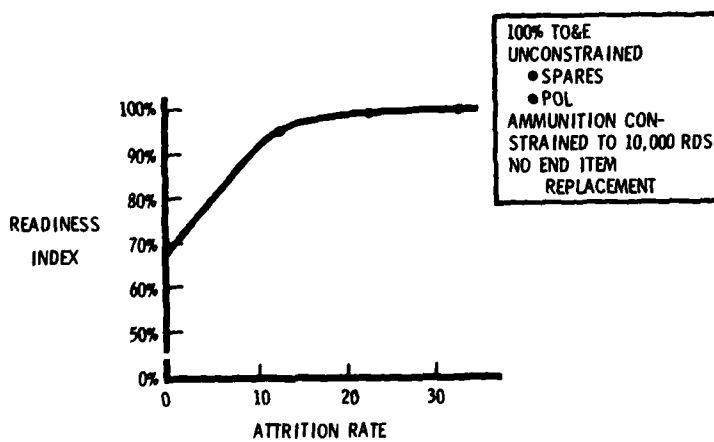


Fig. 13--READINESS INDEX FOR AMMUNITION SHORTAGE CASE

plotted the proposed readiness index--cumulative output over 15 days relative to the base case cumulative output--as a function of the attrition rate for two battalions with two different resource sets. In Fig. 12, we show the proposed readiness index for the battalion that is both C-3 in manpower and has the spares based on the 2nd Battalion, 67th Armored Regiment PLL (see Fig. 6). In Fig. 13, we show the proposed readiness index for a battalion that is identical to the base case battalion, except for its limited stockpile of 105 mm ammunition (see Fig. 11).

The attrition rate is just one of the SOC or oplan parameters we could have chosen as the independent variable in Figs. 12 and 13. Nonetheless the importance of the attrition rate in the assessment of resource readiness is clearly evident in the figures. A word of further caution should be mentioned here. The readiness index in these figures refers only to the attack SOC. For other SOCs, the curves might look entirely different. As a general rule, a battalion's resource readiness index will be higher for those SOCs that intensively use those resources the battalion happens to be relatively well stocked in.

As Fig. 12 shows, the battalion under consideration can produce about 58 percent of the cumulative output of the base case battalion when the attrition rate is 0 percent, but it can produce 84 percent of the cumulative output of the base case battalion when the attrition rate is 30 percent. At high attrition rates the TSAR/AURA simulation suggests that *for the attack SOC*, support resources--spares and manpower--are less important than having OR tanks and crews available at the start. At low attrition rates the simulation suggests that *for the attack SOC*, these support resources are very important and are interactive because spares can substitute for manpower.

The readiness index improves as the attrition rate increases because cumulative output of the well-provisioned base case battalion falls dramatically as the attrition rate increases. The cumulative output of the poorly provisioned battalion depicted in Figs. 6 and 12 also falls as the attrition rate increases, but not nearly so much *in percentage terms* as the base case battalion. Furthermore, although the poorly provisioned battalion may have been hard pressed to support 54

tanks early in the simulated series of operations, it may do quite well when it has to support, say, only a third of that number later in the simulation.

As Fig. 13 shows, consumables for which there are no substitutes--for example, main gun ammunition--must be provided in sufficient quantities to take advantage of the output-producing potential of the battalion's other resources.

The readiness indexes of Figs. 12 and 13 could be converted into discrete measures by applying some agreed-upon breakpoints to the curves. This might be useful for presenting certain kinds of readiness information.

V. IMPLICATIONS FOR RESOURCE AND READINESS MANAGERS

On a conceptual level, this paper provides a way of thinking about readiness for both active and reserve forces that is tied to output under specific conditions of mobilization, deployment, and employment. Second, it demonstrates, albeit in a limited way, a methodology for relating resources to outputs for a specific operational capability.

NEED FOR FUTURE RESEARCH

We view the results just presented as more than illustrative because we used the best data we could find from documented Army sources. However, because more work is needed, we would not recommend policy actions be taken on the basis of the results at this time. We see a definite need to model a combined arms brigade including the DS/GS infrastructure. It would then be possible to test the robustness of our results for a variety of SOC's and alternative time-dependent assumptions, particularly with regard to:

- irregular resupply of consumables;
- enemy attacks on battalion and DS/GS maintenance areas;
- alternative rotation, replacement, and reconstitution policies;
- alternative work load management rules;
- alternative types of training deficiencies;
- different attrition, battle damage, and other oplan assumptions.

