An Initial Evaluation of the VISION Assessment System

Its Relevance and Application to National-Level Sustainment Planning

Christopher L. Tsai, Patricia M. Boren,
Robert S. Tripp

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PREFACE

This report describes the outcome of a national-level demonstration prototype of the VISION Assessment System (VAS). VAS is a decision support system designed to help logistics planners evaluate and improve equipment sustainability. It is part of a larger initiative called VISION (for Visibility of Support Options), which is aimed at enhancing operational effectiveness through better logistics decision-making in the Class IX (spare parts) arena.[1]

VAS focuses on three questions of fundamental importance to sustainment planners: Can the logistics system support operational needs and objectives? If not, what are the impediments most likely to be? And what can be done beforehand to avoid or mitigate potential problems? VAS is intended to help planners devise robust and effective support concepts to meet different operational requirements.

The need for a planning tool like VAS at the national level was highlighted during Operation Desert Shield when the Chief of Staff of the Army (CSA) asked the major subordinate commands of the Army Materiel Command (AMC) to forecast equipment readiness rates for several key weapon systems and identify strategies for improving them. The purpose of our work here was to demonstrate the ability of VAS to address questions such as those posed by the CSA. Also, we hoped to provide an initial evaluation of system feasibility and usability as a first step toward full-scale implementation.

This research was performed in the Military Logistics Program of RAND's Arroyo Center. The research project, entitled "Logistics Management System Concepts to Improve Weapon Systems Combat Capability," is jointly sponsored by the Assistant Deputy for Materiel Readiness of AMC, the Commanding General of the Combined Arms Support Command (CASCOM), and the Director of the Strategic Logistics Agency (SLA). This research should be of particular interest to logistics planners and information systems developers at both the national and field levels. It may be of general interest to the wider Army logistics community and to sustainment planners in other services, in the Office of the Secretary of Defense, and on the Joint Staff.

[1]VISION has three components: VAS (Tsai et al., 1992), the Readiness-Based Maintenance System (Tripp et al., 1990), and the VISION Operational Interface.

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SUMMARY

PURPOSE OF THIS REPORT

This report presents the outcome of a demonstration prototype of the VISION Assessment System (VAS) at the national level. The concept paper (Tsai et al., 1992) establishes VAS as a Class IX (spare parts)-oriented decision support system designed to help logisticians at any level evaluate and improve equipment sustainability. If the current support concept seems inadequate, VAS helps planners identify the shortcomings, formulate alternative concepts, and examine and compare the projected performance of those alternatives. With VAS, logisticians may be able to devise more robust and effective plans to meet different operational requirements.

The concept paper called for prototyping to test the viability of the VAS concept—that is, to illustrate conceptually the ability of VAS to address relevant questions and help planners evaluate and improve equipment sustainability. It is not to predict the outcome of any war, nor even to make definitive statements about the worth of different support concepts and management policies. Thus, the illustration in this report is not a comprehensive analysis but a simple demonstration of how VAS might be used as a planning tool at the national level.

THE NEED FOR ENHANCED ASSESSMENT AT THE NATIONAL LEVEL

We believe that subjective estimation is an unreliable method for capturing all of the factors relevant to sustainment analysis. The logistics system is very complex, with many subtle but important interactions among echelons and functions. Moreover, the unique characteristics of some contingency operations may engender support concepts that are quite different from those that doctrine and practice have made familiar. It is asking a great deal of unassisted planners to process the applicable information even at the individual item level, much less to roll it all together into such weapon system-oriented measures as readiness and sustainability. VAS offers a badly needed mechanism for integrating a variety of factors into a coherent whole.

A real-life situation during Operation Desert Shield (ODS) highlighted the need for enhanced assessment techniques. Early in ODS,

the Chief of Staff of the Army (CSA) asked the Major Subordinate Commands (MSCs) of the Army Materiel Command (AMC) to forecast equipment readiness rates for several key weapon systems (e.g., the M1 tank and the AH-64 helicopter) over a 12-month horizon. The CSA was interested in:

- Whether acceptable levels of readiness in both the deployed and nondeployed forces could be *sustained* over the coming year;
- How adaptive strategies might improve sustainability;
- What tradeoffs might be required between deployed and nondeployed force sustainability to provide adequate support to ODS.

Normally, the MSCs monitor only historical readiness without attempting to project future sustainability. They had no formal, well-rehearsed procedures for answering the CSA, especially in the short time they were allotted. Their responses were generated with difficulty and substantial reliance upon the qualitative judgments of experts. Some limitations of their approach were:

- A tendency to focus upon historical trends moderated by subjective correction factors;
- The restriction of quantitative analysis to *existing* problem areas (possibly overlooking significant *potential* problems);
- A lack of integration with other MSCs, which made it difficult to obtain consistent, *weapon system-oriented* viewpoints.

AN ILLUSTRATION OF VAS IN NATIONAL-LEVEL PLANNING AND ASSESSMENT

At the suggestion of the Tank-Automotive Command (TACOM) Readiness Directorate, we attempted to install VAS and use it to help answer the CSA's questions. Although this exercise was only partially successful, it did show considerable promise. Consequently, with the continued support of TACOM and the Strategic Logistics Agency (SLA), we used the CSA's questions as a backdrop to develop a demonstration prototype of VAS at the national level. This report documents that effort. The goals of the demonstration prototype were to:

- Illustrate the ability of VAS to address relevant questions such as those posed by the CSA;

- Evaluate feasibility from the standpoint of data availability and the suitability of the embedded Dyna-METRIC model;
- Identify enhancements to improve usability by everyday planners.

Although we characterized the strengths and weaknesses of existing and emerging information systems, we did not feel compelled to pursue an "ultimate" level of data accuracy here. We believe that the use of some notional data does not detract from a conceptual illustration of the applicability of VAS to sustainment planning and assessment. Follow-on prototypes can address data issues in a more comprehensive fashion.

Scenario

We developed a scenario based on the M1 tank that loosely reflected the situation in ODS at the time of the CSA's questions. Some key features of this scenario included:

- A deployed force of two divisions plus one armored cavalry regiment and a nondeployed force aggregated by region;
- A more intense, dynamic operating tempo (optempo) for the deployed force (120 days at 50 percent higher optempo than the nondeployed force, followed by 60 days at optempo 350 percent higher over that);
- A "DS-plus" support structure that essentially fused the direct support (DS) and general support (GS) echelons;
- Class IX item characteristics drawn from a variety of standard Army management information systems (STAMIS).

Where data were unavailable or inaccessible (problems that were often compounded by ongoing ODS support efforts), we tried to use reasonable assumptions.

Strategies Evaluated

In addition to examining M1 sustainability under a standard support concept (our base case), we considered three readiness-enhancing strategies both singly and in combination, all of which were adopted to some extent during ODS:

- Expedited requisition processing and transportation, to reduce order-and-ship time (OST);

- Forward-deployed depot-level maintenance capability, to decrease the turnaround time of reparable items;
- Prioritized allocation of national-level assets, to provide a higher level of response to the deployed force.

Evaluation Outcomes

We used the projected time-varying percentage of fully mission capable (FMC) tanks as the basis for comparing strategies. The base case served as a benchmark. Unsurprisingly, VAS indicated that without some sort of logistic adaptation, the deployed force FMC rate would decline to unacceptable levels. Also as expected, it showed that each of the three strategies offered some degree of improvement. However, VAS provided quantitative evidence to contradict some of our intuitive estimates of the magnitude of those improvements. Key results were:

- Expedited requisition processing and transportation offered only a small gain in deployed force FMC rate because the reduction in the OST pipeline was dominated by the national-level backorder time for a few critical items.
- Forward-deployed depot-level maintenance capability offered only a small gain in deployed force FMC rate because our data implied that the primary problems were shortfalls of consumable items.
- Prioritized allocation of national-level assets offered a more substantial gain to the deployed force, but balanced against that was a significant drop-off by the nondeployed force.

Implications

The verity of the preceding results must be discounted because our data contained a number of gross assumptions and other deficiencies. However, we believe that such problems can be overcome in time. If so, VAS has considerable potential as a sustainment planning tool. It can:

- Help planners examine a broader array of support concepts;
- Supplement and reinforce the judgment of unassisted planners;
- Provide insights (and explanations to back them up) that may not be intuitively obvious;
- Identify cost-effective strategies.

LESSONS LEARNED

Beyond demonstrating the ability of VAS to address important planning questions, our work here shed further light on the issues of feasibility (encompassing data availability, data accessibility, and model suitability) and usability.

Data Availability

Much of the data needed to operate VAS effectively already reside in STAMIS. For instance, the identities of mission-essential items and their demand rates, field-level maintenance characteristics, and systemwide asset balances can be extracted from various sources. These data are not perfect, but they can probably support useful assessments.

On the other hand, some data are either of dubious quality or are incomplete or missing altogether. These include certain operational scenario parameters, specialized demand rate factors, depot-level maintenance data, and in-transit asset balances. Their significance varies, but steps should be taken to upgrade or collect those that are central to sustainability planning.

Data Accessibility

Even when data are available, they can be inaccessible to planners, especially in urgent situations when scant time is alloted for planning and assessment. Accessibility problems take such forms as incompatible information management techniques and data systems, incomplete processing of raw data, the wide gulf between national-level and field-level STAMIS, and the diffusion across MSCs of the item management responsibilities associated with single weapon systems.

Model Suitability

At present, the Dyna-METRIC model embedded in VAS is further developed than the data systems upon which it draws. However, in the course of this demonstration prototype, we identified a number of modifications that would enhance its representational powers. These include a wider assortment of asset allocation rules, expanded multiechelon scope, a more detailed submodel of the transportation function, and an improved method of accounting for battle damage. Model upgrades should proceed in parallel with ongoing STAMIS evolution.

Usability

In many respects, VAS is still an analyst's tool. If it is to be placed in the hands of everyday planners, it must become more usable and user-friendly. The complex and cumbersome tasks of assembling inputs and viewing outputs need to be simplified. An assortment of tailored spreadsheets, database management packages, and graphical interfaces could greatly ease the burden on planners and improve their ability to generate relevant and timely assessments.

CONCLUSIONS AND THEIR IMPLICATIONS FOR FUTURE WORK

This demonstration prototype showed in principle that VAS can help planners evaluate and improve equipment sustainability. It also highlighted a number of limitations that must first be overcome; these are found in current Army data systems, in the Dyna-METRIC model, and in the interface between VAS and its potential users. Although these findings are helpful in defining an implementation plan, they are only a first step. The work that has begun here needs to be extended.

We recommend that two paths be pursued. The first is development of a national-level *operational prototype* to be exercised by Army planners in a "live" setting. The goals of this effort should be to:

- Stress the capabilities of VAS under actual planning conditions;
- Obtain a more complete picture of feasibility, usability, and system costs and benefits;
- Design and test upgrades to the concept and methodology.

The second path we recommend is extension of prototyping to the field level. The emphasis here should be on:

- Identifying relevant planning questions and assessment needs;
- Establishing feasibility, usability, and costs and benefits in the field-user environment;
- Exploring mechanisms for integrating national-level and field-level planning systems.

The field-level prototypes should capitalize upon existing work at the national level by focusing upon the same weapon systems.

ACKNOWLEDGMENTS

This effort would not have been possible without the interest, support, and active participation of the management and staff at the U.S. Army Tank-Automotive Command (TACOM). Major Paul Nobels of the Readiness Directorate was the driving force behind the idea of using the VISION Assessment System (VAS) to address the questions of the Chief of Staff of the Army. It was at his invitation that we first visited TACOM, and he helped us throughout by providing advice and access to key organizations and sources of information. Timothy Payne, also of the Readiness Directorate, and Lee Dowd of the Systems and Cost Analysis Directorate worked tirelessly to assemble data and install and test the Dyna-METRIC model on TACOM's computers. Lieutenant Colonel Tom Dickinson, John Dugan, and George Bednarik of the Readiness Directorate provided high-level support and advocacy before TACOM's senior leadership. Tony Cuneo of the Fielded Vehicle Performance Data System (FVPDS) organization heads a long list of those who devoted time and energy to explaining and extracting data on our behalf.

We also benefited from the ongoing encouragement and counsel of Cecilia Butler, Jeff Crisci, and Colonel Terry Chase of the Strategic Logistics Agency (SLA). In this phase of VAS prototyping, as during the earlier concept development period, their perspective and guidance helped sharpen the focus of our work.

Finally, we gratefully acknowledge the contributions of our RAND colleagues. Karen Isaacson gave frequent technical advice on how to structure input data and interpret output reports from the Dyna-METRIC model. Jerry Sollinger improved the organization and clarity of the writing. Marygail Brauner and Nancy Moore provided thoughtful and careful reviews.

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ABBREVIATIONS

ABF	Asset Balance File
ACR	Armored Cavalry Regiment
AMC	Army Materiel Command
AMCCOM	Armaments, Munitions, and Chemical Command
ASL	Authorized Stockage List
ATCCS	Army Tactical Command and Control System
AVSCOM	Aviation Systems Command
CASCOM	Combined Arms Support Command
CECOM	Communications-Electronics Command
CIF	Candidate Item File
CONUS	Continental United States
CSA	Chief of Staff of the Army
DS	Direct Support
DS4	Direct Support Supply Standard System
EHAT	Equipment Historical Availability Trend
FAD	Force/Activity Designator
FCFS	First Come, First Served
FEDC	Field Exercise Data Collection
FMC	Fully Mission Capable
FRA	Forward Repair Activity
FVPDS	Fielded Vehicle Performance Data System
GS	General Support
IM	Inventory Manager or Item Manager
LIF	Logistics Intelligence File
LRU	Line Replaceable Unit
LSAR	Logistics Support Analysis Record
MICOM	Missile Command
MRDB	Materiel Returns Data Base
MRO	Materiel Release Order
MRSA	Materiel Readiness Support Activity
MSC	Major Subordinate Command
MTD	Maintenance Task Distribution
MUBR	Mean Usage Between Replacements
NICP	National Inventory Control Point
NMCS	Non-Mission Capable, Supply
NSN	National Stock Number
NSNMDR	National Stock Number Master Data Record
ODS	Operation Desert Shield
OPLAN	Operation Plan
OSC	Objective Supply Capability

OST	Order-and-Ship Time
PD	Priority Designator
PLL	Prescribed Load List
PMR	Provisioning Master Record
POMCUS	Prepositioning of Materiel Configured in Unit Sets
RBMS	Readiness-Based Maintenance System
RCT	Repair Cycle Time
RIDB	Readiness Integrated Data Base
RO	Requisitioning Objective
SAILS	Standard Army Intermediate Logistics System
SAMS	Standard Army Maintenance System
SARSS	Standard Army Retail Supply System
SDC	Sample Data Collection
SDS	Standard Depot System
SIMS–X	Selective Item Management System–Extended
SLA	Strategic Logistics Agency
SMR	Source, Maintenance, and Recoverability
SPARC	Sustainability Prediction for Army Spare Component Requirements for Combat
SRU	Shop Replaceable Unit
STAMIS	Standard Army Management Information System
TACOM	Tank-Automotive Command
TAV	Total Asset Visibility
TLRS	Total Logistics Readiness and Sustainability
UBRD	Usage-Based Requirements Determination
ULLS	Unit-Level Logistics System
UMMIPS	Uniform Materiel Movement and Issue Priority System
UND	Urgency of Need Designator
USAREUR	U.S. Army in Europe
VAS	VISION Assessment System
VISION	Visibility of Support Options
WOLF	Work Order Logistics File

1. INTRODUCTION

The VISION (Visibility of Support Options) project was created to explore concepts to improve logistics support of major Army weapon systems through enhanced management of Class IX items (spare parts) and associated processes (supply, maintenance, and transportation). VISION has evolved into an integrated series of decision support systems aimed at increasing combat capability and/or reducing support costs through the use of advanced information systems and management techniques. RAND has developed concepts for three VISION elements that address assessment (Tsai et al., 1992), execution (Tripp et al., 1990), and the interaction of operations and logistics.

