Arroyo Center

Diagnosing the Army's Equipment Readiness

The Equipment Downtime Analyzer

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PREFACE

Through the Velocity Management (VM) initiative, the Army has been working to adopt best business practices to make its logistics processes faster, better, and cheaper.[1] The goal of VM is to improve the Army's ability to keep equipment ready while reducing total support costs and enhancing mobility. At present, however, the Army has difficulty determining how logistics processes and equipment reliability affect equipment readiness. In contrast, many corporations have information systems that allow them to decompose operational results and determine how each process and each organization affects the bottom line.

Recognizing this gap in the Army's measurement capability, the Honorable Bernard D. Rostker, then Under Secretary of the Army and subsequently Under Secretary of Defense for Personnel and Readiness, and MG Charles Cannon, then the Army's acting Deputy Chief of Staff for Logistics (DCSLOG—now the G-4), asked RAND Arroyo Center to examine the feasibility of creating such a system for the Army (under the sponsorship of the G-4).

This document describes the results of that effort, the Equipment Downtime Analyzer (EDA). The EDA is a hierarchical set of metrics and a relational database that links process performance to equipment readiness, thus giving decisionmakers a tool for gathering and

[1]See Thomas J. Edwards and Rick A. Eden, *Velocity Management and the Revolution in Military Logistics*, Santa Monica, CA: RAND, RP-752, 1999, and John Dumond, Rick Eden, and John Folkeson, *Velocity Management: An Approach for Improving the Responsiveness and Efficiency of Army Logistics Processes*, Santa Monica, CA: RAND, DB-126-1-A, 1995.

interpreting the information they need. This document describes the EDA, how it works, and how it can inform decisionmaking, and it should be of interest to operators, logisticians, and materiel developers throughout the Army. In addition, it may provide ideas about information system structure and logistics analysis to logisticians in the Navy, Marine Corps, and Air Force.

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SUMMARY

The new Army Vision,[2] with its emphasis on rapid force deployment followed by immediate employment, demands logistics processes and robust equipment that enable soldiers to keep equipment ready to fight. Forces will have to pick up and go in the "readiness state" they find themselves in at the time they receive a deployment order, must arrive at the area of operation ready to fight, and then must have the ability to sustain a high level of equipment readiness. Achieving this, in turn, calls for dramatic progress in optimizing the Army's ability to keep equipment ready. This requires optimizing the logistics system's equipment sustainment processes as well as enhancing the companion processes—product development and recapitalization—that produce equipment reliability.

To do this, the Army must have metrics that realistically portray how well its equipment readiness capabilities support the Army Vision. These metrics should connect the underlying logistics and equipment reliability processes to equipment readiness and illuminate their interactions. Without the ability to make these connections and to see how the component parts fit together to create the overall picture, the Army could make some individual processes highly efficient yet still fall short of satisfying equipment readiness needs.

This document describes a conceptual framework for providing these capabilities and a new initiative, the Equipment Downtime

[2]General Eric Shinseki, U.S. Army Chief of Staff, and the Honorable Louis Caldera, Secretary of the Army, "The Army Vision Statement," *http://www.army.mil/armyvision/vision.htm,* October 1999.

Analyzer (EDA), which applies the basic principles of this framework to the extent possible solely by leveraging data collected by existing Standard Army Management Information Systems (STAMIS). It promises to facilitate the achievement of the Army Vision by providing an integrated set of metrics that tie the performance of equipment sustainment processes to equipment readiness, directly focusing efforts on not only the critical customer at the end of the Army's logistics chain—the warfighter—but also on what that customer cares about—keeping equipment operational.

THE NEED FOR METRICS

Today it is very difficult, if not impossible, to answer many critical operating questions reliably, consistently, and quickly. This is because the Army does not have a mechanism for "drilling down" into equipment readiness results to understand what drives readiness. This is in contrast to many corporations that have activity-based cost systems that help assess how each process and each organization within a firm contribute to overall operational results. With these systems, managers can see how all their processes and business units affect the bottom line. They know where the problems and opportunities are, which process improvements are paying off, and where additional leverage is possible.

THE EQUIPMENT DOWNTIME ANALYZER: WHAT IS IT, AND HOW DOES IT WORK?

The EDA is designed to give Army logisticians insight into equipment readiness comparable to the insight that activity-based cost systems provide to corporations with regard to their costs. It aims to increase the Army's understanding of how processes influence equipment readiness—and thereby to ensure that today's process improvements work synergistically, achieving the maximum possible impact. It enables managers to look inside equipment readiness results to understand the contribution made by each logistics process, by equipment usage, and by equipment reliability and to see how these factors combine to produce equipment readiness.

The EDA starts from the simple mathematical relationship that underlies the "not mission capable" (NMC) rate. The NMC rate is the product of the average end item repair time and the end item failure rate; a rate of 10 percent means that the equipment was not ready 10 percent of the time. Currently, the Readiness Integrated Database (RIDB) records the amount of time that equipment is down, but neither it nor any other Army STAMIS captures how many times each item failed or how long it was down each time. Thus, it is impossible to know which of these two principal components, much less which of their elements (such as customer wait time), is driving equipment readiness.

This is the heart of the challenge the Army faces when trying to make objective decisions on such issues as the need for recapitalization or when trying to understand the cause of NMC trends; there is little or no information about the relative contributions of failures and repairs to equipment readiness trends. Further, downtime is saved in monthly totals, making it difficult to systematically examine downtime in the field versus the motor pool. So this produces the second fundamental challenge: the lack of a clear, realistic understanding of how equipment readiness fares in demanding environments.

The EDA works by capturing a history, by day, of every reported deadlining event[3] across all supply and maintenance activities at all echelons that directly played a part in returning the deadlined system to fully mission capable status. From these histories, the EDA produces end item repair time and equipment failure rate metrics as well as several others not currently available, such as organizational-level repair time. Through the use of metrics that span all equipment readiness processes, the EDA provides a systems view that can detect whether changes in root-level processes, such as the wholesale order fulfillment process, “bubble up” to affect equipment readiness or whether reactions in other processes consume the improvement. The systems approach allows one to see reactions resulting from process interactions.