The data that are processed by the TSAR/AURA simulation model should be validated, which is not an easy task. It may be possible to use data from previous field training exercises (FTXs) or to develop new FTXs to validate TSAR/AURA.

Finally, because there are a number of possible applications of readiness measurement systems, there is a need to think carefully about

how to design such systems and how to tailor them to various uses. The uses of readiness measures generally fall into two classes: near-term management questions and longer-term resource requirements issues. Each may require different kinds of readiness information, but both are likely to rely on a detailed understanding of the relationship of inputs to outputs.

USES OF READINESS MEASURES

Some near-term management questions that might be addressed in a readiness 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. 14 illustrates an example of currently reported data from the FORSTAT system as it appears in the FORSCOM *Blue Book*. The hypothetical 2nd 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,

DAMP 31802
ALO 1

Xth ARMORED DIVISION
ORGANIC BATTALIONS

UNIT	OVER ALL	STR	MOS	SGD	EOH	EOH PI	ES	ES PI	TNG	TNG WKS	AUTH	OP STR	%	DEPL	%
MANEUVER 2/99 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 SOC 1	XXXX SOC 2		SOC 3		MPLAN SOC 1	XXXX		DPLAN SOC 1	XXXX SOC 2		
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. 14--CURRENT AND POSSIBLE READINESS REPORTS

equipment on hand, and pacing items on hand; but it is C-2 in senior grade fill, equipment status, pacing item status, and training.¹ 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. 14 illustrates the kind of readiness information that could be calculated using the readiness concepts proposed in this paper. The same unit could be rated by its ability to perform various specific operational capabilities under various opplans. 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 SOC1 for *Oplan 9999*, but is only C-3 in SOC2.² The number in parentheses indicates that this unit was C-2 in SOC1 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 opplans and associated SOC's could be rated. The usefulness of this kind of information depends, of course, on the ability of Army decisionmakers to move resources across units in response to readiness deficiencies.

The longer-term uses of readiness measurement systems include (1) the computation of resource requirements for a force over a set of opplans; (2) the evaluation of new weapon systems, particularly with regard to capital-labor tradeoffs; and (3) the evaluation of alternative force structures. Each of these uses requires a great deal of hard thinking about what information is needed, who will use it, and how.

The resource requirements issue was discussed earlier in connection with the computation of readiness (p. 16). The kinds of information in Fig. 14 are not sufficient for the computation of requirements because of the problem aggregating over SOC's and opplans, and then "rolling up" requirements to the theatre or world-wide level. The

¹See Table 1 for the criteria for each category.

²It 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.

issue of evaluating various capital-labor tradeoffs for proposed weapon systems fits easily into the readiness framework because such tradeoffs should be looked at in terms of present value cost for *equal output resource combinations*. The force structuring issue is also closely allied with readiness measurement. Once basic questions are answered, such as: "Does the U.S. want a force that emphasizes surge capability or longer-term sustainability?", a readiness measurement system can help design the appropriate force. In each of these uses, a necessary building block is the ability to translate resources into output, and it was toward this end that the research reported here was conducted.

Appendix A

PREVIOUS STUDIES ON ARMOR FORCES AND READINESS

Measuring readiness and the interaction between resources and output for armored units are long-standing issues. Most recent studies have identified the same problems of resource shortfalls, training deficiencies, and general readiness measurement difficulties. Some of the studies have suggested changes in current management methods and emphasis, but most have suggested only marginal changes in procedures and readiness reporting policies. We briefly review some of these studies below.

GAO REPORT ON ARMORED UNIT READINESS

A critique of Army readiness measurement and resource allocation is contained in a 1976 GAO report that attempted to determine whether armored units were ready to perform their assigned mission.¹ Their report identified the four specific problems. First, armored units were not required to report on the readiness condition of their ammunition. Second, the standards for computing and reporting personnel readiness in AR220-1 *Unit Status Reporting* had been relaxed to the point where units could almost always be reported as combat ready. Third, minor pieces of equipment were averaged with critical major end items, distorting the true material readiness condition of a unit. And fourth, the Army's reporting system allowed the application of judgmental factors by various levels of command, resulting in readiness ratings at the regimental or divisional level that were not always a reliable indicator of combat readiness.