The focus of this report is the VISION Assessment System (VAS). The following summarization of VAS is offered as background for readers unfamiliar with the concept.

AN OVERVIEW OF THE VISION ASSESSMENT SYSTEM

VAS is a decision support system designed to help logisticians evaluate and improve equipment sustainability throughout the Army. VAS focuses on three questions that are fundamental to Class IX sustainment planning:

- Can the logistics system support operational needs and objectives throughout the course of a planned conflict?
- If not, where and when are problems most likely to emerge, and how serious are they likely to be?
- What can be done *beforehand* to avoid or mitigate those potential problems?

These questions have always been relevant. Even now, in a time of great uncertainty and widespread change for the Army, the critical importance of sustainment to success in combat remains constant. And, of the five "sustainment imperatives" of logistics doctrine, the special recognition given to *anticipation* places added emphasis on the need for effective *planning*.[1]

[1]Both AirLand Battle (FM 100-5, 1986) and AirLand Battle-Future doctrine identify five sustainment imperatives: anticipation, integration, continuity, responsiveness,

These questions have always been difficult to answer, too; they may be even more so today, given the present state of flux in world affairs. The waning of the Soviet threat in Europe and the greater relative likelihood of regional contingencies around the globe are changing the scope and focus of sustainment planning. Planners must now be concerned with a wider variety of settings for the conduct of military operations. The unique requirements of individual contingencies and the capabilities and limitations of the respective local infrastructures may suggest many new and different support concepts; such considerations increase the complexity of the planning problem.

The changing size and shape of the Army also seem likely to affect long-standing planning assumptions and common perceptions of equipment sustainability. For instance, future budget cuts may alter the customary balance between support resources and the combat force. Or, doctrinal structures and policies designed to support large, heavy, forward-deployed units may turn out to be poorly suited to the needs of a smaller, lighter, continental United States (CONUS)-based Army. Under such circumstances, the potential of the logistics system for effective wartime sustainment should no longer be taken for granted. Planners may wish to revisit these areas and develop alternative strategies to fit new environments.

VAS Characteristics

To properly address issues such as those described above, planners require *assessment* tools geared toward evaluating sustainability under both the current system and a spectrum of possible future systems. VAS is designed for this purpose. A number of characteristics that enhance its applicability to sustainment planning are discussed below.

Forward-Looking Methodology. VAS projects sustainability by explicitly modeling the interaction between operational demands and logistics resources. Thus, unlike trend analysis (which depends on the future being similar to the past), VAS can be used to examine a wide variety of scenarios and resource allocation strategies.

Wartime and Weapon System Orientation. Because sustainment is most meaningful in the context of a wartime setting, VAS is equipped to deal with several key aspects of combat operations (e.g., dynamic operating tempos, attrition, and battle damage and repair).

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and improvisation. Further, "effective anticipation of requirements" is cited as "the cornerstone of the AirLand Battle-Future combat service support concept" (Foss, 1991).

In addition, it uses weapon system availability as its primary measure of performance rather than less operationally relevant, item-oriented measures such as the range and depth of supply.

Integrated View of the Logistics System. VAS enables planners to consider not only Class IX supply but also maintenance, transportation, and procurement. Furthermore, it can accommodate multiechelon support structures in many different configurations. This scope and flexibility are important; planners should be free to envision and then evaluate a broad range of support concepts without being limited by planning tools that are too firmly entrenched in the current system.

Attention to Uncertainty and Adaptation. In practice, logisticians are routinely confronted by unanticipated demands, to which they often respond by adapting standard policies and procedures. Because uncertainty and adaptation are so prevalent, VAS incorporates a number of significant sources of uncertainty and several common adaptations. VAS is also fairly fast and easy to use; these attributes allow planners to spend more time exploring scenario variations and identifying persistent problems and robust solutions.

Exploitation of Enhanced Information Systems. VAS is intended to evolve in parallel with and take advantage of ongoing and planned improvements in standard army management information systems (STAMIS).[2] When fully implemented, it will allow planners to employ such information as up-to-date failure factors and repair times, systemwide asset positions, and operational planning factors.

Potential Users and Uses

VAS has many potential users and uses across the Army logistics community. In the field, at echelons ranging from divisions and corps to theaters, major commands, and contingency task forces, its primary users may be the G-4 (a command's principal staff officer for logistics) and the attached support command's materiel management center and Assistant Chief of Staff for Materiel. At the national level, VAS can assist weapon system managers, elements of Army Materiel Command (AMC) and its Major Subordinate Commands (MSCs), and developers of logistics concepts and doctrine at the Combined Arms Support Command (CASCOM) and elsewhere. Some of the principal uses of VAS are likely to be:

[2]Section 4 provides an in-depth discussion of these systems.

- Assessing and improving the supportability of existing operation plans (OPLANs);
- Formulating logistics plans in conjunction with ongoing OPLAN development, either in a deliberate or a time-sensitive planning environment;
- Analyzing the cost and sustainability implications of evolving concepts and doctrine;
- Examining alternative resource allocation strategies and tradeoffs among supply, maintenance, transportation, and the like;
- Formal reporting of unit sustainability.

THE NEED FOR PROTOTYPING

Within the AMC community, the Tank-Automotive Command (TACOM) has taken the lead in recognizing the potential of VAS. In cooperation with the Strategic Logistics Agency (SLA), TACOM will spearhead system development at the national level. However, a number of major implementation issues have yet to be resolved. The concept paper (Tsai et al., 1992) outlines some of these and groups them under the headings of feasibility, costs vs. benefits, and usability. It further suggests that by building a series of incrementally expanding prototypes, the Army may address these issues and move toward full-scale implementation while still retaining a large measure of control over development risk, cost, and the disruption caused by identifying and correcting problems.

The concept paper calls first for a *demonstration prototype* featuring off-line, computer-based case studies of sustainment planning and assessment applications at different echelons of the logistics system. The goals of this effort would include:

- Illustrating the ability of VAS to address a wide range of questions;
- Evaluating feasibility from the standpoint of data availability and the suitability of model structures and assumptions;
- Identifying user interface enhancements that might improve the usability and accessibility of VAS to Army planners.

PURPOSE OF THE REPORT

This report discusses the outcome of a *national-level VAS demonstration prototype*. It uses questions posed by the Chief of Staff of the

Army (CSA) during Operation Desert Shield (ODS) as a backdrop for showing how VAS can assess equipment sustainability, identify potential problems, and evaluate strategies for avoiding those problems. The remainder of the report is organized as follows:

- Section 2 discusses the relevance and need for VAS in light of the CSA's questions.
- Section 3 describes the situation that led to this demonstration prototype, lists the assumptions underlying the scenario and database, enumerates the cases that were examined, and explains the results of each assessment.
- Section 4 briefly summarizes the lessons learned regarding the feasibility and usability of VAS at the national level.
- Section 5 recommends follow-on work and outlines some goals for the next stage of prototyping.

2. THE NEED FOR ENHANCED ASSESSMENT AT THE NATIONAL LEVEL

THE RELEVANCE OF VAS

On or about Day 45 of ODS, the CSA[1] asked AMC's MSCs to forecast equipment readiness rates for a number of key weapon systems over the following 12-month period.[2] At that stage of ODS, there was still a great deal of uncertainty regarding whether and when actual hostilities would commence. The CSA's request stemmed from a wish to know whether the deployed force could *sustain* acceptable levels of equipment readiness over a protracted interval of waiting and heightened alert.

Also, by that time a number of logistics problems had surfaced that, if left uncorrected, could have degraded both readiness and sustainability. Some of these were one-time incidents related to the deployment effort (e.g., the breakdown of the supply ship *Antares* while en route to Saudi Arabia with the bulk of a division's spare parts). Other, more persistent problems included higher than expected failure rates due to the harsh desert environment. In view of these difficulties, the CSA further instructed the MSCs to provide a list of short-term solutions together with their estimated costs and expected contributions to improved performance.

Finally, although prompted by ODS, the CSA's questions did not concern the deployed force alone. He wanted forecasts covering the Total Army, with an additional breakdown into ODS and non-ODS components. If any of the steps taken to improve the readiness of the deployed force were projected to simultaneously degrade that of the nondeployed force (e.g., extensive cross-leveling from non-ODS units to ODS units, diversion of wholesale assets to support ODS, etc.), the CSA wanted to know both the extent of degradation and the amount of time and resources needed to restore the nondeployed force to its customary posture. He did not consider it acceptable to inflict sub-

[1]Then, General Carl E. Vuono.

[2]Among these were four weapon systems managed by TACOM: the M1 Abrams tank, the M2/M3 Bradley infantry/cavalry fighting vehicle, the M551 Sheridan tank, and the M901 improved TOW vehicle; and four helicopters managed by Aviation Systems Command (AVSCOM)—the AH-64 Apache, the OH-58D Kiowa, the UH-60 Blackhawk, and the CH-47D Chinook.

stantial, lasting damage upon the readiness of the nondeployed force, especially if the gain to the ODS component was comparatively small.

It is easy to see the parallels between the CSA's questions and the three fundamental planning questions that occupy the heart of VAS. Could the logistics system support the deployed force's increased operating tempo (optempo) while sustaining it—and the nondeployed force as well—in a combat-ready state for as long as 12 months? If not, what obstacles (both current and potential) stood in the way? And, given that these questions were asked fairly early in ODS, what could be done to circumvent those obstacles before they might become a significant drag on combat capability? The CSA's questions highlighted two additional issues of consequence to sustainment planning. First, even when conflict appears imminent, it may still be appropriate to give thought to the cost-effectiveness of different courses of action. Second, in a sizable operation such as ODS, steps taken to strengthen one part of the force may weaken another; such tradeoffs may be justifiable, but commanders need to know their scope and duration in order to make informed decisions.

Many agree that at a conceptual level, VAS addresses issues of fundamental importance to the Army. The striking similarity between the questions that it aims to answer and the questions asked by the CSA in the midst of a very real operation demonstrates the relevance of VAS in a practical sense as well.

LIMITATIONS OF THE CURRENT APPROACH

The CSA's questions would seem to be of basic, continuing interest to any commander, even during peacetime. Therefore, it is somewhat surprising to discover that they had rarely, if ever, been asked of the MSCs (TACOM and AVSCOM, at any rate) before this instance.[3] The MSCs regularly monitor equipment readiness as reported through the Materiel Readiness Support Activity's (MRSA's) Readiness Integrated Data Base (RIDB). However, they generally do not attempt to project sustainability across specific operational scenarios.[4] Certainly, they

[3]The MSCs do provide supporting data for the biennial OMNIBUS exercise, which evaluates the ability of the Army to meet the demands of the Defense Planning Guidance wartime scenarios. The logistics portion of this exercise is handled by the Logistics Evaluation Agency using its Total Logistics Readiness and Sustainability (TLRS) model. TLRS is much broader in scope than is VAS; however, its size also precludes its use in the sort of routine, decentralized planning role for which VAS is intended (TLRS, 1990).

[4]At most, they extrapolate recent trends to gauge the direction in which readiness is moving in the relative stability of peacetime. The Equipment Historical Availability

lack formal tools and procedures to help compute any such projections.

In the absence of established methods for addressing the CSA's questions, both TACOM and AVSCOM hastily assembled ad hoc teams of subject matter experts and charged them to arrive at a consensus opinion. Unquestionably, these teams were knowledgable and their views well informed. However, an examination of the way in which they went about answering the CSA's questions reveals limitations in at least three key areas:

- Reliance upon historical data—augmented by subjective correction factors—to predict future performance in a very different environment.
- Restriction of quantitative analysis to current problem areas only.
- Lack of integration with other MSCs.

These issues are discussed below.

Reliance upon Historical Data with Subjective Corrections

The basic approach taken by the expert teams had two components. First, they studied the past readiness performance of individual weapon systems to determine if pre-ODS readiness had been stable, improving, or declining. Trend analysis and extrapolation provided an initial, crude estimate of sustainability. For instance, "System X readiness has remained steady in the past year at its current level of 92 percent and it should continue at that level for the next 12 months." Of course, the experts also recognized that the differences between a peacetime garrison environment and the more demanding conditions of ODS (higher optempos due to increased training and patrol activities, and higher failure rates due to sand, dust, and heat, etc.) would tend to invalidate such simple estimates. Therefore, the second component of their approach focused on estimating correction factors to reflect the harsher conditions as well as the steps that might be taken to redress them. These estimates tended to be qualitative and at a high level of aggregation. Thus: "The deployed force will experience triple the normal demand for spare parts, which will lower its System X readiness by about 20 percentage points. However, by allocating excess depot capacity in Europe to ODS widget repair, we ought to be able to restore five points. By installing a

Trend (EHAT) report from RIDB contains readiness data for the most recent eight quarters, and is used as the basis for trend analysis (RIDB, 1988).

contractor in theater to repair gizmos, we ought to be able to restore another five points." And so on. Typically, a Delphi-like technique was used to reconcile differing individual estimates of these correction factors.