The systems approach provides a better understanding of how single actions affect the overall process. For example, the EDA highlights maintenance “workarounds” such as the controlled exchanges that

[3]A deadlining event is defined as an end item failure that causes the end item to be NMC.

occur when a requisition has been outstanding for an excessive length of time and maintenance personnel bypass the supply system to get the needed part. Without the detailed information supplied by the EDA, such efforts by maintenance personnel can hide underlying supply problems. In other cases, maintenance problems can be disguised as supply problems. For example, a misdiagnosis can trigger additional parts ordering late in a repair process. Without visibility of this event, an awaiting-parts problem may appear to be one of supply or requisitioning, when, in reality, the problem was one of misdiagnosis.

Figure S.1 illustrates an actual history recorded by the EDA for a deadlined tank. The tank was deadlined for 19 days, during which time there were three major repair segments: diagnosis and parts ordering, awaiting parts (AWP), and the actual "fix" process (often there is an additional delay—actually a fourth process segment—for part pickup and receipt by the maintenance organization). After the initial diagnosis, parts were ordered on day 2, and the tank was then AWP until day 18. The tank was then "fixed" and returned to fully mission capable (FMC) status one day later. The figure also shows the day on which maintenance ordered each part, when the part was issued, and the source of supply. For example, a wiring harness was ordered on day 2 and was supplied via an on-post referral, which was issued on day 5. Each day on which parts were ordered represents what we term an "order cycle." The second wiring harness was ordered because the wrong one was received the first time; the late extinguisher order resulted from delayed identification of a part need; and the tank's fire control computer was given to another tank. The causes of these order cycles are typical of the reasons we have documented thus far: controlled exchange, diagnostic problems, and requisitioning or part-delivery problems. Of further note, the second time the wiring harness was ordered, maintenance decided to stop waiting for an issue from supply and satisfied the need through a workaround on day 18, which allowed completion of the repair. By combining these detailed histories, the EDA can produce both repair process and reliability metrics at any level of aggregation from an individual tank, or even a tank part, through the entire Army fleet.

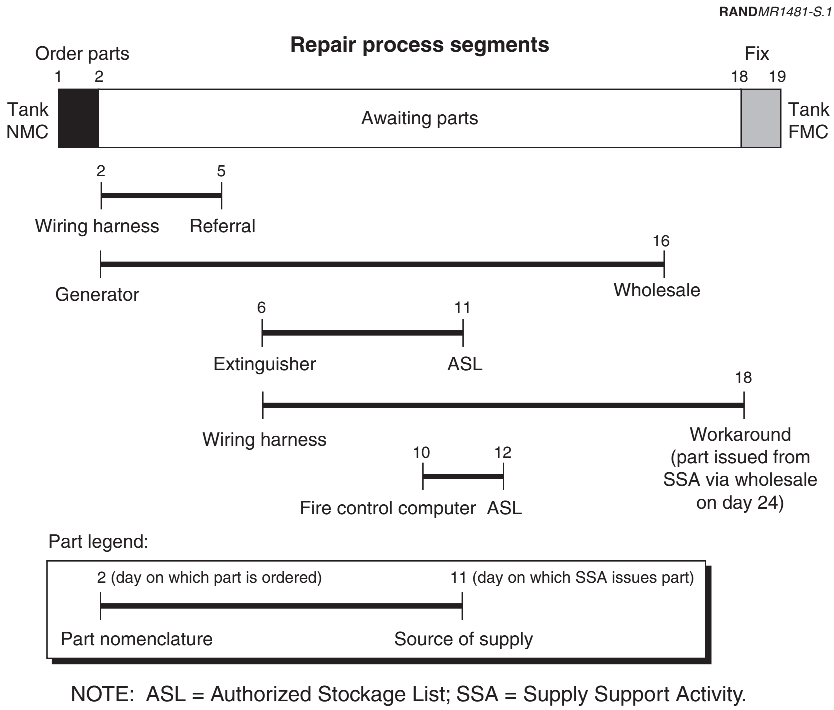

Figure S.1—Linked Maintenance Snapshots and Supply Data Create Cross-Functional Repair Records Across Echelons

With this detail, the EDA can also provide a much richer picture of equipment readiness than the one available today. The straight horizontal lines in Figure S.2 depict the monthly NMC tank rates for one Armor battalion. The jagged line shows the tank NMC rate by day. This line reveals highly volatile daily NMC rates that paint a much different picture of equipment readiness than the "smoothed" monthly rates, which combine periods of motor pool inactivity and training. As an example, in late July 1999, an exercise caused the NMC rate to increase from 5 percent to almost 30 percent in just four days. Once the battalion completed the exercise, it experienced just two tank failures during the remainder of the monthly reporting

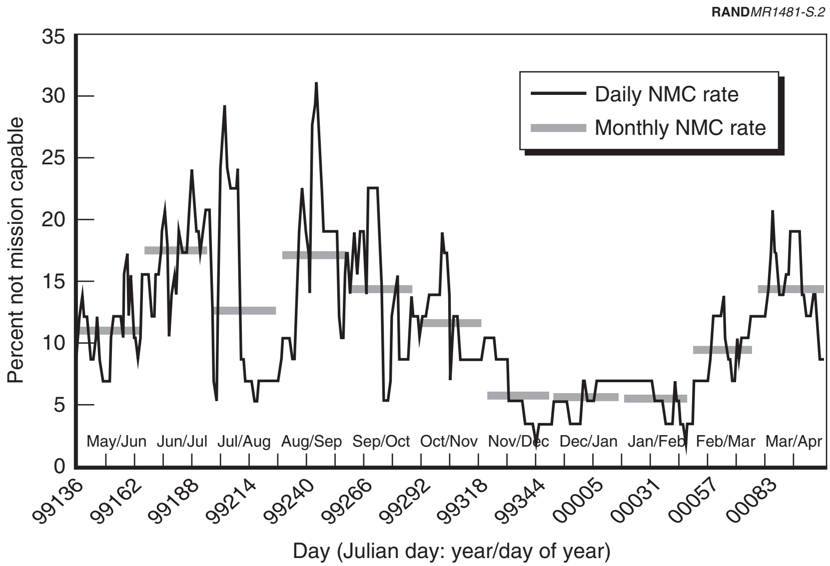

Figure S.2—Daily NMC Rates Produce a Much Richer Portrayal of Equipment Readiness Than Monthly Averages

period, recovering to 94 percent readiness in early August. As a result, the monthly NMC rate was only 13 percent, reflecting neither the battalion’s sustainment capability when equipment was actively used in a mission profile (which was worse) nor the condition of the tanks after recovery (which was better).