The GAO recommended further that the Army insure that combat units have full crews assigned for all tracked combat vehicles, develop simplified equipment checklists to determine the equipment's serviceability in combat, review its training program, reevaluate the subjective reporting of readiness at combat level, and develop separate means of rating

¹General Accounting Office, *The Readiness of U.S. Army Units in Europe*, B-146896, Washington, D.C., July 1976.

combat and support assets. In addition, GAO recommended that USAREUR specifically identify unserviceable basic load ammunition, rehabilitate or replace it, make certain that combat loads are readily available to armored units at all times, and have material handling equipment available for moving ammunition to consumption points.

The Army addressed many of these problems in revising AR220-1 by improving the standards for personnel readiness and by reporting on major *pacing* items.¹ However, an input-output approach to readiness measurement was not developed, nor was a revision made in reporting methods to highlight this relationship.

WSEG-IDA REPORT

OSD initiatives to examine readiness reporting were also stimulated by the GAO report. In response to an OSD request, the Weapon System Evaluation Group (WSEG) addressed armored unit readiness along with other general purpose units. The objective was to show to what extent the readiness of major types of U.S. combat units was related to the resources allocated to maintain readiness. This report was to be followed by a Phase II study that examined U.S. force readiness in the context of a major European war; Phase II was not undertaken.

The WSEG study accepted the JCS definition of unit readiness as the degree to which it is capable of performing the operations for which it was organized or designed. Study effort then focused on assessing the readiness of unit weapon systems and the ability of unit personnel to use the systems effectively.

With regard to the first objective, the WSEG study concluded that unit resource allocation policies for assuring equipment readiness were consistent with both the equipment characteristics and the operational readiness goals then established by the Army. However, equipment readiness varied from unit to unit depending on personnel transiency and local perceptions of policy.

¹For example, the tank is the pacing item for armored battalions.

The second objective provided a more difficult task. The study assumed that unit readiness could be determined by relating TRADOC-developed training events to readiness. These training events consisted of expertly designed individual and unit exercises that had to be completed under specific environmental and time constraints (day-night, time-distance route marches, target acquisition times, etc.). Each event was to be point scored and weighted. Unit scores on this proposed system were to be related to a readiness index. Such a system is not yet in use and, at the present time, is not related to any particular opplan requirements.

In sum, the study group was unable to relate readiness benchmarks to an output that corresponded with any opplan or scenario oriented requirements. Readiness measurements still reflected individual resource availabilities and conditions.

TOTAL TANK SYSTEM STUDY

Concurrent with the above efforts to examine readiness measuring systems, the Army conducted two more fundamental examinations of the management of armor units and resources. The most far reaching of these was the Total Tank System Study (T²S²) report, entitled *Improving the Tank Force*. This study was conducted by the U.S. Army Training and Doctrine Command (TRADOC) during the period December 1975 to September 1976 and resulted in the formation of an Armor Action Agency within the DA staff.

The avowed objective of T²S² was to evaluate methods for "maximizing the combat potential of one of the Army's most important weapon systems--the tank." The report noted that the Army does not manage tanks as systems and recommended such an approach as one of the methods of controlling the acquisition and application of resources related to tank units. It specifically identified shortfalls and solutions for supporting subsystems, grouped for management under the general headings of personnel, training, and logistics.

The study team used battlefield simulation models to estimate the sensitivity of battlefield output measures to various alternatives in the application of personnel, training, and logistics resources. It

did not address the problem of readiness reporting, but the simulation analysis did provide insights on the critical resources that affect unit output.

The key recommendation was that the Department of the Army form and staff a Total Tank Management Systems Office, headed by a general officer and working directly for the Army Chief of Staff. This was necessary because the solution to present tank-related problems requires crossing a wide spectrum of staff and organization lines of authority and, as T²S² argued, the "normal reaction of the hierarchy of the Army is to bureaucratically suppress initiatives" that are outside the normal management structure of the Army.

This recommendation resulted in the Tank Forces Management Office (TFMO) of the Department of the Army.

TANK FORCES MANAGEMENT GROUP

The report of the Tank Forces Management Group on *Tank Weapon System Management* was the first direct product of the recommended system office established as a result of the T²S² report. This report made 83 specific recommendations on five major areas affecting tank force readiness and capability. The Army subsequently adopted these initial recommendations as a continuing agenda for action. Since that time, many of the recommendations have been deleted, completed, modified, or augmented. Recently the TFMO has been reorganized to support the weapon system orientation for the Army's Big Five system modernization programs.