Although the approach described above may well yield accurate answers from the right group of experts, we find it to be somewhat troubling in a number of respects. First, it has a tendency to gravitate toward the initial estimate, possibly because the effects of proposed solutions are so often intended—and therefore deemed—to exactly offset the effects of anticipated problems. But, in a very rigorous scenario (say, one in which a hastily and lightly deployed force faces immediate combat), the initial estimate may be so far off the mark as to be dangerously misleading. At least in these cases, the VAS method of direct estimation based on a given operational scenario and a given set of logistics resources would seem to be more firmly grounded in the realities of the planning situation.

A second shortcoming is the potential lack of objectivity and consistency from one group of planners to another. Without a stronger quantitative framework, this approach is overly vulnerable to misguided but assertive personalities. Also, it may be too easily manipulated by a collective desire to stay within a certain range of answers (e.g., "Come what may, we had better end up projecting readiness to be at the stated Army objective."). A tool such as VAS could help planners adhere to certain standards of objectivity and consistency. Of course, this is not to say that the outputs of a mathematical model should necessarily take precedence over the opinions of system experts. However, such outputs might serve as an additional voice providing reinforcement, reassurance, and at times, corrective insights.

Finally, we believe that subjective estimation is an unreliable method for capturing all of the factors relevant to this sort of analysis. The logistics system is very complex, with many subtle but important interactions among echelons and functions. Moreover, the unique characteristics of some contingency operations may engender support concepts that are quite different from those that doctrine and practice have made familiar. It is asking a great deal of unassisted planners to process the applicable information even at the individual item level, much less to roll it all together into such weapon system-oriented measures as readiness and sustainability. VAS offers a badly needed mechanism for integrating a variety of factors into a coherent whole.

Restriction of Quantitative Analysis to Current Problems

The reliance upon qualitative judgment was moderated in part by the explicit, quantitative analysis of current problem areas. Class IX items that were in short supply at the time of the CSA's questions were examined separately in terms of their demand level, backorder status, and expected "get well" date. Their estimated contribution to readiness degradation was considered to persist from the start of the 12-month period until such time as new shipments were due from procurement or large repair programs were scheduled for completion. Beyond that point, they were considered to have no residual effect on readiness, and they received no more special attention.

This sort of analysis was certainly relevant, but it may have been too narrowly focused. In particular, it may have missed a key class of problem items—those not in immediate difficulty, but in relatively weak positions and exposed to further slippage over the next 12 months. Items that are backordered or that are deadlining[5] weapon systems (i.e., rendering them non-mission capable for reasons of supply, or NMCS) are easily visible to the MSCs; items that cause no such problems and yet are in precarious supply postures are not always so readily identified. Whether there were a sizable number of items in this latter category at the time of the CSA's questions is unknown. Restricted as they were by the lack of an automated assessment tool, the expert teams had time to consider only existing problems; typically, these constituted just a small fraction of each weapon system's full set of mission-essential parts.

Although a tool such as VAS may be no better at pipeline computations than a competent logistician, it does have the advantage of being able to process large volumes of data quickly. With VAS and the right data, the expert teams would have been able to analyze *all* mission-essential parts. The timely discovery in this manner of additional, *latent* problems could eventually have reaped important dividends in the form of improved sustainability over the course of ODS.

Lack of Integration with Other MSCs

Many major weapon systems are jointly managed by two or more MSCs. Consider the M1 tank, for example: TACOM manages items in the hull; Armament, Munitions, and Chemical Command (AMCCOM) manages items in the turret; and Communications-

[5]In military usage, an item "deadlines" a weapon system if that item is responsible for the system's being out of commission.

Electronics Command (CECOM) manages the radio and its component items. As the MSC of primary responsibility, TACOM was directed to respond to the CSA's questions concerning the M1. However, its answer depended in large part upon obtaining information from AMCCOM.[6] This task was difficult in several respects. Predictably, there were the usual problems associated with coordinating the real-time participation of several directorates at a separate location. Although AMCCOM cooperated fully and made extensive use of telephone, facsimile, and electronic mail facilities to pass information and data, its inability to participate directly in the ongoing deliberations of TACOM's expert team proved to be an obstacle.

Also troublesome was the potential for different interpretations of the CSA's questions, different notions of what does and does not constitute a significant readiness problem, and different ideas regarding the feasibility and effectiveness of potential strategies for improvement. However, as neither MSC was an expert in the details of the other's business, it proved impossible to arrange for central oversight in this area, especially on short notice. That this situation occurred as it did only reinforces the continuing need for improved coordination and communication among MSCs. It adds weight to the arguments in favor of *weapon system* managers who could assume a number of management responsibilities after initial fielding is complete. They would be logical candidates to address questions such as those posed by the CSA, and they would consequently benefit from tools like VAS.

Inconsistency between parallel information systems is a third issue of concern. Although AMC-wide standards exist in some cases, each MSC has a number of unique systems (or unique versions of common systems) tailored to support its own management interests. Although nominally the same in terms of content and purpose, some parallel systems at different MSCs may nevertheless be sufficiently distinct that they cannot confidently be combined to yield an integrated weapon system view. Some examples of such inconsistencies include:

- Age of data. Some MSCs constantly use and update certain categories of data that other MSCs consult only infrequently.
- Quality of data. Some MSCs expend a great deal of effort to scrub data that other MSCs dismiss out of hand as being hopelessly inac-

[6]The radio was not explicitly considered because of its widespread application to other weapon systems and the ready availability of spares—by controlled exchange from less critical vehicles, if need be.

curate. A case in point is the Selective Item Management System–Extended (SIMS–X), which TACOM alone seems to understand and find useful (albeit after some in-house processing).

- Comprehensiveness of data. MSCs may apply different standards to determine what should and should not be included in a particular type of database. For instance, TACOM, AMCCOM, and Missile Command (MICOM) maintain lists of the mission-essential M2/M3 parts that they manage. The TACOM and AMCCOM lists each contain approximately 100 to 200 parts. The MICOM list contains over 1200 parts, even though MICOM manages only the TOW subsystem in the M2/M3. On the surface at least, it would appear that MICOM deals in considerably more detail than do the others.

The existence of significant information system inconsistencies points to the need for greater uniformity and accessibility across logistics organizations. The motivation for such enhancements lies in the need for a weapon system orientation. VAS and other weapon system-oriented tools could then be used to fully exploit the advantages of integrated information systems.

HOW VAS MIGHT EXTEND CURRENT CAPABILITIES

We believe that VAS can provide valuable assistance to the MSCs and other national-level organizations in terms of:

- Examining a broader array of issues related to equipment sustainability and sustainment planning;
- Expanding the range of scenarios and support concepts that can be evaluated;
- Supplementing and reinforcing expert judgment and adding quantitative depth beyond what unassisted planners are able to achieve;
- Supporting integrated weapon system management across the Army.

The CSA's questions and the responses that they evoked seem to confirm both the relevance and the need for a tool like VAS at the national level. The examples in the following section lend further substance to this position.

3. AN ILLUSTRATION OF NATIONAL-LEVEL PLANNING AND ASSESSMENT

The purpose at this stage of prototyping is to illustrate conceptually the ability of VAS to address relevant questions and help planners evaluate and improve equipment sustainability. It is not to predict the outcome of the war, nor even to make definitive statements about the worth of different support concepts and management policies. Thus, this illustration should not be viewed as a comprehensive analysis but as a simple demonstration of how VAS (or a model like it) might be used as a planning tool.

Readers are further cautioned that the operational scenario and data underlying our case studies are often notional. They contain many gross, simplifying assumptions that reflect our inability at the time to obtain more realistic figures. In view of the modest objective of this prototype, some compromises in data quality can be accepted. In fact, the very necessity for such compromises is an important lesson of the demonstration prototype. Still, the assessment outputs seen here should be considered strictly in context as illustrations only.

BACKGROUND

The work described here originated with TACOM's efforts to answer the CSA's questions. Upon hearing those questions, TACOM's Readiness Directorate asked RAND to send a small team of analysts to help complete the installation of the Dyna-METRIC model,[1] assemble the required databases, and provide quantitative input to the deliberations of the expert team. The time available for this exercise was three days. Significant progress was made, but this deadline ultimately proved to be too taxing. Although the model was successfully loaded and two databases (for the M1 and M2/M3) partially constructed, the short-term inaccessibility of several major data elements prevented us from generating useful outputs.

Despite this initial disappointment, the Readiness Directorate continued to express interest and belief in the value of VAS as a planning tool. In conjunction with other TACOM directorates and SLA, the

[1]Dyna-METRIC is a mathematical model of the logistics system that provides VAS with its assessment capability (Isaacson et al., 1988; Isaacson and Boren, 1988). A few weeks before the CSA asked his questions, the Readiness Directorate had requested a test copy.

Directorate put together a plan for further system development. In the meantime, we proposed using the TACOM experience as the basis for a national-level demonstration prototype. With the support of SLA and the ongoing participation of the Readiness Directorate, we upgraded the M1 database (although still not to a high degree of accuracy—our reasons are explained below) and embarked upon the study documented here.

Our work on this demonstration prototype took place as the level of forces and support resources committed to ODS were rapidly escalating. However, we continued to use the situation at the time of the CSA's questions as our point of reference. The case studies developed here all reflect that perspective.

SCOPE OF ANALYSIS

In constructing case studies to demonstrate the use of VAS in national-level sustainment planning, we concentrated on three readiness-enhancing strategies that are often available to national-level organizations in time of need. These were:

- Expedited requisition processing and transportation;
- Forward-deployed depot-level maintenance capability;
- Prioritized allocation of national-level assets.

Under the current system, these strategies tend to be applied in an informal, ad hoc fashion. However, as discussed below, all are related to ongoing Army initiatives to develop advanced information systems and support concepts for routine use in future peacetime and wartime environments.

Expedited Requisition Processing and Transportation

The purpose of expedited requisition processing and transportation is to reduce order-and-ship time (OST).[2] Because of practical limitations, this strategy can be pursued today only on an exception basis and for a limited set of (typically) critical items. Usually, it entails off-line communication of requisition information (e.g., by telephone

[2]OST is the delay experienced by units in the field between the time they requisition an item and the time they receive it. Reducing OST yields two major benefits: (1) it enables the national level to provide more timely support to the field, and (2) by shortening the depot-to-field pipeline, it allows Class IX stockage levels (and hence, procurement expenditures) to be cut.

or facsimile rather than through the more cumbersome standard channels), intensive management effort to facilitate materiel handling within the depot system, and some sort of high-priority or otherwise dedicated transportation link. The Desert Express system that evolved to support ODS included all of these features.[3]

A permanent, systemwide reduction of OST is the primary goal of the Objective Supply Capability (OSC).[4] By processing requisitions through a central gateway computer linking the field directly to the National Inventory Control Points (NICPs, which are housed at the MSCs), OSC will cut down on the number of steps and the time required to generate a Materiel Release Order (MRO) at the NICP level. Furthermore, by exploiting systemwide asset visibility, OSC will be able to arrange cross-leveling (materiel transfers between units) when one unit places a requisition and a neighboring unit has excess supply; this expedient will lower the frequency with which requisitions can be satisfied only by delivery from CONUS depots and will shorten OST even more. Prototype tests of OSC at Fort Hood saw a reduction in average OST from an original range of 12–25 days down to 5–7 days. When OSC is fully implemented, systemwide OST may be trimmed to as little as 3–5 days.

Forward-Deployed Depot-Level Maintenance Capability

By deploying depot-level maintenance capability forward, logisticians can significantly decrease the turnaround time of unserviceable spare parts that would otherwise have to be returned to a CONUS depot for repair. Such parts would avoid the lengthy and problematical process of retrograde transportation to CONUS as well as succeeding delays resulting from depot repair (often thought to take longer than similar work in the field), forward transportation, and in-theater materiel receipt, processing, and delivery.

In ODS, the Army made extensive use of forward-deployed depot-level repair. Thousands of AMC personnel and private contractors armed with specialized tools and test equipment were stationed in theater to provide the needed capability and capacity. Despite the high cost of

[3]Earlier, a similar system had been established to support Operation Just Cause (OJC) in Panama.

[4]Formerly known as the Objective Supply System (1988).

this venture, it was thought that the resulting gain in maintenance throughput would be sufficient return.[5]

Although the deployment of depot-level repair in ODS was largely an ad hoc response, formal and well-established examples of this capability do exist. The most notable are the Forward Repair Activities (FRAs)[6] that handle the repair of the AH-64 Target Acquisition and Designation Sight (TADS) and Pilot Night Vision Sensor (PNVS) subsystems. As the FRA concept evolves, the number of such facilities may eventually increase to support not only a broader array of Apache subsystems but other major Army weapon systems as well. In addition to their promised gains in repair efficiency, FRAs offer potentially significant savings in Class IX pipeline investment. To realize these savings, however, it will be necessary to closely couple FRAs to the units they serve; this might be achieved by basing them forward, or perhaps even better, by consolidating them regionally and providing for access to responsive, assured transportation systems.

Prioritized Allocation of National-Level Assets

When shortages occur, the NICPs may be unable to immediately fill all incoming requisitions. Under such circumstances, inventory/item managers (IMs) at the NICPs must decide which requisitions to fill and which to place on backorder. Normally, the priority designators (PDs) attached to each requisition are used to determine the order in which assets are to be distributed.[7] In wartime, deployed units may be authorized to use special project codes that allow their requisitions to bypass those of nondeployed units; such a code was employed during both ODS and OJC.

Beyond the simple issue of contention outlined above, there lies a more complicated question: should IMs reserve assets or even push them forward in anticipation of the future needs of deployed units *in-*

[5]Note that a tool such as VAS could have helped planners quantify benefits and justify costs in terms of sustained weapon system availability, and not just item-by-item turnaround time.

[6]Formerly called Special Repair Activities.

[7]As specified in the Uniform Materiel Movement and Issue Priority System (UMMIPS), PDs reflect both the military importance of the requisitioning unit (via its force/activity designator, or FAD) and the urgency of need (via its urgency of need designator, or UND). For example, units based in Europe take precedence over units based in CONUS in terms of FAD; requisitions to fill a "hole" in a weapon system take precedence over those to replenish safety stocks in terms of UND. There are five different FADs and three different UNDs; combined, they yield 15 possible PD values (AR 725-50, 1989). Requisitions with identical PDs are typically filled on a first come, first served basis.

stead of filling open requisitions from the nondeployed force? If so, how should they balance the quantity to be reserved and/or pushed with the number of backorders allowed to accumulate against the nondeployed force? There is anecdotal evidence that some IMs did indeed fence off a portion of national-level assets exclusively to support ODS. However, no formal policy governed such actions; the rules for apportionment were based wholly upon the individual judgment of the IMs. Therefore, it can reasonably be assumed that the effect of this sort of prioritization was extremely uneven when viewed across entire weapon systems.