Once we understand sustainment capability and determine a need for improvement, EDA metrics shine the spotlight on the need to either improve failure rates or reduce “broke-to-fix” time, or both. From a total repair process perspective, decomposing the broke-to-fix process into maintenance levels and process segments to produce diagnostic metrics, as depicted in Figure S.3, can help illuminate improvement opportunities and identify where to focus efforts. The relative heights of the bars in Figure S.3 roughly represent the proportion of deadlining repairs that are executed at each echelon of maintenance, and the lengths of the process segments roughly represent their relative proportions of total repair time. By further decomposing awaiting parts time into its components—order cycles

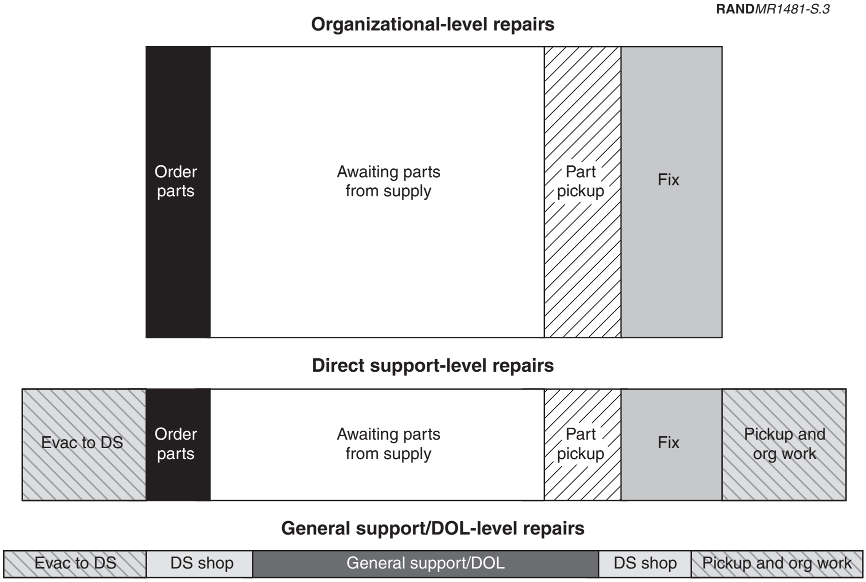

Figure S.3—Decomposing the "Broke-to-Fix" Process Is Useful for Downtime Diagnosis

(the number of unique days on which parts are ordered for a job) and last part customer wait time (LP CWT) (how long it takes to get all of the parts that are ordered on the same day for one repair)—and then the components of CWT,[4] we can drill down to find out how each process is affecting repair time.

IMPLEMENTATION OF THE EDA

The Army's G-4 has developed a plan to implement the EDA as a user-friendly, flexible tool with the design based upon feedback from users of the prototype system. In conjunction with the Combined Arms Support Command (CASCOM) and the Ordnance Center and

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[4]Overall CWT can be decomposed into the percentage of requisitions filled by each source of supply as well as the CWT for each source of supply. Sources of supply include Department of Defense wholesale distribution centers, direct vendor delivery, local maintenance, referrals, lateral transactions, and local inventory.

School (OC&S), the Army's G-4 created an EDA operational requirements document (ORD) and gained funding approval from HQDA for the integration of the EDA into ILAP as part of its migration into the GCSS-A management module. The needed data are being archived within the Integrated Logistics Analysis Program (ILAP) and the Logistics Integrated Database (LIDB).

The ultimate promise of this effort is an enhanced capability to focus constrained resources where they will have the greatest effect on keeping equipment ready to fight, whether by improving equipment reliability or by reducing repair time. By enabling logisticians and those engaged in the acquisition and recapitalization processes to examine which improvements will most likely lead to higher equipment readiness, the EDA should improve the Army's ability to sustain equipment readiness while reducing total support costs and enhancing mobility.

Several organizations are already making use of prototype data and metrics. A division has used the data to justify improved stockage through the estimated equipment readiness benefits, and to help identify end items for turn-in. A corps staff is using it to identify repair process improvement opportunities, and to help justify changes in stockage. A major subordinate command of the Army Materiel Command has used it for recapitalization plan analyses. The VM Repair Process Improvement Team is using it to identify opportunities for improvement in unit maintenance operations. At RAND, we are using the EDA to support other research efforts for the Army such as evaluating the effects of age and other factors on failure rates.

In the future, enhanced data capture at the operational level as GCSS-A is fielded will improve the power of the EDA to help the Army identify more efficient methods of achieving better equipment readiness. This should be complemented by seamless integration of the logistics and failure metrics produced by the EDA with other types of data such as personnel readiness, equipment usage, training schedules, customer wait time, repair quality, and scheduled service execution to enable more complete diagnosis of equipment readiness. Together, improved data and seamless database integration will enable the Army to build a comprehensive equipment readiness diagnostic system.

In all of its applications, the EDA and future derivatives will provide new, valuable information intended to help people in the Army conduct better analyses and make well-informed decisions about equipment sustainment.

ACKNOWLEDGMENTS

In early 1999, using existing Marine Corps data, RAND's Marc Robbins (one of the EDA development team members) prototyped the Marine Readiness Scorecard (MRS), a system based upon the same basic concepts as the EDA. A briefing on the MRS led the Honorable Bernard D. Rostker, formerly Under Secretary of Defense for Personnel and Readiness and at the time Under Secretary of the Army, and MG Charles Cannon, then the Army's Acting DCSLOG, to encourage us to pursue the research that led to the development of the Equipment Downtime Analyzer. We are grateful to MG Cannon for formally sponsoring this research based upon the promise of early-stage research. We thank MG Dennis Jackson, then Chief of Ordnance, for also recognizing the potential of the EDA at an early stage and actively championing its continued development through support provided by a team from the Ordnance Center and School. His deputy, COL Kone Brugh, has been an ardent supporter and has played an active role in moving the EDA forward. Throughout the development, Mr. Tom Edwards, Deputy to the Commanding General at the Army's Combined Arms Support Command, and LTG Charles Mahan, then Chief of Staff of the Army Materiel Command and now the Army's G-4, have provided feedback to improve the EDA and have continually envisioned new applications for the information it provides. They have also expressed strong support to others in the Army.