Neither this nor the preceding TRADOC study made any major substantive recommendations concerning readiness reporting and measurement. However, in the context of the major recommendations on the functions examined, they implicitly focused on the key elements of resource aggregations as they affected tank unit output.

THE DIVISION RESTRUCTURING STUDY

During 1976, the Army initiated the Division Restructuring Study (DRS) to evaluate a new organization for armored and mechanized divisions. The concepts used were designed to furnish more concentrated firepower and increased mobility in a smaller, more controlled force.

The DRS was aborted in late 1977, when the concepts for the Division 86 Study were being formulated. The evaluations of the DRS features already in test were to be completed under the Division Restructuring Evaluation.

DIVISION RESTRUCTURING EVALUATION

The Division Restructuring Evaluation (DRE) was formulated to evaluate the organizational and doctrinal implications of the partial field tests of the DRS concepts. The Test Brigade of the 1st Cavalry Division, organized using "T" series TO&Es, was evaluated against units organized with the current "H" series TO&Es; data collected during the tests were then fed through simulation models under the direction of the Combined Arms Center and Development Activities (CACDA) and the TRADOC Combined Arms Test Agency (TCATA). In general, the concepts tested appeared to be too light in mass and sustainability to be suitable for engaging Pact armor/mechanized regiments. Particular concepts--the ammunition transfer point and the augmented logistic tail--were selected for immediate implementation, however.

DRS/DRE experience proved to be a valuable background for the succeeding study, Division 86, now underway. However, as in the other studies, no specific effort was made to evaluate readiness concepts or measurement methods.

DIVISION 86 PROGRAM

The Division 86 Program (DIV 86) involves almost all the study and management agencies of the Army. Its purpose is to develop the most combat-effective organization for the Army's heavy division in 1986 and to facilitate the integration of new equipment, operational concepts, and human resources. It is designed as a total planning process that projects the Army of the future to a certain point and then retrospectively determines how to achieve the evaluated posture. The entire planning approach is to assess the effects of new weapon systems and threats upon force structure, doctrine, training, and manpower requirements to win the central battle and generate the forces that sustain this battle.

The Division 86 effort will attempt to explore the input/output relationships among force structures, resources, and war fighting capability. It will not address detailed questions concerning unit readiness and day-to-day readiness for a specific task. Nonetheless, it appears to be a major methodological step in assessing force structure alternatives.

Concurrent with these major efforts--the DRS, DRE, and Division 86--there have been lesser Army initiatives to determine the resource/output relationship for smaller units. Among these were the CELOGS methodology¹ and the Restructured General Support Model (RGSM). This set of models was designed to relate logistics support directly to measures of combat effectiveness such as combat losses and FEBA movement. It attempted to assess the effect on the logistics system of incremental changes in combat activity. Models were developed to evaluate: (a) the ammunition supply requirements for a given force to sustain firepower, (b) the bulk POL requirements in a scenario context, (c) the capability of the maintenance structure to generate material availability, and (d) the transportation network.

Most of the CELOGS effort was overtaken by support requirements for the DRS/DRE and Division 86, and was thus terminated. Although these models may be useful for force-wide requirements analysis, they do not seem to be adaptable to unit readiness evaluations.

AIR FORCE READINESS MEASUREMENT

Because of the rather explicit output objectives of most Air Force units, the Air Force has developed more focused readiness reports than the Army. Using the UCMS methodology as a starting point, the Air Force Tactical Air Forces (TAC, PACAF, and USAFE) have further developed techniques to convert most resources and facilities on a Wing/Base to a common output function.² This output is a launched sortie of a

¹Methodology for Correlating Combat Effectiveness with Logistic Support, Final Summary Report, Department of the Army, TRADOC/U.S. Army Logistics Center, July 1978.

²Joint Chiefs of Staff, Force Status and Identity Report (FORSTAT)--Annex 5, Unit Capability Measurement System, JCS Publication No. 6, Washington, D.C., June 1974.

particular configuration. The technique under test at present is a set of algorithms called TAFOCAS (Tactical Air Forces Capability Assessment System), which provide estimates of the number of sorties of a particular type that the on-hand and projected aircraft, spares, munitions, POL, base facilities, and crews can produce.

This methodology evolved against a background of studies and critiques of Air Force readiness measurement.¹ Most critiques made the general observations that readiness measurement should include estimates of mobility, capability, and sustainability.