Systematic prioritization of allocation actions is the key thrust of VISION's execution system, known as the Readiness-Based Maintenance System (Tripp et al., 1990). RBMS helps logisticians decide which unserviceable assets to repair and where to distribute serviceable assets. In doing so, it accounts for a variety of factors, including weapon system availability goals on a unit-by-unit basis (RBMS allows the use of differential goals to distinguish between more critical and less critical units), optempo forecasts, and current systemwide asset position. Because it focuses upon weapon system availability, RBMS promises to improve the operational relevance of logistics decisionmaking. Moreover, its value will tend to increase as the level of logistics resources (e.g., spare parts inventories and maintenance capacity) declines and a greater premium comes to be placed on effective management.[8]

SCENARIO ASSUMPTIONS

Because we designed this exercise only to illustrate the types of questions that can be addressed by VAS, we did not attempt to capture operational data with a high degree of precision. Thus, we did not identify deployed units by name, nor did we use actual counts of on-hand M1 tanks. Instead, we modeled notional units with end item densities approximately equal to the standard, authorized values (FM 101-10-1/1, 1987). This approach had the additional advantage of avoiding any problems with security classification.

[8]Demonstration prototypes of RBMS have been conducted and evaluated (Boren et al., 1991). The Army is currently developing and exercising a series of follow-on operational prototypes.

Forces and Densities

At the time of interest, the initial deployment from CONUS was still in progress. The follow-on deployment of VII Corps from Europe had not yet begun. The deployed force consisted of three units equipped with M1 tanks:[9]

- One armored division (six battalions, or approximately 360 tanks);
- One understrength mechanized infantry division (four battalions, or approximately 240 tanks);[10]
- One armored cavalry regiment (approximately 130 tanks).

Because we were primarily interested in the status of the deployed force, we aggregated the nondeployed force into the same four categories used by the RIDB EHAT report: active units in CONUS, U.S. Army in Europe (USAREUR), Eighth U.S. Army in Korea, and the combined U.S. Army Reserve and National Guard. Of course, had we been interested in greater detail from a worldwide perspective, these could have been broken down into divisions or even smaller units. The M1 densities of each of the four nondeployed "super units" were obtained from the previous quarter's EHAT report and rounded to even numbers. We did not count tanks held in POMCUS (Prepositioning of Materiel Configured in Unit Sets) or other war reserve or special-purpose accounts.

For the sake of simplicity, we chose to consider a situation in which all deployed units started out fully in place. If required, it is possible to model the dynamic fluctuation of force strength and operational activity associated with the deployment process. Initially, for instance, optempo can be reduced and forces decremented at the unit's home station. There can be a period of inactivity to account for the physical transportation of the unit. Finally, forces and optempos can be gradually increased in theater to represent the arrival, assembly, and movement to position of the deployed unit. In our case studies, the question of equipment status during deployment was not of primary interest, and we suppressed such details.

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[9]There was some confusion as to which variants of the M1 had been deployed. Consequently, we chose not to distinguish among different variants (e.g., the M1, M1A1, and M1IP).

[10]A full-strength mechanized infantry division typically has five tank battalions.

Optempos

The optempos used in our scenario were highly aggregated and purely notional. At the time of the CSA's questions, there was no solid information available to TACOM concerning the actual optempo of the deployed force. The presumption was that it was higher than during peacetime garrison duty because of expanded patrol and training activity; we were asked to assume a 50 percent increase above peacetime rates for both miles driven and operating hours per vehicle per day.

The CSA's questions specified a long-term (12-month), steady-state optempo for the deployed force. However, we chose to examine a shorter but slightly more varied scenario, primarily because we were interested in observing the effects of a peacetime-to-wartime transition. We constructed a simple, dynamic example, with four months of somewhat elevated activity (representing a preconflict, heightened alert posture) followed by two months at a significantly higher intensity (representing actual combat operations). The nondeployed force was assumed to maintain a normal peacetime optempo throughout. Figure 3.1 portrays this six-month scenario graphically. Note that optempo, plotted on the vertical axis, is expressed in terms of a multiple of normal peacetime intensity. We considered normal peacetime optempo to be 67 miles driven and 20 operating hours per vehicle per month.[11]

Attrition

In our scenario, we accounted for neither attrition nor (as we will discuss later) battle damage. Both of these processes can in fact be represented in VAS, but we chose to disregard them as being incidental to the main objectives of the demonstration prototype. When specified, attrition rates are applied to the existing population of end items. For example, if 80 tanks are on hand on day 7 and the attrition rate for that day is 5 percent, the number of tanks will be decremented by four (i.e., 5 percent of 80) to yield an on-hand quantity of 76 tanks on day 8. If attrition is not considered—or, alternatively, if it is assumed that reserves are sufficient to replace losses—end item density remains constant throughout the scenario.

[11]The mileage figure translates to 800 miles driven per vehicle per year, which is roughly in line with funded training levels for active units. The operating hours estimate is based on a previous year's statistics from the M1 Sample Data Collection (SDC) effort.

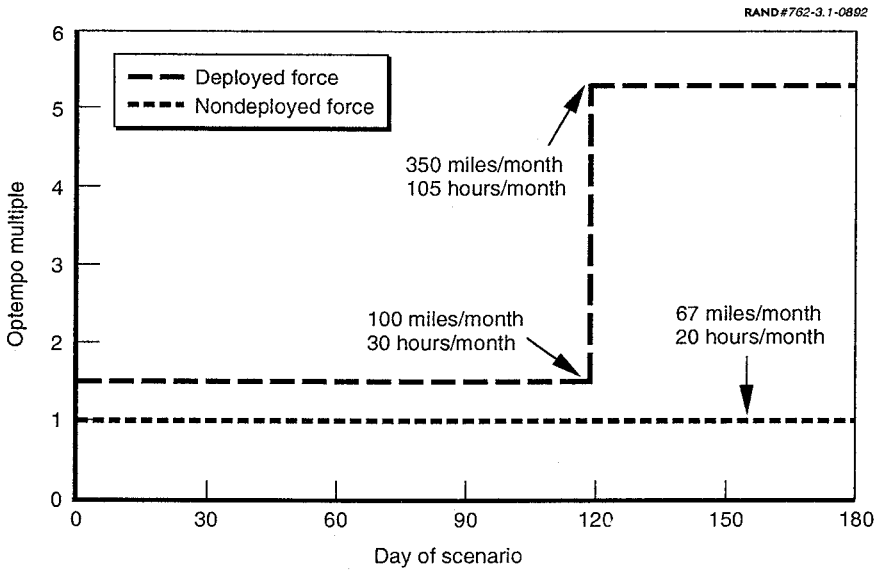

Figure 3.1—Hypothetical Six-Month Scenario

SUPPORT STRUCTURE ASSUMPTIONS

At the time of the CSA's questions, the in-theater logistics support concept for ODS was still being refined. It was not yet clear, for example, whether the U.S. Central Command's Army component would try to implement a doctrinal structure consisting of organizational, direct support (DS), and general support (GS) maintenance or whether it would favor a simpler "DS-plus" concept, in which the DS and GS echelons would essentially be fused into a single intermediate echelon. The role of in-theater AMC and contractor support was also open to discussion. Although there had been some commitment to having such resources in place, their exact scope and capability were still to be determined.

In this uncertain setting, we chose what seemed at the time to be the most likely alternative—DS-plus. Thus, the basic structure in our cases comprised three echelons of maintenance: organizational, DS-plus, and the CONUS depot system. Because maintenance data typically reflect the presence of both DS and GS echelons, we were obliged to aggregate individual DS- and GS-related factors to produce a composite picture of DS-plus.

In addition to the number of echelons of activity, a logistics support structure is characterized by the delays associated with materiel flow from one echelon to the next. VAS considers three types of delays: administrative (a catchall category for miscellaneous intra-echelon processing), forward transportation (to include the entire OST for serviceable materiel being sent toward the field), and retrograde transportation (i.e., for unserviceable materiel being sent toward the depots). Figure 3.2 offers a schematic view of our support structure, with labels indicating the average duration of the delay along each link. For the most part, these are nominal values. Only the CONUS-to-DS-plus forward transportation times are drawn from published sources. They reflect the UMMIPS OST standards for CONUS direct support system and overseas air line of communication (AR 725-50, p. 170). We assumed that without expedited processing in place, transportation time from CONUS to ODS would be the same as from CONUS to Europe.

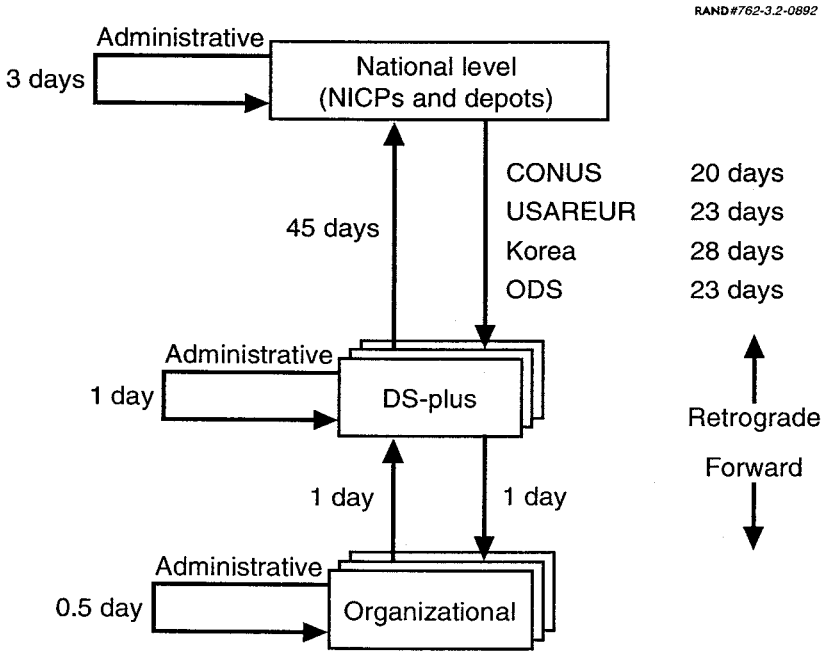

Figure 3.2—Hypothetical Support Structure

COMPONENT DATA SOURCES AND ASSUMPTIONS

Many of our data concerning the individual characteristics of weapon system components are based on conjecture or contain numerous simplifying assumptions. Compromises of this sort may be unavoidable when dealing with future optempos and the like, but they are harder to accept in connection with logistics data (which are, after all, largely historical and can be directly observed and measured). The difficulty lies not so much in the *unavailability* of needed data (although that certainly cannot be ignored), but rather in its relative *inaccessibility* within the time frames allotted for planning and assessment. In our case, the extraordinary effort at TACOM to monitor and support ODS further compounded this problem.

These data issues are important to address as we develop the VISION Operational Interface (VOICE), a module that could provide translated scenario information to the VAS input databases through online access to STAMIS. A number of information systems under development appear to improve accessibility by offering single-point entry to multiple sources and providing visibility of pertinent information to various levels. For example, the Army Tactical Command and Control System (ATCCS) will collect and disseminate timely and reliable command and control information to support tactical and logistical decisionmaking in the planning and execution of battle. Section 4 of this document offers additional thoughts and observations about data availability and accessibility. The remainder of the present discussion covers the content of the demonstration prototype database.

Range of Components

The question of which Class IX items to examine when assessing the sustainability of a weapon system is a fundamental one. In principle, all items—down to the smallest "bits and pieces"—should be included. However, the cost of gathering, maintaining, and manipulating the necessary data may far outweigh the benefits of such comprehensiveness. A more rational approach may be to consider only those items that are essential to mission performance *and* that also meet some general cost or scarcity criterion.[12]

[12]By this standard, a large number of consumable items might be excluded. For example, nuts and bolts may hold a weapon system together and yet be so inexpensively purchased or readily obtained that they can be thought to be "always available." Given such assurances, planners can reasonably cease worrying about such items from the standpoint of equipment sustainability.

For purposes of this demonstration prototype, we chose to work only with those items included in the M1 Candidate Item File (CIF).[13] It identifies, by National Stock Number (NSN), all mission-essential Line Replaceable Units (LRUs) on the weapon system.[14] The CIF listed 198 items; 128 were managed by TACOM and 70 by AMCCOM. The CIF contains no information concerning items at a lower level of indenture than LRUs. Therefore, our database did not include any subcomponents, even though many are no doubt both mission essential (by virtue of their contribution to the function of their parent LRUs) and relatively costly.

Demand Rate Data

The CIF provides several important logistics parameters for each item. The *usage basis* (e.g., miles driven, rounds fired, or operating hours) indicates the presumed causal relationship between operational activity and the demand for spares. As a rule, TACOM-managed items are thought to fail as a function of miles driven and AMCCOM-managed items to fail as a function of operating hours.[15]

An item's mean usage between replacements (MUBR) specifies its demands per unit of usage (e.g., mile driven or operating hour). At the time of this work, it was generally agreed that deployed units were experiencing inflated demand rates (or, alternatively, reduced MUBRs) primarily as a consequence of the harsh environmental conditions (both heat and sand) in which they were operating. In the absence of hard data concerning the amount of increase, we followed the common assumption that ODS demand rates were running at double the norm.

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[13]The CIF supports the Combat Authorized Stockage List (ASL) and Prescribed Load List (PLL) programs that determine field-level spare parts stockpiles. The ASL is by far the larger of the two and supports an entire division. The PLL is a company-level resource and typically consists of no more than 300 lines (i.e., types of items), most of which are relatively inexpensive but frequently consumed. In practice, ASLs and PLLs differ from one unit to the next; their contents are determined by a combination of individual unit demand history and the judgment of unit commanders. The Combat ASL/PLL program is intended to identify a core group of spare parts (the so-called Mandatory Parts List) that *must* be held in each ASL and PLL for purposes of wartime sustainment. The MPL is selected from among the items identified in the CIF.

[14]LRUs are items that can be removed and replaced at organizational level. As a group, LRUs include the most highly aggregated and costly elements of a weapon system. Often, LRUs are composed of Shop Replaceable Units (SRUs) that can only be removed and replaced in suitably equipped shops. For instance, the M1 fire control computer—an LRU—contains a number of circuit card assemblies that are SRUs.

[15]Usage basis is not as stable as one might think. In the previous year, the usage basis for AMCCOM-managed items was rounds fired.