Within the office of the G-4, the enthusiastic support of Ms. Kathleen Schulin, Chief of the Retail Supply Policy Division, has been instrumental in moving the EDA toward implementation. First, MAJ Diane Del Rosso and then MAJ John Collie, as G-4 EDA action officers, did an excellent job of keeping the G-4 staff informed about the EDA's progress, preparing EDA documentation for the CS/CSS Transformation effort, and preparing proposals for EDA funding.

At CASCOM, Ms. Jan Smith, VM Repair PIT (Process Improvement Team) Manager, was the central figure in coordinating early-stage development and tying the EDA into the VM initiative. CW5 Jonathon Keech and CPT Doug Pietrowski of the Ordnance Center and School worked closely with Ms. Smith to coordinate the EDA's development, and they also served as technical advisors.

We owe our greatest thanks to CW3 David Cardon of the 1st Cavalry Division as the one person who really made the development of the EDA possible. His deep technical knowledge of both maintenance and supply STAMIS, combined with his expertise in division-and-below logistics processes, has made him a valued advisor on all fronts. From the beginning he has served as a key figure in developing the logic necessary to transform the EDA concept into an operational program, and he stepped forward to gain command approval and establish the first live data feed to test the concepts.

We gratefully acknowledge MAJ Rich Clark for bringing the EDA into the 4th Infantry Division. This second live data feed enabled validation of the logic developed with the first division. Active use of the data by the Division Materiel Management Center (DMMC) and others in the 4th ID has provided feedback crucial to improving the usefulness of the EDA's output and developing its production system interface requirements. SFC Gilbert and SFC Doak have enabled this work by establishing and maintaining a consistent flow of data.

At TACOM, we wish to thank Mr. Jerry Holly, Deputy Director of the Readiness Operations Management Directorate, and Mr. Tony Cuneo for their interest in integrating the EDA's information into their Real Time Situational Awareness Initiative. They have provided feedback valuable to developing focused applications for the U.S. Army Materiel Command.

At CALIBRE Systems we are indebted to Ms. Deb Kotulich for providing database extracts from ILAP as we expanded beyond the initial two divisions and for serving as a sounding board for technical issues. She also provided data extracts from ILAP that were used to help validate EDA logic.

At RAND, prior work by Kenneth Girardini, Mark Totten, and Darlene Blake in developing the concept of customer wait time (CWT) and CWT diagnostic metrics was crucial to developing the EDA's integrated maintenance and supply records. Throughout the EDA's development, Art Lackey has served as a valued advisor. Mitchell Wade and Rachel Hart, RAND communications analysts, also contributed significantly by focusing the document, improving the language, and suggesting sections that needed better explanation. Nikki Shacklett provided a very thorough and responsive final edit, and Pamela Thompson helped with graphics and formatting.

We are particularly thankful to John Dumond for his careful critiques and excellent recommendations through many iterations of this report. His experience provided valuable insights that enabled tailoring of this research for many different senior-level audiences.

GLOSSARY

AMC	Army Materiel Command
AREM	Army Readiness Equipment Module
ASL	Authorized Stockage List
AWP	Awaiting Parts
BN	Battalion
CASCOM	Combined Arms Support Command
CBS-X	Continuing Balance System—Expanded
CTASC	Corps Theater Automatic Data Processing Service Center
CWT	Customer Wait Time
DA	Department of the Army
DISCOM	Division Support Command
DLA	Defense Logistics Agency
DMMC	Division Materiel Management Center
DOL	Directorate of Logistics
DON	Document Order Number
DS	Direct Support
EDA	Equipment Downtime Analyzer
ER	Equipment Readiness
FMC	Fully Mission Capable

GCSS-A	Global Combat Support System—Army
GS	General Support
HEMTT	Heavy Expanded Mobility Tactical Truck
HMMWV	High Mobility Multipurpose Wheeled Vehicle
HQDA	Headquarters, Department of the Army
ILAP	Integrated Logistics Analysis Program
INOP	Inoperative
LIDB	Logistics Integrated Database
LOGSA	Logistics Support Agency
LP CWT	Last Part Customer Wait Time
MIRP	Master Inventory Record Posting
MMC	Materiel Management Center
NMC	Not Mission Capable
NMCM	Not Mission Capable—Maintenance
NMCS	Not Mission Capable—Supply
NTC	National Training Center
OC&S	Ordnance Center and School
OCONUS	Outside the Continental United States
OEM	Original Equipment Manufacturer
OPTEMPO	Operational Tempo
ORD	Operational Requirements Document
ORGWON	Organizational Work Order Number
PIT	Process Improvement Team (VM)
PLL	Prescribed Load List
PMCS	Preventive Maintenance Checks and Services
RDD	Required Due Date
RIDB	Readiness Integrated Database
RON	Request Order Number

RWT	[Wholesale] Requisition Wait Time
SAMS	Standard Army Maintenance System
SARSS	Standard Army Retail Supply System
SSA	Supply Support Activity
STAMIS	Standard Army Management Information System
TACOM	Tank Automotive and Armaments Command
TAMMS	The Army Maintenance Management System
TEDB	TAMMS Equipment Database
TK4	SARSS transaction code indicating receipt at supply
TRU	Thermal Receiver Unit
ULLS	Unit Level Logistics System
ULLS-A	ULLS–Aviation
ULLS-G	ULLS–Ground
USR	Unit Status Reporting
VM	Velocity Management
WOLF	Work Order Logistics File
WON	Work Order Number

Chapter One

COMPREHENSIVE EQUIPMENT READINESS METRICS ARE VITAL

The new Army Vision, with its emphasis on rapid force deployment and immediate employment capabilities, demands robust equipment and streamlined logistics processes that maximize the ability of soldiers to keep equipment ready to fight. The 96-hour closure target for a brigade and the 120-hour target for a division mean that forces will have to pick up and go in whatever "readiness state" they are in when they receive a deployment order, arrive at the area of operations ready to fight, and then immediately transition to sustaining a high level of equipment readiness during active operations. To achieve this transformation, the Army must optimize the logistics system's equipment sustainment processes and enhance the companion processes that "prevent" equipment failure, including product design, recapitalization, and preventive maintenance checks and services (PMCS).