SUMMARY

A review of these studies has helped identify many of the major considerations in assessing the relationship between unit resources and outputs. In Table A.1, we have tried to summarize what topics each of these studies discussed. Most of these studies on armor organizations, operations, and readiness dealt with the status of resources or of intermediate products such as operationally ready (OR) tanks. Only a

¹See, for example, General Accounting Office, *The Readiness of U.S. Air Forces in Europe, Selected Aspects & Issues*, LCD 78-430, Washington, D.C., February 16, 1979, p. 59:

The costs of developing and procuring new tactical weapon systems are visible. The costs of deploying and fully supporting them are much less so. Also, key items such as *munitions and fuels* are not measured in the regular Air Force or JCS required readiness reporting systems. We believe a comprehensive assessment of the impact of *WRM shortages* on planned wartime activity is necessary to clearly identify priorities and develop realistic plans. . . . This would not only assist Air Force managers, but would also provide a realistic basis for congressional evaluation of major policy and funding decisions. Such assessments should emphasize the requirements and assets on hand by force type--place/augmenting--so as to allow managers to evaluate the relative status and additional needs for each force. It would appear this would better facilitate prioritizing needs and filling open requirements.

Also, Office of the Secretary of Defense, *Defense Planning & Programming Guidance*, March 11, 1977, p. 81:

DoD needs to enhance its capabilities to define and measure readiness, relate changes in resources applied to changes in readiness and adjust allocations of Defense resources to attain the desired levels.

Table A.1
STUDY SUMMARY

Topics Addressed on Armor/Readiness	Study/Evaluation							
	GAO (ARMOR)	WSEG/ IDA	T ² S ²	TFMG	DRS/ DRE	DIV 86	CELOGS	AF UCMS
<u>Resources</u>								
Design			X	X		X		
Equipment			X	X		X		X
Tools			X	X		X		X
Spares			X	X		X		X
Personnel			X	X		X		X
Organization			X	X	X	X		
Basic load	X		X	X	X	X	X	
POL	X		X	X	X	X	X	X
WRM	X				X	X	X	X
Replacement						X	X	
<u>Intermediate Products</u>								
OR tanks	X	X		X		X	X	X
Crews	X	X	X	X				X
Unit training	X	X	X	X		X		X
<u>Setting</u>								
Mobilization								X
Oplan								X
Scenario	X					X	X	X
<u>Outputs, Measures, and Methods</u>								
Readiness	X	X						X
Output units						X		X
Simulation						X		

few touched upon the operational context of mobilization, deployment, and employment, or on the measurement of output or readiness in a specific operational context. It is not our purpose, however, to criticize these studies, but rather to highlight the broad scope of elements that can have an effect on readiness assessment.

Appendix B

MAINTENANCE TASK AND MANPOWER ALLOCATIONS AT BATTALION, COMPANY, AND CREW LEVELS

CMAC Group	Simul Shop	Shop Name	Number of Tasks	Basis of Failure	MOS Assigned	MOS Name
0100	01	Engine	4	Miles Driven	63C 63A	Tracked Vehicle Mechanic Tracked Vehicle Mechanic Helper
0300	03	Fuel	17			
0400	04	Exhaust	2			
0500	05	Cooling	5			
0600	06	Electrical	23			
0600	02	Electrical	17			
0700	07	Transmission	5			
0800	08	Transfer Assembly	4			
0900	09	Propeller Shaft	1			
1200	12	Brakes	5			
1300	13	Wheels and Tracks	19	Days on Line	44B 45K 45N 31E	Welder Tank Turret Maintenance Supv Tank Turret Mechanic Field Radio Mechanic
1400	14	Steering	1			
1500	15	Towing	1			
1600	22	Fire Extinguisher	5			
1800	18	Hull	6			
1900	19	Turret	29			
1900	20	Turret	14			
2300	23	Sighting/Fire Control (Opt)	17			
2500	24	Sighting/Fire Control (Mech)	9			
2700	10	Armament	20			
2700	11	Armament (Elect)	31	Rounds Fired	76Y 63F 19E	Armorer Recovery Vehicle Operator Ammunition Handler Specialist
25	25	Recovery	1			
26	26	Munitions	2			
29	29	Refueling	1			

Source: FM42-9-1.