In combat, of course, usage-related failures are likely to account for only a portion of the total demand for spares. Battle damage could be a significant, or even dominant, source of demand, especially if the enemy is highly lethal. However, because the modeling capabilities of VAS in this area are still somewhat primitive, we decided to overlook battle damage demands in the demonstration prototype. In Section 5, we describe a model upgrade that will permit an improved representation of the battle damage process.

Maintenance Data

The CIF also contains data pertaining to the maintenance characteristics of each item. The Source, Maintenance, and Recoverability (SMR) code indicates whether an item is reparable (can be repaired and returned to service) or consumable (is discarded outright and replaced with a new asset). Reparable items are further described in terms of their Maintenance Task Distribution (MTD), which describes the proportion of failed items repaired at each echelon. For instance, failed widgets may be repaired at the organizational level 10 percent of the time, at DS 30 percent of the time, and at depot 60 percent of the time.

The M1 CIF does not offer empirical values of MTD. Instead, it shows only the original, notional numbers used to create the Provisioning Master Record (PMR). These are nothing more than engineering estimates that predate M1 fielding. Altogether, there are only five or six combinations of MTD (e.g., the 10 percent, 30 percent, 60 percent combination cited as an example above) across all items; the particular combination attached to an item is strictly determined by its SMR code. We had no intuitive sense of what actual MTDs might be, so we continued to use the ones given in the CIF.

The PMR also carries another important data element that pertains to maintenance—repair cycle time (RCT). RCT specifies the average time required to repair a failed item at each echelon of maintenance and encompasses not only hands-on repair time but expected delays. Values of RCT are invariably 30 days at organizational level, 45 at DS, 60 at GS, and 90 at depot *for all items.* TACOM personnel felt that the field-level value was unreasonably high, particularly in view of the sense of urgency that was thought to prevail among repair facilities deployed in ODS. Consequently, we adjusted the RCTs in our database to be 7 days at organizational level, 7 days at DS-plus, and 90 days at depot.

Asset Balance Data

A number of gaps in our database clearly attest to the Army's current lack of systemwide asset visibility. Not unexpectedly, given that we were at TACOM, we had much better visibility of national-level assets than of field-level assets. In the future, near-real-time visibility of assets across all levels should be provided by SLA's developing Total Asset Visibility (TAV) system (SLA, 1990).

National Level. Our source for national-level asset balances was Sector 5 of the NSN Master Data Record (NSNMDR), an important reference for IMs. Even here, however, the picture was substantially incomplete: We found entries for only 91 of the 198 CIF items.[16] Sixty-four of the missing entries were for AMCCOM-managed items and were therefore properly absent from TACOM information systems. However, the difficulty of gaining timely access to their NSNMDRs (we tried, but did not succeed in the time we were at TACOM) presents a continuing impediment to time-sensitive, weapon system-oriented planning and assessment.[17] The absence of national-level asset balance data for 43 TACOM-managed items (over one-third of all CIF items managed by TACOM) is puzzling and calls for further investigation.

Most of the 107 items with missing balances were consumable, which allowed us a simplifying assumption that their stocks would be virtually unlimited. Thus, we set all 107 items' national-level (i.e., depot) asset balances equal to such high values that there was no chance that they would be backordered during the scenario.

Field Level. With a few exceptions (e.g., the items monitored in SIMS–X), the NICPs have no routine visibility of field-level asset balances. They can tell neither the quantity of assets on hand nor the requisitioning objective (RO, or authorized stockage level) of items held in unit ASLs and PLLs. The only information available to us at TACOM was an ASL listing for an armored cavalry regiment (the 3rd ACR) that had been obtained previously to support another special study and a company PLL listing for M1s. With no better short-term alternative, we used the ASL listing to compute the DS-plus assets

[16]We considered only serviceable and reparable balances of general issue stocks. A more complete analysis might consider other stocks in the system, such as war reserves, assets in transit, and assets in maintenance.

[17]We did obtain data for six AMCCOM-managed items that were considered to be immediate problems from the standpoint of readiness; AMCCOM reported their asset balances by facsimile.

and the PLL listing for the unit assets. Our method was simply to scale the ROs in proportion to each unit's M1 density.[18]

The range of items in the 3rd ACR's ASL struck TACOM personnel as being unusually narrow (only 34 of the 198 CIF items were listed) and not representative of larger, division-sized units. Therefore, as a final step, we were asked to assign a default value of four (which was also scaled in proportion to M1 density) to all items not listed on the ASL. The value of four was based on the average level of all items on the 3rd ACR's ASL.

VAS OUTCOMES

To demonstrate the potential of VAS to answer questions such as those asked by the CSA, we first considered equipment sustainability under a standard support concept, with no special adaptations in place. Subsequently, we considered the effects of the three previously discussed readiness-enhancing strategies, taken both singly and in combination, to total six cases:

1. Base case (no special strategies)
2. Expedited processing only
3. Forward depot only
4. Expedited processing plus forward depot
5. Prioritized allocation only
6. All three strategies.[19]

The time-varying percentage of M1 tanks projected to be fully mission capable (FMC) serves as the basis for comparison.[20] All results are subject to the scenario, support structure, and component data assumptions outlined above. In each instance, we describe our representation of the support concept in terms of additional or modified data assumptions. Moreover, we recall our own pre-analysis hypoth-

[18]Suppose the 3rd ACR had an RO for widgets of r. A unit (and its associated DS-plus organization) with T tanks (as compared with the 3rd ACR's authorized quantity of 123) would have been assigned an RO for widgets of $rT/123$.

[19]In a more formal policy analysis setting, evaluation of these strategies could be integrated with estimates of their implementation cost to yield a cost and operational effectiveness analysis.

[20]We define an FMC tank as one that is installed with a full complement of serviceable Class IX components.

esis concerning each case and show how that view is either reinforced or contradicted by VAS outputs.

Case 1: Base Case (No Special Strategies)

It is hardly conceivable that an operation of the scale and projected intensity of ODS would fail to spur a variety of extraordinary support measures. In fact, as discussed earlier, all three of the strategies that we are considering were enacted to some degree during ODS. The purpose of this base case, then, is solely to convey an initial sense of the magnitude of the support problem and to provide a handy reference point for comparing different strategies.

The assumptions of the base case regarding OST, in-theater maintenance capability, and national-level asset allocation are:

- Worldwide OSTs are as set forth under the UMMIPS guidelines, with the OST for ODS being set equal to that for USAREUR (i.e., 23 days).
- In-theater maintenance capability is in accordance with our assumed RCTs and the MTDs found in the M1 CIF.
- National-level assets are allocated on a first-come, first-served (FCFS) basis.[21]

In light of these assumptions and the rigorous conditions faced by the deployed force (both a higher optempo and higher component demand rates), our hypothesis was that ODS M1 availability rates would dip below peacetime levels even during the first four months of the scenario and would drop sharply at the start of the surge on day 120. As shown in Fig. 3.3, this view is borne out by VAS. The graph indicates the percentage of deployed and nondeployed tanks expected to be FMC at each point in the scenario. Note that the deployed force starts out at an FMC rate of virtually 100 percent. This advantage results from its presumed deployment with a full complement of FMC tanks and spare parts. In essence, it is taking more than its "fair

[21]By assuming an FCFS allocation rule, we do something of a disservice to the current system, which at least makes use of UMMIPS PDs to differentiate among requisitions. In some cases, however, FCFS is not an unreasonable representation. For instance, in time of crisis, eligible units tend to employ a special project code that elevates all of their requisitions to the same (high) priority.

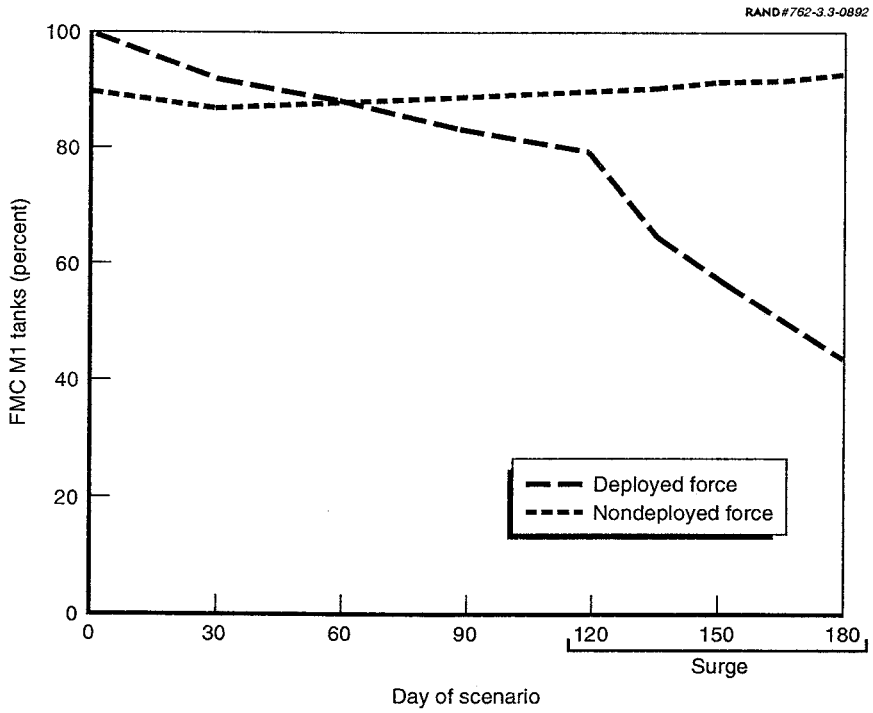

Figure 3.3—Case 1: Base Case (No Special Strategies)

share" of serviceable items and leaving behind more than its fair share of unserviceables. The effect of this arrangement on the nondeployed force is shown as a slight initial dip in its FMC rate. However, although the nondeployed force can be expected to recover over time, the deployed force clearly does not have sufficient logistics resources to sustain a satisfactory level of performance.

Case 2: Expedited Processing Only

Because significant problems are likely if no special measures are taken, we next consider the potential benefits of a dramatically shorter OST for ODS. To represent such a reduction, we changed the CONUS-to-DS-plus forward transportation delay from 23 days to 6 days for deployed units. A general reduction of this magnitude would admittedly be unrealistic under the current system (although OSC eventually may make it attainable). However, there is no question that *some* requisitions can be processed and delivered that quickly. Because it is plausible that the *selective* reduction of OST can be al-

most as productive as an across-the-board reduction, we were content to let this simple representation stand. Finally, to give token recognition to the idea that such gains do not come free of consequences for the rest of the force, we lengthened the OSTs for nondeployed units by 33 percent (an entirely arbitrary factor); this increase was meant to account for the diversion of lift resources needed to achieve a shorter ODS OST.

At the outset, we believed that a strategy of reducing OST would yield a significant improvement in ODS FMC rates. However, VAS sharply contradicts this hypothesis. Figure 3.4 indicates a disappointingly small gain for the deployed force (and an almost undetectable loss for the nondeployed force). Why should this be? After all, almost three-quarters of the resupply pipeline would be eliminated, leaving more assets on the shelf and allowing the NICP to provide more responsive support. An examination of the detailed problem components report produced by VAS leads to the following explanation: several items in generally short supply are shown to have numerous backorders at the

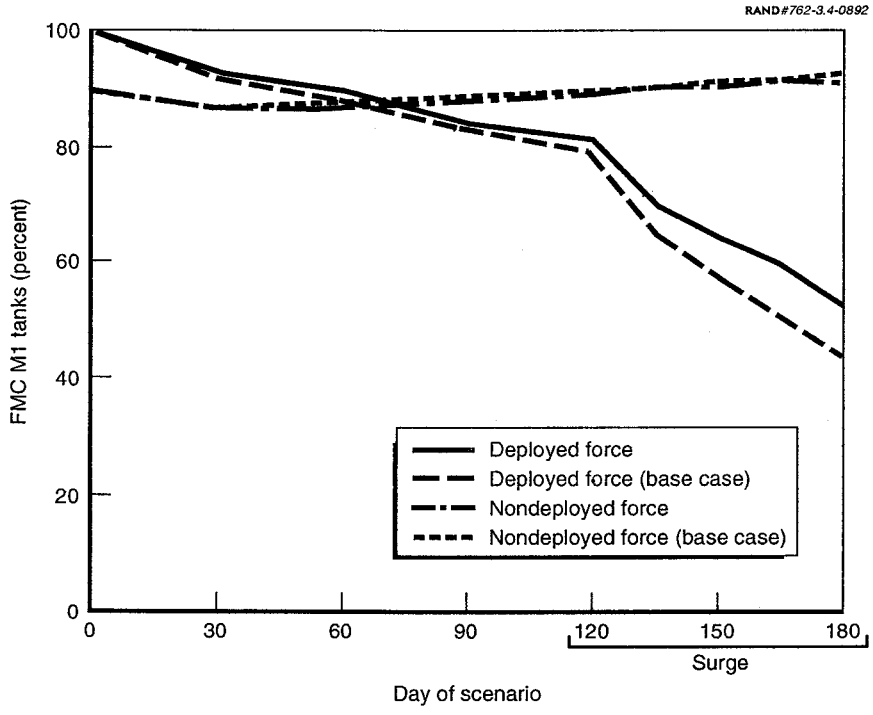

Figure 3.4—Case 2: Expedited Processing Only

national level. The average delay associated with filling these backorders is much longer than OST, and therefore dampens out most of the effect of even a 17-day reduction in OST. Moreover, because there is no prioritized allocation of national-level assets, ODS requisitions must contend on an equal footing with those of the nondeployed force. The lesson is clear: simply moving assets more quickly does not necessarily pay if critical shortages cannot be overcome by changing allocation rules, increasing the overall level of supply, or some other expedient.

Case 3: Forward Depot Only

Another option for improving upon the outcome in the base case is to allow depot-level maintenance to be performed in the field. This case simply extends the capability of the DS-plus echelon to include some depot-level capability.

At the time of this work, the eventual scope of field-level maintenance in ODS had not yet been defined. We did not know what would be repairable in the field—whether it would be all depot-level reparable items, a subset of those items, a proportion of all items, or some proportion of some subset. In the face of such uncertainty, we again turned to a simple, arbitrary rule: the rates at which unserviceable items were to be returned from ODS to CONUS depots for repair were cut to one-half of the rates implied by the CIF MTDs.[22] As speculative as this rule may be, it does at least represent in gross fashion the shift of maintenance workload and activity associated with forward deployment of depot-level capability.