Although developing and acquiring more supportable weapon systems is critical in the long term, process improvements and recapitalization programs will continue to draw major attention for several reasons. They:

- Are often achieved at relatively little cost compared to the procurement of new systems and sometimes can even reduce total costs by reducing both investment and recurring costs.
- Can reduce the assets needed to achieve a given level of results and to meet the demand for services or products (e.g., with improved maintenance diagnostic capabilities), thereby reducing the logistics footprint.

- Provide a hedge against problems that may arise when developing and acquiring more supportable weapon systems.
- Produce results almost immediately—results that will bear fruit throughout their long period of service and will also multiply the benefits provided by the next generation of weapon systems.

To ensure that logistics process and equipment supportability improvement efforts provide maximum benefit, the Army should have metrics that realistically portray how well its equipment readiness capabilities support the Army Vision. Only well-designed performance measures will give effective feedback to logistics system managers as well as weapon system developers. These metrics should directly connect the underlying logistics and failure-prevention processes to equipment readiness results to provide bottom-line feedback on improvement initiatives. Without these metrics, the Army could achieve far higher efficiency in some processes, yet still fall short of satisfying overall equipment readiness needs.

Chapter Two of this report reviews the Army's current reporting methods for equipment readiness and why they were developed, and it illustrates why the Army needs new metrics to better understand and diagnose equipment sustainment capability.

Chapter Three presents a general framework for measuring equipment readiness and linking it to process performance, and it introduces a prototype initiative based upon this framework, the Equipment Downtime Analyzer (EDA). The EDA leverages advances in information technology to better utilize data collected by existing Standard Army Management Information Systems (STAMIS). It provides an integrated set of metrics that tie equipment sustainment and reliability to equipment readiness.

The EDA has grown out of the Army's five-year-old Velocity Management (VM) initiative, which aims to improve support to the warfighter by improving the responsiveness and efficiency of logistics processes. To date, the success of process improvement efforts have been evaluated using logistics process metrics. The indirect focus on the warfighter has been largely a matter of necessity, because tools to link process improvements and logistics metrics to overall results have not been available. The EDA will allow VM and other efforts to take the next step, namely to focus efforts on what the critical customer at the end of the Army's logistics chain—the warfighter—cares about: keeping equipment ready for operations.

Chapters Four and Five illustrate potential EDA applications and describe the power of the EDA to provide more complete and effective information for managing equipment readiness than that available in the Army today.

Finally, Chapter Six looks at EDA implementation and some of the ways that the Army might enhance it through increased data integration, thereby improving its ability to help the Army understand equipment readiness.

Chapter Two

THE NEED FOR IMPROVED ARMY EQUIPMENT READINESS METRICS

In this chapter we will look at the Army's current equipment readiness reporting methods. An example that focuses on one Army division, and one battalion within it, will then illustrate why the Army needs new metrics to better understand its equipment readiness or sustainment capability. Next, we will discuss the need for metrics that go below the surface and reveal *why* equipment readiness capability is what it is. These are the metrics that are necessary to diagnose problems and to identify the best opportunities for improvement initiatives. But first, what is the objective of measuring at all? We start this discussion by reviewing the measurement goals the Army has set for its readiness reporting system.

WHY MEASURE? UNIT STATUS REPORTING

The objective of the Army's readiness reporting system, called Unit Status Reporting (USR), is to measure an organization's readiness to accomplish its assigned mission—in other words, to measure how ready it is to go to war today and how effectively it could prosecute the war.[1] USR aims to answer three questions:

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[1]The "objectives of the USR system are to provide the current status of United States units to the National Command Authorities (NCA), the office of the Joint Chiefs of Staff (JCS), HQDA, and all levels of the Army chain of command. In addition the USR system provides indicators to HQDA that:

1. Portray Army-wide conditions and trends.
2. Identify factors that degrade unit status.

- Do the units have the correct number and mix of personnel?
- Are the personnel and the units properly trained?
- Do the units have the correct equipment, is it operational, and can it be kept operational (given that it is not damaged or destroyed by the enemy)?

With the answers to these questions, USR is intended to reveal trends in readiness, identify the factors that affect readiness, inform resource allocation, and facilitate judgments about the deployability and employability of units.

So the Army measures equipment readiness to:

- Assess the readiness of Army equipment in the event it is needed for an actual deployment. Is the equipment ready to go?
- Understand how well the Army could sustain equipment in the different situations in which its use is anticipated. When the equipment is deployed and then employed, how well can the Army keep it working?
- Detect changes in logistics support performance and failure rates. Are any new problems developing Army-wide?
- Understand what drives the Army's capabilities to keep equipment operational and where there are long-term problems in sustaining equipment. This in turn should guide improvement efforts—both in weapon system development and in the logistics system.

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3. Identify the difference between current personnel and equipment assets in units and full wartime requirements.
4. Assist HQDA and intermediate commands to allocate resources.
5. Allow senior decision makers to judge the employability and deployability of reporting units.

Unit status reports are designed to measure the status of resources and training of a unit at a given point in time." Army Regulation 220-1, *Unit Status Reporting*, Washington D.C.: Headquarters, Department of the Army, 1 September 1997.

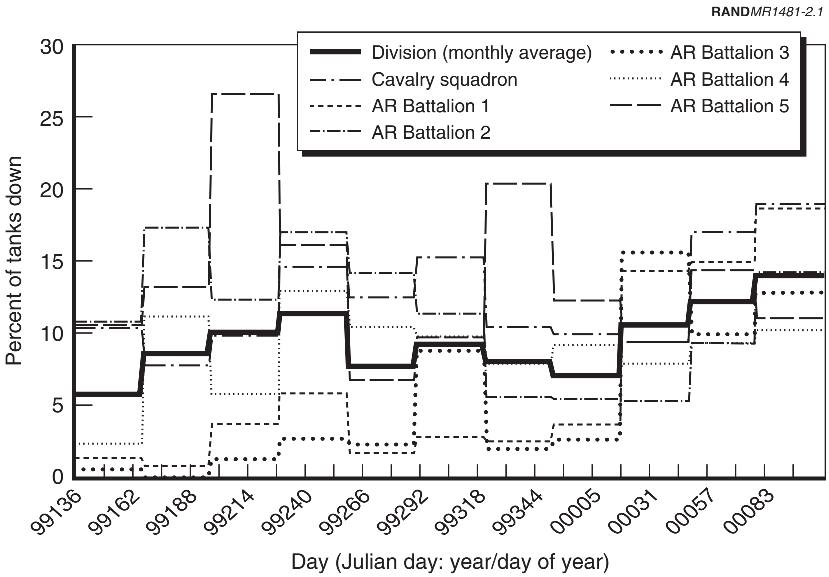
HOW DOES THE ARMY MEASURE EQUIPMENT READINESS TODAY?