Appendix C

DOCTRINETHE TANK BATTALION

The tank battalion is the largest maneuver unit that has the tank as the major pacing item of equipment. Under current doctrine, it is common for a brigade task force commander to organize and fight battalion task forces consisting of armored and mechanized infantry companies, although pure tank battalions may be employed as needed.¹

There are 48 active Army tank battalions and about 43 tank battalion cadres in the reserve forces. All the battalions are currently organized or being converted to a standard organizational structure. The operative Table of Organization and Equipment (TO&E 17-35HO Change 2) provides for the manning, organization, and major equipment as shown in Table B.1.

As indicated, there are three tank companies plus a Headquarters, Headquarter Company, and a Combat Support Company. Each tank company is manned by 88 men and has 17 tanks with either a 105 mm or 152 mm main gun. The total battalion is authorized 533 men at the ALO-1 level.

Table C.1
PERSONNEL ALLOWANCES
TANK BATTALION TO&E 17-35 HO

Organization	Personnel	Pacing Item Tanks (M60A1, A2, A3)
HQ & HQ Co	178	3
3 Tank Cos	264	51
Combat Support Co	<u>91</u>	—
	533	54

¹Department of the Army, *The Tank and Mechanized Infantry Battalion Task Force*, FM 71-2, HQDA, Washington, D.C., June 30, 1977.

THE MISSION

The wartime mission of a tank battalion, as stated in its TO&E, is "to close with and destroy enemy forces using fire, maneuver, and shock effect." Field Manual 17-15, dated March 1966, *Tank Units, Platoon, Company and Battalion*, further specifies that this is to be done in coordination with other arms. Battalion capabilities for units at the ALO-1 level are amplified in the TO&E as follows:

- conduct operations requiring a high degree of firepower, mobility, armor protection, and shock effect,
- attack or counterattack under hostile fire,
- destroy enemy armor by fire,
- organize, command, and control combined arms teams through cross attachments with infantry or mechanized infantry to engage the enemy with fire, maneuver, and shock effect,
- provide mobility, armor protection, firepower, and flexible communications to successfully exploit the effects of nuclear and non-nuclear fire support,
- conduct combat operations under limited visibility conditions, employing night-viewing devices and surveillance equipment.

In addition to the specific objectives and capabilities spelled out in the TO&E, the ARTEP manual for combined arms operations has identified some 29 different training outlines at ARTEP Level 1 that a tank/mechanized infantry force may be called upon to accomplish.¹ These outlines specify capabilities required by maneuver forces in four general areas. These are attack, defense, conduct of road marches, and occupying an assembly area. The outlines vary to include day and night exercises, and specify different evaluation criteria for high risk and fast reaction time situations.

¹Department of the Army, *ARTEP for Mechanized Infantry/Tank Task Forces*, ARTEP 71-2, U.S. Army Training and Doctrine Command, Ft. Monroe, Va., September 29, 1978.

THE UNIT OF OUTPUT

Given this brief description of the mission of a tank battalion from the TO&E, what unit of the tank battalion are the smallest possible that can be defined for control purposes and tasking?

Field Manual 71-2 describes task force composition and organization as follows:

The Major Components: Capabilities and Limitations-- To properly task organize, brigade and task force commanders must have a clear understanding of the capabilities and limitations of the major building blocks or components they have available to allocate. Brigade commanders generally think in terms of the number of TOW weapons, tank companies, and mechanized infantry companies to assign, and which task force to weight with available artillery, air defense, TACAIR, attack helicopters and engineers. *Task force* (battalion) *commanders* think in terms of TOW sections, *tank platoons*, and mechanized platoons as well as the distributions of other available support (p. 3-5).

Note that the operative level of command, the task force (battalion) commander, manages and tasks down to the platoon level. In discussing how to organize the battalion task force the manual stresses the need for flexibility and tailoring the task force to accomplish a specific mission. The units of reorganization are specified under the heading The Maneuver System:

*The Maneuver System--*The maneuver system of the task force consists of the three major components--*tank platoons*, mech platoons, and TOW sections--organized under the control of a team headquarters. Usually the commander will be allocated from six to twelve platoons organized under two to four team headquarters (p. 3-8).

Field Manual 71-1 reinforces the platoon concept:¹

The tank platoon operates as a unit. It consists of five tanks under the control of the platoon leader. Tank platoons are organized into two sections. Tanks 1, 2, and 3 in the

¹Department of the Army, *The Tank and Mechanized Infantry Company Team*, FM 71-1, HQDA, Washington, D.C., June 30, 1977.

first section, known as the heavy section; it is led by the platoon leader in the first tank. The second, or light, section consists of Tanks 4 and 5 and is led by the platoon sergeant in Tank 4 (p. 3-7).