Our hypothesis regarding this strategy was that it would show a very high payoff. With the stream of unserviceable items returning to the depot being cut in half, the pipeline savings would be huge.[23] But, as shown in Fig. 3.5, VAS again contradicts us. The explanation is simple and startlingly obvious when (and if) it comes to mind. The VAS problem components report indicates that shortfalls of *consumables*—not reparables—present the greatest obstacle to sustainment in this scenario. In fact, the two leading problem components, which

[22]In conjunction with such an adjustment, it might have made sense to increase the DS-plus RCT for deployed units on the theory that depot-level maintenance takes longer on average than normal field-level maintenance. However, in view of the uncertainty of the underlying assumption, this sort of refinement seemed superfluous.

[23]In effect, half of the retrograde, depot RCT, and OST pipelines (which total 158 days of activity) would be eliminated for all reparable items.

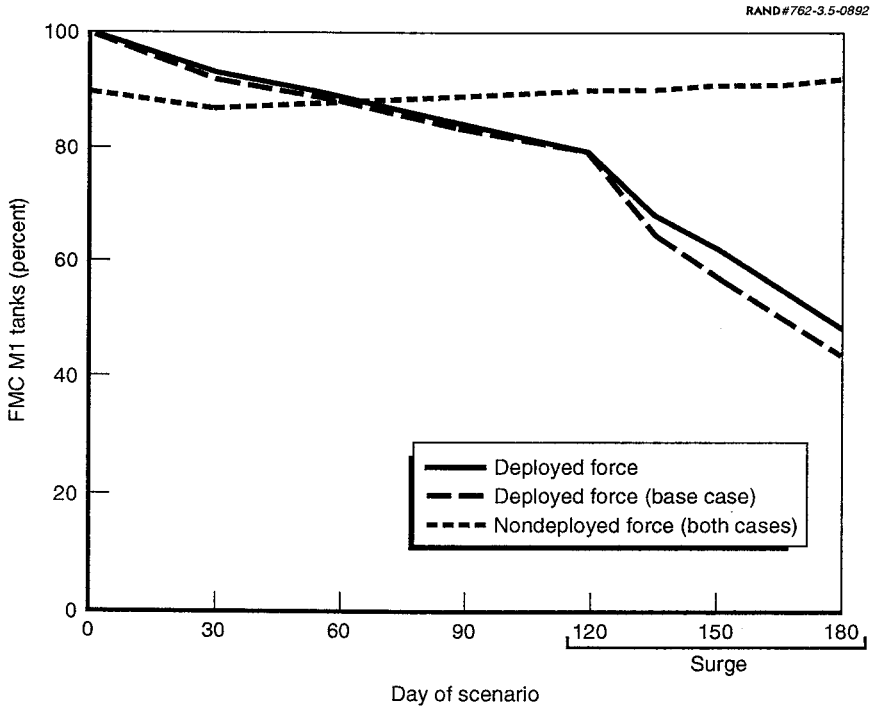

Figure 3.5—Case 3: Forward Depot Only

together drive overall performance, are consumables. Clearly, no amount of depot-level maintenance, whether forward-deployed or not, can affect their status. Although this strategy improves the availability of *individual reparables,* the fact that none of these are pacing items means that the sustainability of the *weapon system* is barely affected.

Case 4: Expedited Processing Plus Forward Depot

With each of the first two strategies appearing to yield only marginal improvements over the base case, one question that comes to mind is how their combined effect would compare with the sum of their individual effects. In other words, are these strategies mutually reinforcing, simply additive, or partially redundant?

Our hypothesis in this instance was that a substantial degree of redundancy would be found because both strategies aim for the same objective—namely, to couple the national level more closely with the

field. Expedited processing accomplishes this by reducing OST. Forward deployment of depot-level repair accomplishes it by moving certain elements of the CONUS depot system (i.e., part of its capability and capacity) to the field. The application of either strategy reduces the potential, and hence partially obviates the need for the other. As illustrated in Fig. 3.6, VAS supports this view. The gain achieved by the combined strategies is shown to be only slightly greater than that from either strategy alone.

Case 5: Prioritized Allocation Only

The indications from VAS thus far are that the dominant sustainment problem in this scenario is a shortfall of certain consumable items. As neither of the first two strategies does much to alleviate this problem, we now consider a change in the priority rules governing national-level asset allocation. We implemented a simple varia-

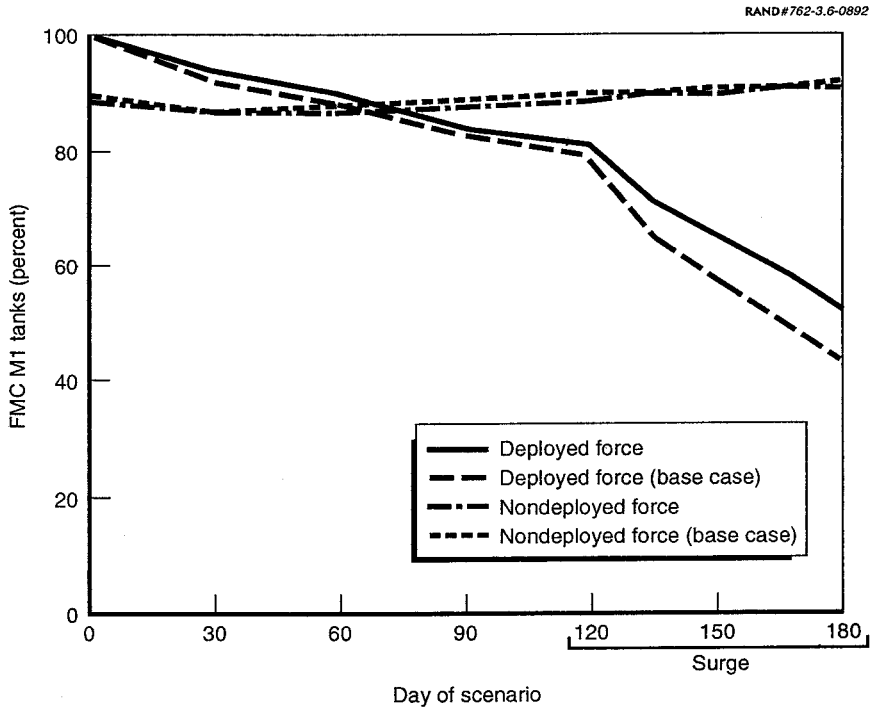

Figure 3.6—Case 4: Expedited Processing Plus Forward Depot

tion of this strategy. Specifically, we "fenced off" a subset of national-level assets in a special account accessible only to deployed units.[24] Our intent was to drive up the requisition fill rate (particularly for scarce items) experienced by the deployed force. Under this arrangement, fenced assets would be held in reserve to satisfy future ODS demands even at the cost of backordering requisitions (including NMCS requisitions) by the nondeployed force. If the special account were to be exhausted, the deployed force would then compete on an equal footing with the nondeployed force for assets in the general-purpose national-level account.

Our hypothesis was that this strategy would yield a marked improvement in ODS sustainability at the cost of some degradation in the condition of the nondeployed force. Because it involved only the shifting of scarce assets *within* the system (and not the addition of more assets from *outside*), we did not believe that this strategy could achieve significant gains in one area without incurring offsetting losses in another. As shown in Fig. 3.7, VAS corroborates our thinking. The improvement in M1 availability rates in the deployed force is much greater than under either of the two previous strategies. On the other hand, the nondeployed force suffers a substantial drop from which it is apparently slow to recover. The question remains as to whether such a tradeoff is worthwhile. Although VAS cannot answer that question, it can at least provide quantitative input to help commanders make informed decisions.

Case 6: All Three Strategies

Once again, we consider the question of how different strategies interact. As suggested by the outcome of Case 4, strategies with similar objectives tend to diminish one another so that their combined effect is less than the sum of their individual effects. However, unlike expedited processing and forward-deployed depot-level repair, prioritized allocation does not aim to shorten the pipeline between the national level and the field.[25] Instead, it is intended to facilitate a dif-

[24]We did not attempt to compute an optimal fencing policy. Instead, we used a straightforward partitioning scheme that set aside 40 percent, 60 percent, or 80 percent of national-level assets depending upon whether an item's asset balance was high (greater than 1000), medium (between 100 and 1000), or low (less than 100).

[25]At least, not in a direct fashion, as by expediting requisition processing, hastening CONUS-to-field shipment, or partially eliminating the need for retrograde transportation and repair in CONUS. Prioritized allocation *can* reduce the backorder segment of the OST pipeline for *some* units by decreasing the likelihood that a backorder will even occur. Naturally, this will tend to increase the backorder rate and lengthen the OST pipeline for less-favored units.

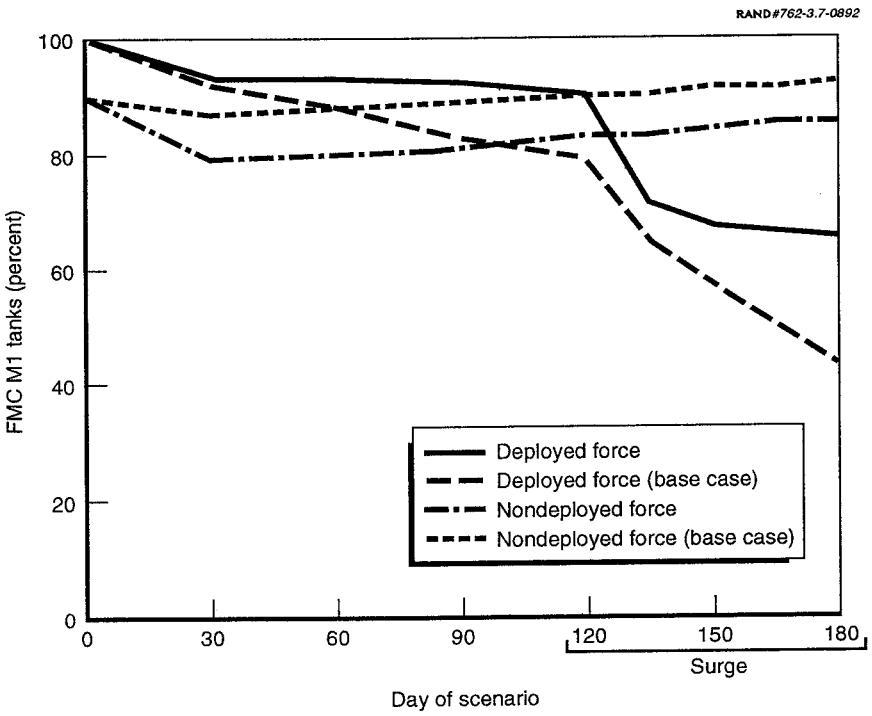

Figure 3.7—Case 5: Prioritized Allocation Only

ferential support concept by selectively improving and degrading supply availability across the force. Because their objectives did not seem redundant, we hypothesized that the effect of prioritized allocation would largely be additive to the combined effect of the first two strategies. As shown in Fig. 3.8, VAS reinforces this hypothesis.

Additional Notes

Even though all three of the strategies considered above appear to offer some improvement upon base case performance, their combined effect still falls short of the ideal in two respects. Among deployed units, M1 availability continues to drop sharply at the onset of combat on day 120; in the nondeployed force, it remains below 90 percent throughout the six-month scenario. If this were an actual planning exercise, more work would be required. Other promising strategies that could be evaluated with VAS include cross-leveling of ASL/PLL

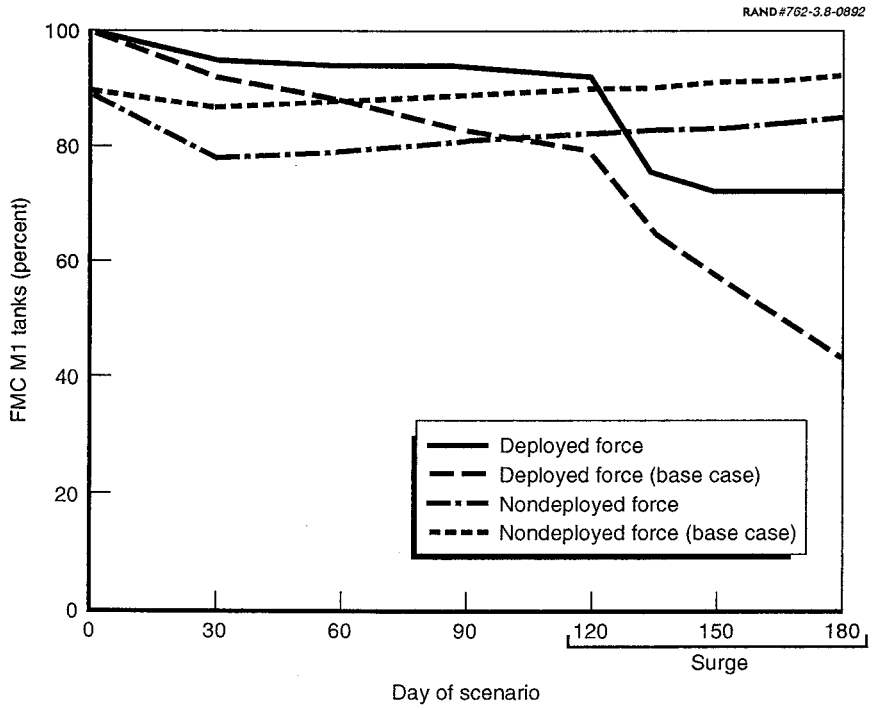

Figure 3.8—Case 6: All Three Strategies

assets from the nondeployed force to the deployed force, enrichment of deployed unit ASLs and PLLs with national-level assets, expedited procurement of problem items, engineering modifications to improve equipment reliability, and process modifications to streamline or even eliminate the need for certain types of maintenance.

ANALYSIS IMPLICATIONS

As emphasized earlier, *none of the results shown above should be taken literally.* The scenario underlying these cases is purely notional, many of the component data are highly suspect, and even the representations of the three readiness-enhancing strategies are sketchy in places. Why then should any of this work be given a second glance? Because all of these deficiencies can be addressed and corrected.

Numerous ongoing initiatives promise advances in current areas of weakness. For instance, TAV enhances the visibility of assets by

providing a systemwide view; ATCCS should improve the ability of logisticians to monitor the status of combat units; and VOICE is being designed to facilitate communication between operators and logisticians by translating planned operational activity into logistically meaningful terms (e.g., end item densities, optempos, attrition rates, and weapon system availability goals). STAMIS modernization will enhance both the availability and the accessibility of a wide variety of logistics data; the Army is heavily committed to such efforts. And the involvement of careful, knowledgeable planners will increase the fidelity and the quality of assumptions underlying representations of alternative support concepts and strategies.