The Army measures and reports equipment readiness (ER) as the percent of a given fleet for a given organization that is fully mission capable (FMC) from the 16th of each month until the 15th of the next. Such division-level ER rollups are reported to the Joint Staff for use in evaluating overall division readiness, and the Army further aggregates the data to provide Army-wide fleet ER information. These measurement techniques are an artifact of the Army's legacy information systems, which were developed in a era when computer memory was expensive, digital communications were slow, bandwidth was limited, and electronic communication capabilities were not widely distributed. Thus the Army designed a reporting system that aggregated information in as compact a form as possible (across time and units) and minimized the frequency of data flow from input sources (once per month). This reduced the requirements for memory and bandwidth.

Short-Term Variation in Equipment Readiness Is a Function of Training Schedules

To illustrate what these measurements look like, in Figure 2.1 we present ER results using the Army's standard reporting methodology for the tanks of one division and its six battalion-sized units that have tanks (five armor battalions and one cavalry squadron). The root data are the same as those used for the official readiness reports, but they were gathered prior to aggregation and processing by the STAMIS. The resulting "not mission capable" (NMC) rates are similar to, but somewhat different from, actual reported ER results. The reasons for the differences are discussed in Chapters Four and Five.

The chart begins on the left with the 136th day in 1999 (99136) and continues to the 96th day of 2000 (00096) on the right. The thick, discontinuous line depicts the percentage of the division's tank fleet that was down each month (from the 16th of each month to the 15th of the next), which is defined as the monthly NMC rate. The fainter lines in the background are the corresponding monthly tank NMC rates for the division's five armor battalions and its divisional cavalry squadron. By definition, the division monthly NMC rates are simply



SOURCE: Daily deadline reports.

NOTE: Monthly average numbers replicate current reporting method, which averages downtime from the 16th of each month to the 15th of the next.

Figure 2.1—Monthly Tank Readiness in a Division and Its Component Battalions

the weighted averages of the battalions' rates. Changes and trends in the division's monthly NMC rate are not typically the result of any systemic improvement or degradation in logistics performance or failure rates across the battalions. Rather, as most readers familiar with the Army will have already discerned, the battalion-level rates vary broadly from month to month, mostly in direct relationship to the battalion training schedules, which dictate how much the equipment is used. So variation in the division's NMC rate comes primarily from the proportion of units at high, medium, and low levels of training intensity each month.

The fundamental difficulty the Army faces when evaluating its ability to sustain equipment is that most of its equipment sits in motor pools for the majority of the year with short, intense periods of use during training exercises. During some months, equipment will sit idle for the entire month, and even during heavy training cycles it is very unusual for equipment to be actively employed in exercises for an entire month. The proportion of a month in which a unit is training accounts for much of the variation in monthly NMC rates for a given battalion (although the relationship between this proportion and the NMC rates varies significantly among fleets and units). If most battalions struggle to meet ER standards for a given fleet, the division will struggle during months in which OPTEMPO is high for several battalions and do better only during months in which OPTEMPO is more moderate.

In essence, for battalions, measures of ER represent a weighted average of high ER when equipment is idle in motor pools and lower ER when it is actively being used. At higher levels of aggregation, the measures are averages of these averages (which vary primarily as a function of monthly OPTEMPO). The more ER is aggregated across echelons and over time, the more the effects of actual usage are smoothed and hidden. But though it hides what performance looks like during periods of intense usage, aggregation does have some value. Given that overall Army OPTEMPO is similar from year to year, changes in aggregate fleet ER from year to year generally reflect some systemic change in failure rates or logistics responsiveness. So the current aggregate measures facilitate the third purpose of ER reporting described earlier: signaling systemic changes in fleet failure rates or logistics responsiveness. However, aggregate metrics that rely on the bulk of the Army completing a training cycle to clearly indicate a change provide delayed feedback of problems. Today, if a fleet or division does worse than usual one month, that result tends merely to indicate a higher-than-average level of usage that particular month across the fleet or division. Less often it reflects that a problem has developed. But the distinction is often unclear. Compounding this difficulty is an inability to decompose ER into its root elements, which is a problem we will discuss further in Chapters Three, Four, and Five.

We should note that in many types of organizations, measuring ER in this fashion provides effective information, because their equipment usage is much steadier. Airlines fly their aircraft every day, and the Air Force, Navy, and Army aviation units operate their equipment fairly continuously to keep pilots trained. Trucking companies use their trucks every day, as do most other organizations that operate fleets and other types of equipment, such as factories. The Army is somewhat unique, then, and this calls for a different type of ER measurement.

A Closer Look at One Battalion Illustrates the True Volatility of Equipment Readiness

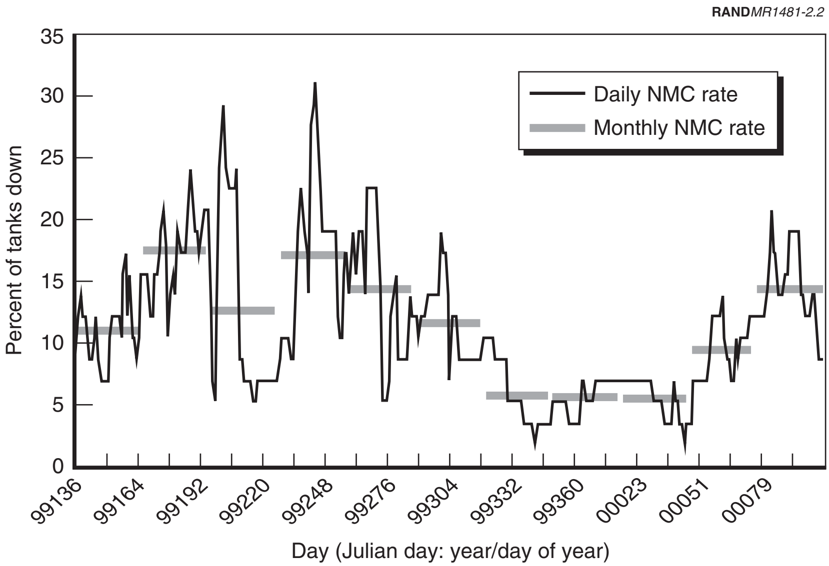
We have suggested that current ER reporting does little to address its purpose of providing an understanding of how well the Army can sustain equipment in different usage conditions. Examining ER for one battalion in detail will better illustrate this gap. The graph in Figure 2.2 was constructed using the division's daily deadline reports, a list of all end items that are NMC, commonly known as the O26 print.[2] The black horizontal lines depict the monthly tank NMC