On the basis of policies and procedures spelled out in the field manuals and *how-to-fight* manuals,¹ the tank platoon is the smallest unit of command and management.

¹Field Manual 17-95, *The Armored Cavalry Regiment*, addresses the same concepts for the armored cavalry squadron, which is the equivalent of a tank battalion. These squadrons consist of armored cavalry troops, which are similar to a tank company. Paragraph 49A of Field Manual 17-95 reads as follows: "The armored cavalry troop normally operates without attachments. However, helicopters may be provided to facilitate command control and reconnaissance." Paragraph 56 reads as follows: "The tank troop is organized, trained, and equipped to close with and destroy enemy forces using fire, movement and shock effect." The squadron commander may employ the tank troop as a unit, with or without reinforcement, under squadron control, or he may attach one or more tank platoons to an armored cavalry troop. Thus, the tank platoon in the armored cavalry troop is again the unit of output, and it consists of five tanks, in a heavy and a light section.

Appendix D

DAILY AND CUMULATIVE OUTPUT FOR
ATTACK SOC BY RESOURCE SET

Table D.1

BASE CASE

Day	Attrition Rate							
	0%		10%		20%		30%	
	Mean Output	Standard Deviation	Mean Output	Standard Deviation	Mean Output	Standard Deviation	Mean Output	Standard Deviation
1	9.0	0	9.0	0	9.0	0	9.0	0
2	7.0	0.70	6.8	1.09	7.2	0.44	6.0	0.70
3	7.8	2.16	7.4	0.54	6.2	0.83	5.4	1.14
4	7.2	1.09	6.8	0.83	5.6	0.54	4.4	0.89
5	8.2	1.78	6.6	0.54	5.2	0.44	3.2	1.09
6	7.2	1.30	5.6	0.89	4.8	0.83	2.4	0.89
7	7.4	1.51	5.4	0.54	3.6	0.54	2.0	0
8	8.0	1.00	5.6	0.89	3.0	1.22	1.4	0.54
9	7.8	0.83	5.2	0.44	2.2	0.44	1.4	0.54
10	8.2	0.44	4.3	1.30	2.0	0.63	1.0	0.70
11	7.4	0.54	4.4	0.54	2.0	0.63	1.2	0.44
12	6.8	1.30	4.0	0.70	2.0	0.63	0.8	0.44
13	7.8	1.09	3.6	0.89	1.2	0.44	0.6	0.54
14	6.2	1.78	3.6	0.54	1.2	0.44	0	0
15	8.4	0.89	3.0	1.00	1.4	0.54	0.4	0.54
CUMULATIVE	114.4	1.14	81.2	5.80	56.6	6.34	39.0	4.79

Table D.2
C-2 IN MANPOWER CASE

Day	Attrition Rate					
	0%		10%		20%	
	Mean Output	Standard Deviation	Mean Output	Standard Deviation	Mean Output	Standard Deviation
1	9.0	0	9.0	0	9.0	0
2	6.6	0.89	7.0	1.00	6.8	0.44
3	7.8	0.44	7.0	1.22	6.4	0.89
4	7.2	0.83	7.4	0.89	5.4	0.89
5	6.4	1.14	5.2	1.64	4.8	0.83
6	8.2	0.83	7.0	1.00	4.6	0.54
7	7.0	0.70	5.8	1.09	3.6	0.54
8	7.8	1.64	5.4	1.14	3.4	0.89
9	7.8	0.83	5.2	0.44	2.2	0.83
10	7.6	1.34	5.2	0.83	2.4	0.89
11	8.0	1.22	4.6	0.54	1.6	0.54
12	6.6	0.89	4.4	0.54	1.6	0.89
13	8.0	0.70	4.2	0.83	1.8	0.83
14	7.2	0.44	3.4	0.54	1.0	0.70
15	7.0	0.70	3.6	0.54	1.2	0.44
CUMULATIVE	112.2	1.30	84.4	2.60	55.8	5.06
					39.8	5.06