Assuming for the moment that the problems described above will be overcome, the value of VAS as a tool for sustainment planning becomes more apparent. Our six case studies demonstrate its ability to address questions such as those asked by the CSA. We have shown how VAS can supplement and reinforce the judgment of unassisted planners, and perhaps more important, how it can provide insights (and explanations to back them up) that may not be intuitively obvious. For instance, we were surprised by the small gains realized from expedited processing and forward-deployed depot-level repair. From a purely item-oriented perspective, these strategies were expected to (and did) offer significant advantages. However, when rolled up to the weapon system level, their effects were greatly diminished. Although these were not "bad" strategies in an absolute sense, they certainly seemed to be less productive than many might have supposed. And although their apparent redundancy was not completely unexpected, it too may have escaped notice in an actual planning context.

Thus, VAS has the potential to help planners identify and avoid strategies that are not cost-effective or are ineffective in general. Consider that both Desert Express and the deployment of depot-level maintenance capability in ODS were very expensive undertakings. If our analyses here truly reflected reality, they would suggest that resources had been expended inefficiently. Certainly, the *combination* of Desert Express and forward-deployed depot-level repair would have been wasteful; it would have been better to have spent the effort and money first on the consumable items that appeared to be most critical to sustainment.

Although it does not explicitly treat the costs of all strategies that it is able to evaluate, VAS can contribute to cost-benefit analyses as described above. It can also help planners assess *availability* tradeoffs when existing resources are insufficient to meet all goals. For in-

stance, our cases suggested that without additional procurement of scarce assets, ODS availability could be significantly improved only by degrading the availability of the nondeployed force. Much as we might have liked to do so, we were unable to maintain an across-the-board availability rate of 90 percent, as was possible during peacetime in the base case. Under such circumstances, commanders need to understand the range of options available to them for spreading a limited amount of availability across the total force. Is a 90 percent/75 percent deployed/nondeployed mix possible? How far must the nondeployed force drop in order to raise the deployed force to 95 percent availability? And so on. VAS is well suited to providing this sort of decisionmaking input.

Finally, VAS could serve as a convenient mechanism for routinely monitoring equipment sustainability. Our work was hindered primarily by difficulties in constructing usable databases. If the Army can develop procedures for automatically extracting relevant data and scenario information from various STAMIS and other sources, it would be feasible to periodically perform a set of basic systemwide assessments. In fact, assessments of unit sustainability could be conducted on the same schedule by which readiness is reported. Not only would this focus management attention on sustainability issues and problems, but it might also alleviate much of the scrambling that otherwise seems likely to accompany any time-sensitive planning situation (witness the response to the CSA's questions).

4. LESSONS LEARNED IN THE DEMONSTRATION PROTOTYPE

Beyond demonstrating the ability of VAS to address important planning questions and to help planners evaluate and improve equipment sustainability, our work on this prototype has revealed a number of specific shortcomings that must be corrected before VAS can be implemented as an everyday decision support system. As intended, our findings center on the issues of feasibility (encompassing data availability, data accessibility, and the suitability of model structures and assumptions) and usability.

DATA AVAILABILITY

In assembling our database for the demonstration prototype, we were obliged to make many assumptions—some reasonable and others not so reasonable—about key parameters. More often than not, this was because of our inability to obtain needed data in a timely fashion (especially with the ongoing preoccupation with ODS) rather than the complete absence of those data. Indeed, much of what is needed to operate VAS can be found in one form or another in currently fielded STAMIS. Below, we categorize data into three classes: what already exists in reasonably good condition, what is missing, and what is suspect in terms of quality. Where relevant, we provide additional comments based on our experiences during this prototype.

Existing Data

Range of Components. The list of Class IX items to be included in a sustainability assessment is the most fundamental element of logistics data. The CIF satisfies a large part of this requirement by identifying all mission-essential LRUs.[1] We believe that even if these LRUs are the only items to be considered, VAS will produce useful and meaningful outputs. However, these outputs can be further en-

[1]Although the CIF would appear to contain all the "right" items, we feel that a review of the process by which items are selected is warranted. Contents of the CIF seemed more fluid than might be expected, as noted by the considerable difference in the number of AMCCOM-managed items from the previous year's total. MSCs should rethink whether items such as preformed packing, listed on the M1 CIF, are truly critical to the operation of the tank.

hanced by including SRUs that are important from the standpoint of equipment performance, cost, or scarcity.

The information needed to construct indenture relationships (i.e., "family trees" linking SRUs to LRUs and LRUs to weapon systems) exists in several places, including technical manuals, the PMR, and, partially, in Maintenance Allocation Charts. We understand that it can be a very labor-intensive effort to derive an indenture structure; however, this is not the sort of information that can be expected to change frequently or dramatically, so it would largely be a one-time effort. TACOM's own Fielded Vehicle Performance Data System (FVPDS) has some of this information on-line and that may be a good starting point, albeit for TACOM-managed items only (FVPDS, 1988). Eventually, if SLA's Usage-Based Requirements Determination (UBRD) initiative lives up to its promises, indenture relationships could be determined from the weapon system's updated PMR (Berger et al., 1992).

Demand Rates. The CIF is also a good source for usage-related item demand rates. Its MUBRs can be based on any one of four sources. In order of preference, these are: Field Exercise Data Collection (FEDC), SDC, NSNMDR failure factor 2, and engineering estimates. FEDC and SDC data reflect the demand histories of selected units in the field and are explicitly related to usage. NSNMDR failure factor 2 reports the number of demands per 100 vehicles per year and is obviously not related to usage (although it can easily be integrated with separate usage data if such data exist). Engineering estimates often predate weapon system fielding and are of unpredictable accuracy. FEDC and SDC databases exist for most major Army weapon systems, although collection efforts may no longer be ongoing. These data are as good as can reasonably be expected.[2]

Data describing battle damage demands may be found in the Sustainability Prediction for Army Spare Component Requirements for Combat (SPARC) study (Butler and Baun, 1987). The SPARC data are based on detailed shot-line analyses using results from test-firing experiments. Although very specific to the combination of attacking weapon (e.g., a particular type of munition) and the defensive posture of the target (e.g., a tank in hull defilade or fully exposed), SPARC data are extensive and cover many types of engagements.

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[2]Eventually, built-in usage meters may allow accurate equipment failure data to be collected for *all* units and weapon systems rather than just those participating in exercises or designated as SDC subjects.

Field-Level Maintenance Data. Information about maintenance pertaining to DS and higher echelons is found in MRSA's Work Order Logistics File (WOLF), the repository for data from the Standard Army Maintenance System (SAMS). The WOLF reports RCTs for all field-reparable items and further breaks them down into segments (e.g., hands-on repair, awaiting maintenance, awaiting parts, etc.). It should also be possible to compute MTDs from WOLF data by calculating the proportion of work orders that terminate with the *passback* of unserviceables for repair at a higher echelon (WOLF, 1989).

Data describing organizational-level maintenance (i.e., echelons below the DS level) will eventually be available through the Unit-Level Logistics System (ULLS). Until that capability exists, potential substitutes in this area include FEDC, SDC, and the Logistics Support Analysis Record (LSAR), which contains "measured" process times for a wide assortment of maintenance tasks.

National-Level Asset Balances. IMs at the NICPs uniformly express confidence in the accuracy of national-level asset balances as reported in Sector 5 of the NSNMDR. These data are updated constantly, and, as they are of fundamental importance to the daily business of the IMs, it is reasonable to suppose that considerable care is taken to keep them in good condition. That said, we must still consider the fact that of 128 TACOM-managed items in the CIF, we found only 85 with entries in the NSNMDR. A hit rate of only 66 percent of the mission-essential LRUs of a major weapon system is hardly impressive and needs to be investigated and explained. Perhaps the fault lies not with the NSNMDR but with the CIF. Of the entire 198 items, we noted 13 listed under at least two different (but interchangeable) NSNs, five listed twice under different federal supply classes, and one listed twice but with two digits transposed. Cleaning up such errors and redundancies should be a priority.

Field-Level Asset Balances. Although the NICPs have limited visibility of field-level asset balances, these data exist in field-level STAMIS such as the Standard Army Intermediate Logistics System (SAILS), the Direct Support Supply Standard System (DS4), and the Standard Army Retail Supply System (SARSS). SARSS represents a substantial gain in capability and when its fielding is complete, materiel managers at all field echelons should benefit from its greater accuracy and wider-ranging view (CSS, 1989).

Units maintain their own asset balance files (ABFs), which are not connected to STAMIS. Because it was impractical to obtain ABFs directly from units in the midst of ODS, we have no observations to make regarding their completeness with respect to the CIF.

However, we would expect a fairly high proportion of CIF items to be held in divisional ASLs; a low hit rate would bear investigation just as it does in the case of the NSNMDR at the national level.

Requisition Processing and Transportation Times. Data regarding OST and retrograde transportation can be found in systems maintained by the Logistics Control Activity. The Logistics Intelligence File (LIF) records the time of completion of each step in the order-and-ship process and can thus report OST in total and by segment (e.g., time required to issue an MRO, processing time at a containerization facility, actual shipping time, etc.). The Materiel Returns Data Base (MRDB) provides similar data for retrograde shipments (DA Pamphlet 700-30, 1990).

Missing Data

Operational Scenario Parameters. Typically, operations planners do not express plans and objectives in terms that are meaningful to logisticians. For instance, a plan to "apply maximum firepower to dislodge the enemy and seize objective X" does not convey a great deal of information about either the logistics resources needed to support it or the target level of weapon system availability that should serve as a goal for the logistics system. To some extent, military judgment on the part of logistics planners should yield an approximate sense of the force size, optempo, and attrition rates associated with a particular course of action or OPLAN. And, given the uncertainty surrounding all aspects of combat, some parametric analysis in this regard is always appropriate. Still, formal mechanisms for inferring logistics objectives from OPLANs would be extremely helpful. The VOICE concept addresses this issue and suggests a translating vehicle between operations and logistics.[3]

Environment-Dependent Demand Rates. Although the MUBRs specified by the CIF seem to be well-founded, ODS highlighted the absence of demand rate data for unusual environments. In theory, NSNMDR failure factor 3 specifies demand rate multipliers for different environments (e.g., arctic, desert, etc.). However, for most items, failure factor 3 is set to the default value of 1.0 (i.e., no environmental effect). It is not clear that anything other than extensive operating

[3]Conceivably VOICE might exist as part of ATCCS, which has access to both operations and logistics planners.

experience in the particular region of interest can provide reliable data of this sort.[4]

Depot-Level Maintenance Data. The depots do not appear to have an information system geared as SAMS is to individual jobs. However, for financial management purposes, they do track a number of relevant statistics at a more aggregate level (e.g., man-hours expended on an entire repair program). In addition, some depot shops keep informal logs indicating when items are inducted into repair and when they are completed. If such data could be entered into a STAMIS such as the Standard Depot System (SDS), it would be a simple matter to compute the average RCT for each item.[5]

In-Transit Asset Balances. Although the LIF and MRDB offer numerous statistics regarding *completed* shipments of materiel, they are difficult to use to monitor *in-transit* shipments. In-transit asset visibility is the focus of considerable attention both within the Army and the joint logistics community. Eventually, TAV (or some more specialized system) may provide higher-quality data than are now available. From the standpoint of VAS, however, it is unclear whether a greater level of detail is strictly necessary or can be exploited to advantage. It may suffice to know only that certain numbers of assets are in the OST and retrograde pipelines.

Suspect Data

In some instances, data may be available and accessible and yet be of dubious quality. It is important not to accept this sort of data at face value simply because it is easy to obtain. Instead, logisticians should either attempt to understand and correct any underlying deficiencies or seek alternative sources. Below, we consider three particular data elements that are suspect in terms of quality; in each case, we suggest a possible approach for resolving current shortcomings.

Repair Cycle Time. The most easily accessible values of RCT are those specified in the PMR and NSNMDR. However, as described earlier, these sources often contain values that are clearly not based

[4]Consider the following anecdote: when F-15 aircraft were originally exported to the Saudi Arabian Air Force, engine failures occurred at a much higher rate than at U.S. Air Force F-15 bases in the CONUS desert. The cause was eventually traced to differences in the chemical composition of the local sand. Had it not already known of and corrected for this condition, the U.S. Air Force could have faced serious engine shortages during ODS.

[5]VAS aside, better visibility of depot RCTs would be helpful in pipeline management and requirements determination.

on empirical evidence (e.g., 45-day DS RCTs for all items in the M1 CIF). SAMS/WOLF, ULLS, FEDC, SDC, and, to a lesser extent, the LSAR at least reflect actual experience in the field. These systems highlight the item-dependent nature of the repair process and provide a better reflection of prevailing conditions in such areas as repair capacity and capability and repair parts availability. Whereas these conditions may differ from one system to the next (e.g., FEDC captures only exercise data while the others are general purpose) and are subject to change over time, it nonetheless seems preferable in some applications to deal in real data rather than abstractions.

Maintenance Task Distribution. As in the case of RCT, MTD is most conveniently extracted from the PMR. And likewise, it is marred by the fact that values are rarely (if ever) updated on the basis of actual experience. The continued use of engineering estimates of MTD overlooks the possibility of deviations from original assumptions and changes that may have occurred in maintenance doctrine and capabilities and in equipment reliability and maintainability characteristics. The UBRD initiative may greatly improve MTDs by updating them regularly with actual usage data from STAMIS such as FEDC, SDC, and SAMS. The passback rate of unserviceables from lower to higher echelons determines MTD; if this is not already an explicit data element in SAMS and ULLS, it ought to be calculable with modest effort.[6]

Beyond supporting VAS, there are good reasons to obtain empirical MTDs. For instance, requirements determination methods can be fairly sensitive to MTD assumptions. Until UBRD is proven and working, we recommend that VAS be operated with inputs from SAMS/WOLF and ULLS.

Field-Level Asset Balances. Although field-level STAMIS may provide adequate asset visibility to their primary users, such visibility does not normally extend upward to the national level. Where it does (as in SIMS–X), the quality of data is generally considered to be poor. In the longer term, the fielding of TAV promises to provide accurate systemwide visibility at the national level. More immediately, however, the only viable option for national-level planners appears to be periodic extraction of ABFs directly from field-level STAMIS. The use of SIMS–X data may be acceptable in a VAS prototype environ-

[6]DS and GS passback rates can be derived by computing the proportion of work orders that terminate with a declaration of not reparable this station and a return of unserviceables for repair at the next higher echelon. Organizational-level passback rates can be estimated as the ratio of unserviceables processed at DS to the total number of unserviceable removals, taken over a long period of time.

ment, but only where a higher level of confidence exists (e.g., at TACOM) or when appropriate qualifications can be attached to assessment outcomes.