[2]End items with failures that render them NMC (as specified in the end item's technical manual) are considered "deadlined." The O26 print is a daily printout that lists an organization's current deadlined reportable equipment, the reason for the deadline, and the necessary parts still needed to complete the repair. It is called the O26 print because it is produced from the "aho26i" file in the Standard Army Maintenance System Level 2 (SAMS-2) management system, which will be described in more detail later in this report.

The monthly rates in this and the other charts in the report, while similar in trend, are likely somewhat different in value from what was actually reported in the official Army equipment readiness reporting system, the Readiness Integrated Database (RIDB), for two reasons. Both start from the same data-entry source, the Unit Level Logistics Systems (ULLS), described later in the report. However, the data take different routes to the RIDB and EDA. The EDA draws data from the daily O26 print root files. However, the RIDB gets summarized data from each unit at the end of monthly periods (ending on the 15th of each month). These summaries are kept in ULLS.

Units sometimes have problems with the daily deadline report file in the SAMS-2 that results in items being cleared from their ULLS computer but left on their daily deadline reports past the actual date on which they are returned to FMC status. Units often refer to these as "ghosts." These down days are included in the EDA but not in the RIDB.

The second reason results from different definitions of when items become FMC. For official readiness reporting purposes for work orders evacuated to direct support (DS) maintenance, an item is considered FMC once the DS work is complete (as long as there are no outstanding organizational-level deadlining faults). If a unit does not pick up an item and then close the organizational work order on the same day that its supporting DS shop closes its work order, the unit may backdate the FMC date in ULLS to the day on which the work order was completed at the DS shop and enter "S" status (closed, completed this maintenance activity). The EDA keeps the clock counting until the organizational work order is closed in ULLS. So there may be a



NOTES: One armor battalion's tanks (based on daily deadline reports). Monthly average numbers replicate current reporting method, which averages downtime from the 16th of each month to the 15th of the next.

Figure 2.2—Daily NMC Rates Are Extremely Volatile

rates for one battalion. The jagged line shows the daily tank NMC rates, revealing high volatility that paints a much different picture of equipment readiness than the smoothed monthly rates.

Figure 2.3 adds the actual number of daily failures, indicated by the columns. As expected, the spikes in the NMC rate correspond to days on which a high number of failures occurred, including two days on which eight of the battalion's 58 tanks failed. Almost all short-term variability in NMC rates is the result of the varying num-

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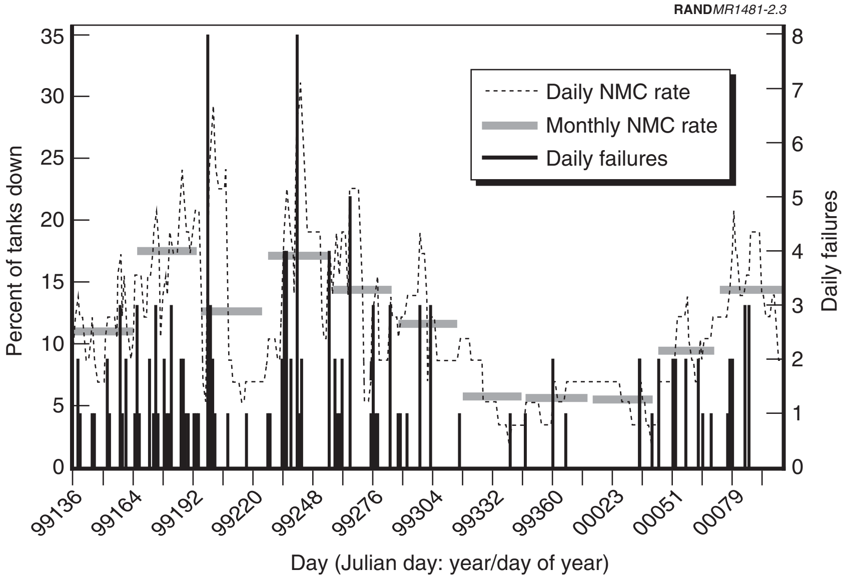
difference in recorded downtime between the RIDB and EDA generated by the sum of times from "S" status until organizational work order close dates for all support-level repairs. See page B-11 of the *Standard Army Maintenance System Level 2 (SAMS-2) End User Manual* (AIS Manual 25-L26-AHO-BUR-EM), Washington, D.C.: Headquarters, Department of the Army, 30 June 1994, for a list of work request status codes considered NMC for readiness reporting.



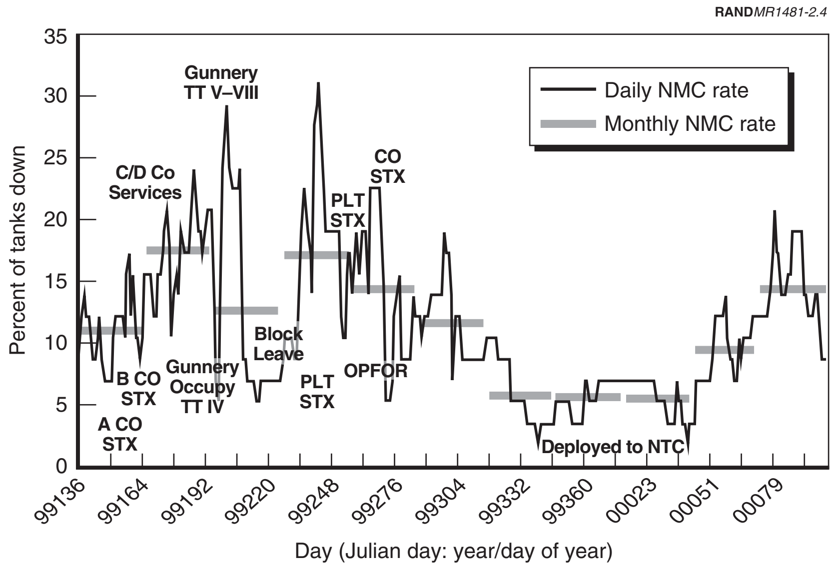
NOTES: One armor battalion's tanks (based on daily deadline reports). Monthly average numbers replicate current reporting method, which averages downtime from the 16th of each month to the 15th of the next.