Table D.3
C-3 IN MANPOWER CASE

Day	Attrition Rate					
	0%		10%		20%	
	Mean Output	Standard Deviation	Mean Output	Standard Deviation	Mean Output	Standard Deviation
1	9.0	0	9.0	0	9.0	0
2	6.2	0.44	6.8	1.09	6.2	0.83
3	6.8	1.48	7.0	1.00	6.8	0.83
4	7.4	0.89	6.6	0.54	5.2	0.83
5	7.0	1.58	6.2	0.44	4.4	0.54
6	7.4	0.54	6.4	0.54	3.4	1.14
7	6.4	1.67	5.2	0.44	3.0	0.70
8	7.8	0.83	5.8	1.09	3.0	1.00
9	5.6	1.14	5.0	0.70	2.2	0.83
10	6.2	1.09	4.6	1.14	1.8	0.44
11	6.8	1.09	4.4	0.54	1.6	0.54
12	8.0	0.70	4.0	0	1.6	0.54
13	6.8	1.09	3.6	0.89	1.0	0
14	7.0	0.70	3.4	0.54	1.0	0
15	7.0	1.22	3.2	0.83	0.4	0.54
CUMULATIVE	105.4	2.60	81.2	6.01	50.6	5.89
					36.2	6.41

Table D.4
2nd BN, 67th ARMORED REGIMENT PLL CASE

Day	Attrition Rate							
	0%		10%		20%		30%	
	Mean Output	Standard Deviation	Mean Output	Standard Deviation	Mean Output	Standard Deviation	Mean Output	Standard Deviation
1	9.0	0	9.0	0	9.0	0	9.0	0
2	5.8	1.09	6.4	0.54	6.2	0.44	5.8	0.44
3	6.8	1.30	6.0	0.70	4.2	0.44	4.2	0.83
4	5.4	0.89	5.2	0.44	3.8	0.83	3.6	0.89
5	5.6	0.54	4.0	0.70	3.2	0.44	3.2	0.44
6	5.6	0.54	4.0	0	2.4	0.54	2.2	0.44
7	5.0	0	3.2	0.44	2.0	0.70	1.6	0.54
8	5.4	0.54	2.8	0.44	1.6	0.54	0.8	0.83
9	5.2	0.44	2.2	0.44	1.6	0.54	1.0	0
10	5.2	0.44	2.0	0.70	1.0	0.70	0.4	0.54
11	5.4	0.54	2.2	0.44	1.0	0	0	0
12	5.2	0.44	2.0	0.70	0.4	0.54	0	0
13	5.2	0.83	1.8	0.83	0.2	0.44	0	0
14	5.6	0.54	1.6	0.54	0.6	0.54	0	0
15	5.6	0.54	1.2	1.09	0	0	0	0
CUMULATIVE	86.0	2.34	53.6	2.60	37.2	3.49	31.8	1.48

Table D.5
C-3 IN MANPOWER PLUS 2nd BN, 67th ARMORED REGIMENT PLL CASE

Day	Attrition Rate							
	0%		10%		20%		30%	
	Mean Output	Standard Deviation	Mean Output	Standard Deviation	Mean Output	Standard Deviation	Mean Output	Standard Deviation
1	9.0	0	9.0	0	9.0	0	9.0	0
2	6.2	0.44	4.8	0.83	6.0	0.70	6.2	0.83
3	6.8	0.83	5.8	1.30	5.2	0.83	3.6	0.54
4	6.2	0.83	5.0	0.70	3.8	0.44	3.0	0.70
5	5.2	0.83	4.6	0.89	3.8	0.44	3.4	0.54
6	5.8	0.83	3.6	0.54	2.2	0.83	2.4	0.54
7	5.2	0.83	3.2	0.83	2.6	0.54	1.4	0.54
8	5.0	0.70	2.8	0.44	1.8	0.44	1.4	0.54
9	3.8	0.44	2.8	0.44	1.6	0.54	0.8	0.44
10	3.8	0.83	2.6	0.89	1.0	0	0.8	0.44
11	3.2	0.83	1.8	0.44	1.0	0	0.4	0.54
12	2.6	0.89	1.6	0.54	0.6	0.54	0	0
13	1.8	0.83	1.2	0.44	0.2	0.44	0.2	0.44
14	1.0	0.70	1.2	0.44	0.4	0.54	0	0
15	0.2	0.44	0.8	0.83	0.4	0.54	0	0
CUMULATIVE	65.8	2.38	50.8	4.96	39.6	2.88	32.6	2.70

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