Data Elements as Control Variables

Up to this point, we have spoken of VAS data elements as though they are fixed quantities determined by historical experience. However, in the context of sustainment planning, this perspective is too narrow. To a large extent, the purpose of planning is to understand the consequences of changing the system; because the system is described by certain parameters, those parameters must be adjustable if alternatives are to be properly represented and assessed.

All of the data elements used by VAS can be set to either "real" or hypothetical values in the course of planning. Operational scenario parameters, of course, are inherently variable and are determined by the mission and the commander's guidance. Logistics data should also vary according to the question at hand. For instance, planners may lower demand rates in order to consider the benefits of improved equipment reliability. Changes to RCT and MTD may reflect proposed changes in repair capacity, efficiency, or capability (recall Case 3 in the previous section). Potential modifications to the support structure can be evaluated in part by adjusting the number of echelons or the transportation times between echelons. And, by varying stockage levels, planners can examine different resource mixes, allocation rules, and investment strategies.

DATA ACCESSIBILITY

Even when needed data are available, they are not always conveniently accessible. The difficulties associated with tapping multiple sources, extracting and processing relevant data elements, and assembling a single, consistent database can frustrate efforts to use quantitative tools like VAS. In a deliberate planning environment, such difficulties may be tolerable. However, in a time-sensitive situation such as that which arose at TACOM over the CSA's questions, they may be sufficient to prevent quantitative planning and assessment altogether. Although our work in the demonstration prototype centered more on data availability than on data accessibility, it soon became evident that a number of serious accessibility problems exist. We believe that these can be overcome if the Army remains commit-

ted to the idea of using more accurate and more accessible data to support management decisionmaking.[7]

Among the problems that we discovered were incompatibilities between information systems. Most of these did not present serious obstacles. For example, some of our data came from the CIF, some from FVPDS, and some from Model 204 databases.[8] All of these data were easily downloaded into the microcomputer-based database management system with which we were working. However, other sources were not so accommodating. At one time, we tried to obtain LSAR repair time data but were stymied by the fact that they were indexed against manufacturer part numbers rather than NSNs; processing these data into usable form would have been too complex and lengthy a programming effort for the time we had available. MRSA's developing Weapon System Analysis Management System may resolve most of these incompatabilities by validating and integrating multiple data sources into a comprehensive database.

In some cases, accessibility to certain data can be limited by the fact that these data are "available" only in principle. For instance, MTD is not routinely computed even though the raw data required to do so are collected directly in such systems as SAMS, FEDC, and SDC. Although the method for deriving such intermediate data may be clear, it may not always be possible to perform the necessary processing quickly enough to support time-sensitive planning applications. To avoid this problem, such data should be computed and updated as a matter of course.

Another rather obvious accessibility problem stems from the separation between national-level and field-level STAMIS. The most striking example of this is the national level's lack of visibility of field-level assets. Until TAV is able to bridge the gap, national-level planners will be forced either to use infrequent and hard-to-get ABF snapshots or to perform the extensive processing necessary to make sense of SIMS–X data. To a lesser degree, this problem also occurs with maintenance data. SAMS is partially accessible to national-level planners (albeit not in real time) via remote links to WOLF. However, the ability to use WOLF independently has not yet spread throughout the national-level logistics community. As long as MRSA continues to be called upon to supply the information needs of others,

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[7]Sustainment planning and assessment with VAS would be only one of several applications to benefit. For example, the requirements determination process uses models that are similarly data-intensive (SESAME, 1988).

[8]Model 204 is the standard mainframe database management system in use at TACOM. It provides access to the NSNMDR and other sources as well.

the potential for delays in data acquisition will remain. Such delays are especially apt to occur in times of crisis (as they did during ODS), when needs are urgent and planners throughout the system require data to support their analyses.

The diffusion across multiple MSCs of the item management responsibilities associated with single weapon systems further complicates data accessibility. The number of different data sources that may have to be tapped could increase in proportion to the number of MSCs involved. As outlined in Section 2, variable standards for the age, quality, and level of detail in each MSC's data can make the problem of data integration even more difficult and time-consuming.

MODEL SUITABILITY

The Dyna-METRIC model included in VAS proved to be a far less constraining factor in the demonstration prototype than the availability and accessibility of data. With only a few exceptions, we were able to represent the support structures, policies, and resource allocation strategies that we felt to be most interesting and relevant. However, it was also clear that enhancements in certain areas would offer a greater degree of flexibility in more complex planning environments. We discuss four of these below.

Prioritization Rules

An expanded selection of prioritization rules would be a valuable addition to Dyna-METRIC. In particular, the ability to more closely represent both RBMS and UMMIPS would lend greater substance and real-world perspective to comparisons of alternative strategies for allocating and controlling resources. In this context, recognition of time-varying weapon system availability goals would also be helpful.

Number of Echelons

Although up to four echelons of activity can be accommodated in Dyna-METRIC, it is not hard to imagine support concepts that require more.[9] The capability to consider five or even six echelons would give planners more freedom to combine speculative thinking with quantitative evaluation of their ideas. Although increasing the

[9]It is important to note here that *model* echelons are often used to represent special support arrangments that do not necessarily correspond to *real-world* echelons. For instance, in Case 5 in Section 3, the ODS-dedicated national-level supply account was represented in Dyna-METRIC by a separate "echelon" collocated with the "real" depot.

number of echelons in the model is not difficult from a conceptual standpoint, it is likely to be a tedious, time-consuming process.

Capacity-Limited Transportation

Dyna-METRIC has always represented the transportation function as a simple, stochastic delay in the passage of materiel between different locations in the support system. Likewise, it once represented (and still can, if the user wishes) the maintenance function as a delay applied to each unserviceable item before it becomes serviceable once again. Past success in modeling the effects of repair capacity limitations has fostered the notion of attempting a similar improvement with respect to transportation. Conceivably, Dyna-METRIC could be upgraded to recognize load capacities, traffic restrictions, and constraints in the availability of transportation resources. Any such development, however, will require careful design and testing. Even more important, users will have to rationalize the existence of an isolated Class IX transportation model when in fact Class IX assets are a nearly inconsequential portion of total military cargoes. In all likelihood, a capacity-limited transportation feature in Dyna-METRIC will make sense only in the context of high-priority, assured transportation systems for low-cube-weight, high-criticality items (e.g., essential Class IX items, high-tech munitions, and the like).

Multiple Usage Bases

Currently, Dyna-METRIC assumes that each item fails in accordance with a specific usage basis. For instance, tank transmission failures may vary with miles driven, whereas fire control computer failures vary with operating hours. The assignment of multiple usage bases to a single item is not allowed. However, such an assignment may be a convenient way to account for battle damage, which is apt to be a major cause of item failures in combat. To extend this idea even further, a separate set of maintenance parameters could be associated with each usage basis. In this fashion, battle damage repairs could be represented as being more (or less) time-consuming than repairs of usage-related failures; similarly, the probability of washing out (i.e., declaring unreparable) battle-damaged items may be set to a higher value.

USABILITY

Although it is flexible enough to represent a wide variety of support concepts, VAS can be difficult to use from the standpoint of assem-

bling inputs and viewing outputs. The demonstration prototype work reminded us that these largely mechanical tasks tend to be slow, cumbersome, unduly complex, and conducive to errors. Although well-trained analysts operating in a deliberate planning mode can easily adapt to such circumstances, this is no justification. VAS is intended to be usable by the broader community of planners in both deliberate and time-sensitive applications.

Clearly, there is a need to improve the user interface aspects of VAS. Planners should be able to assemble, update, and modify databases in simple, clear, and logical steps. They should be able to view key results directly, without first having to dig through surrounding output reports. Moreover, they should be able to manipulate those results in ways that permit examination in different combinations and from different perspectives.

Some developments that would greatly enhance the usability of VAS include:

- An interactive scenario builder to facilitate the assembly and integration of operational parameters.
- An interactive support structure builder to help planners translate concepts into appropriate configurations of echelons and locations.
- A spreadsheet or database management package to allow free-form viewing, editing, and transformation of input data (in contrast to the rigid, unlabeled card-column format used today).
- A similar spreadsheet or database management package to provide customized presentation of outputs (possibly with a windowing capability).
- A graphical interface to build an assortment of graphs, tables, and charts suitable for immediate presentation.

Although intelligence and creativity on the part of planners will always be prerequisites for successful planning, the easier it becomes to move from ideas to model representations to tangible outputs, the greater will be the acceptance of VAS as a usable and useful tool.

5. CONCLUSIONS AND THEIR IMPLICATIONS FOR FUTURE WORK

With this demonstration prototype, we have shown that in principle VAS is broadly applicable to national-level sustainment planning. We have illustrated how VAS can:

- Assess sustainability under different combinations of operational scenarios and logistics resources;
- Identify and characterize potential future problems;
- Evaluate the consequences of a variety of strategies for improving projected performance (e.g., greater responsiveness, more efficient support structures, and prioritized allocation of resources);
- Identify cost-effective support concepts and strategies.

On the other hand, we have discovered that as they stand today, Army STAMIS cannot supply all of the data needed to operate VAS under both deliberate and time-sensitive planning conditions. In some instances, required data are simply not available in currently fielded STAMIS. In others, the data are available but not easily accessible within the sometimes narrow time frames allotted for planning and assessment. However, we believe that data availability and accessibility problems can eventually be overcome. Many are being addressed through ongoing STAMIS modernization initiatives; others may require only a better definition and statement of need to be resolved.

For the moment, the Dyna-METRIC model embedded in VAS appears to be in a more advanced stage of development than its surrounding data systems. Nevertheless, we have identified several areas in which significant improvements can be made; model upgrades should proceed in parallel with STAMIS evolution. Beyond the modeling arena, a number of usability enhancements are needed to help planners assemble and modify databases and interpret output reports. Such enhancements are essential, particularly if VAS is to become an effective instrument for time-sensitive planning.

Although this demonstration prototype has identified and explored a number of key issues regarding the feasibility and usability of VAS, it has not gone far enough to settle them definitively. The issues of quantifying VAS costs and benefits and of estimating the cost of de-

veloping VAS need to be addressed. The work begun here needs to be extended in a national-level *operational prototype* that will expose VAS to more realistic conditions. Furthermore, a complementary field-level effort should be undertaken to evaluate the applicability and value of VAS at other echelons in the logistics system. These two recommendations provide the basis for the remaining discussion.

NATIONAL-LEVEL OPERATIONAL PROTOTYPE

TACOM and SLA are working cooperatively to design, develop, and exercise a national-level operational VAS prototype. The purpose of this effort is to confirm and build upon the findings of the demonstration prototype. By placing VAS in the hands of Army planners and using it in a variety of real-time applications, the operational prototype will provide a more complete picture of feasibility, costs and benefits, and usability. It will also serve as a test bed for evaluating database assembly procedures, new modeling capabilities, and user interface enhancements.

Many of the data assumptions described in this report can be justified only in the context of a demonstration prototype. The operational prototype should attempt to correct these deficiencies. It should provide the impetus to build links to a variety of STAMIS and to test different methods for extracting, processing, and integrating relevant data. It should also highlight any remaining data availability and accessibility problems so that logisticians can devise means for overcoming them. Finally, the operational prototype might help to shed more light upon the important issue of sensitivity to data accuracy and completeness. It could categorize data elements according to the degree to which their variation causes system outputs to fluctuate. Likewise, it could furnish indications of how those system outputs are affected by increasing levels of database detail; for example, completely specifying indenture relationships might not be as important as, say, accounting for the right subset of items. Such findings could give planners a better sense of where to concentrate data acquisition and quality control efforts.

The operational prototype will be used directly by Army personnel, thus providing an opportunity to evaluate the benefits of VAS, even if only in a qualitative sense. A systematic effort should be made to collect testimony from participants regarding such questions as:

- Does VAS address relevant questions?
- Does VAS help to formulate and choose useful strategies?

- Do its outputs furnish useful insights, or are they uniformly obvious?
- Is it a uniquely valuable tool?
- What conceptual weaknesses remain?
- What refinements are necessary?

In addition, it may be possible to construct a framework in which to estimate the benefits of VAS in a more quantitative fashion.

The application of VAS to real-time planning during the operational prototype will further emphasize the need for an enhanced user interface. The operational prototype is the proper vehicle for designing and testing ideas in this area. Prototype participants should be consulted both before and during the development of new input/output processors and graphics, spreadsheets, and database management tools. In this way, system usability upgrades will evolve to more closely reflect the needs of the intended user community.

FIELD-LEVEL PROTOTYPES

The VAS concept encompasses not only the national level but also field echelons as low as the division, although the work described in this report has a purely national-level flavor. The potential to use VAS in field-level sustainment planning and assessment has been asserted, but it has yet to be proven. Field-level prototypes paralleling the national-level demonstration and operational prototypes discussed above could be used to help establish the relevance and need for VAS at lower echelons.

The first step in developing a field-level prototype is to identify the questions faced by planners at that level. These will determine the range of applications that should be addressed and the capabilities and features that should be incorporated into that particular variation of VAS. Once these requirements have been defined, prototyping can follow a course similar to the one described here. Initially, the emphasis should be on demonstrating applicability in a field-level planning environment. In the context of such a demonstration, attention should be given to the issues of feasibility, costs and benefits, and usability. In addition, with the emergence of VAS at another echelon, the topic of inter-echelon connectivity (i.e., transmission and sharing of both input data and output reports) should be explored.

We believe that field-level prototype development should capitalize upon ongoing work at the national level. A focus on such prominent

TACOM-managed weapon systems as the M1 tank and M2/M3 fighting vehicles will exploit existing data acquisition efforts and allow work to be accomplished efficiently. In addition, the important question of multi-echelon integration of planning and assessment activities can better be addressed when both national-level and field-level prototypes are based on the same weapon systems.

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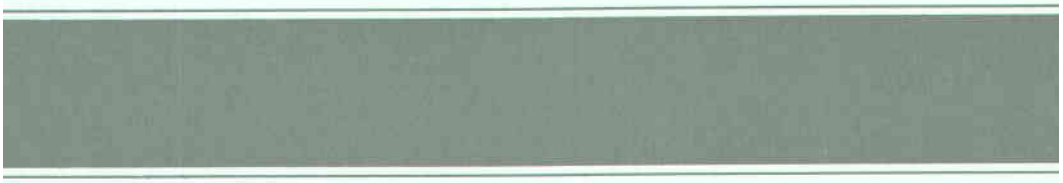
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