Figure 2.3—NMC Rate Variability Is Driven by Equipment Failure Patterns

ber of failures. Logistics performance exhibits much less variability. In this example, the correlation between monthly failures and monthly downtime is highly significant at 0.93.

As one would expect, the high failures, and thus the NMC rate peaks, generally correspond to exercises (as illustrated in Figure 2.4), although scheduled services can also produce failure and downtime spikes. When an exercise occurs, the NMC rate climbs sharply, and when it is over, the rate drops rapidly, albeit typically more slowly than it climbs. As a result, daily tank NMC rates more clearly reflect the battalion's ability to sustain readiness when the equipment is being used than do monthly rates.

The daily rates make two things clear. First, when a unit trains, its daily NMC rate often climbs way above the monthly measurements. Second, ER information ages rapidly, rising and falling sharply in a



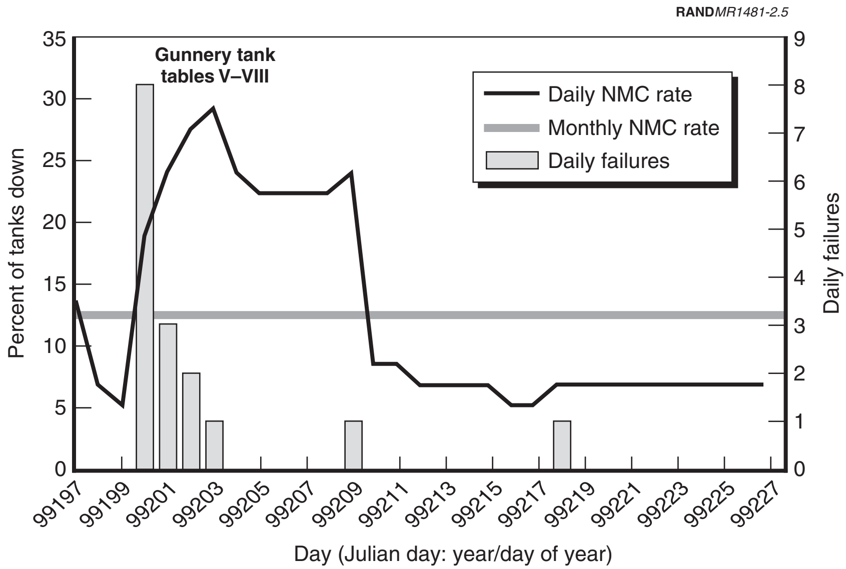
NOTES: One armor battalion's tanks (based on daily deadline reports). Monthly average numbers replicate current reporting method, which averages downtime from the 16th of each month to the 15th of the next. Training schedule available for fiscal year 1999 only.

ABBREVIATIONS: CO = Company; C/D Co = C and D company; TT = Tank table; PLT = Platoon; NTC = National Training Center; OPFOR = Opposing force; STX = Situational training exercise.

Figure 2.4—Monthly Battalion Rollups Do Not Effectively Communicate Sustainment Capability in the Field

matter of days. Since training events rarely last an entire month, monthly averages almost always mix periods of heavy equipment usage with periods of equipment idleness.

In Figure 2.5, the average NMC rate, daily NMC rates, and daily failures are depicted for the third month in the previous figures. A level one gunnery qualification during the first week of the month resulted in the failure of 14 of the battalion's 58 tanks, which drove the NMC rate from 5 percent to almost 30 percent in just four days. Once the battalion recovered from the exercise, it experienced just two tank failures during the remainder of the period. As a result, the monthly



NOTES: One armor battalion's tanks (based on daily deadline reports). Monthly average numbers replicate current reporting method, which averages downtime from the 16th of each month to the 15th of the next.

Figure 2.5—The Average NMC Rate Poorly Reflects the NMC Rate During Gunnery or After Recovery

NMC rate, which averages the two extremes, was only 12.5 percent. This average reflects neither the battalion's sustainment capability when equipment was used in mission-oriented profiles (which was worse), nor the condition of the tanks after recovery (which was better). In other words, the Army's current method for measuring ER does not accurately reflect the number of tanks prepared for missions on any day during the month—described as the first purpose of ER reporting—or at the end of the month when the reports are compiled, and it does not effectively communicate how well the Army can sustain its equipment in anticipated missions.

IMPROVING EQUIPMENT READINESS MEASUREMENT

To provide information about whether the Army's equipment is operational on any given day, metrics based upon the daily NMC rate would be more useful, because it can change very rapidly—such as from 5 to 29 to 9 percent over a period of just 11 days in the previous example. To measure how well a unit can sustain its equipment in the field in mission-type conditions to facilitate assessments of an organization's deployability and employability, the Army should focus on how ER responds during conditions as close as possible to those anticipated during missions. The patterns and peaks during training events communicate this much more clearly than monthly averages.

The next step would be to compute equipment readiness rates during major training exercises as depicted by the thick horizontal bars in Figure 2.6, which show the average NMC rates during battalion-level training exercises and gunneries for an armor battalion. These could be recorded and tracked by exercise types. Trends in exercise performance would be more informative than overall trends in average readiness that mix motor pool and exercise activity.

Today's readiness reporting allows flexibility in how units meet their monthly goals (90 percent for ground equipment and 75 percent for aircraft). If they hit a big NMC rate peak in gunnery, they know they have to find ways to get deadlined end items off the deadline report and ensure that they do not "bust fleet" (not achieve the Army goal for the month). The ability to manage "days to bust" puts an emphasis on getting old repairs off the deadline report—hence, an almost manic focus on aged repairs.[3] Units can avoid busting fleet after poor performance on a field exercise if they do a good job of clearing the report afterward. Yet, when availability really mattered, it wasn't there during the exercise. This is becoming ever more

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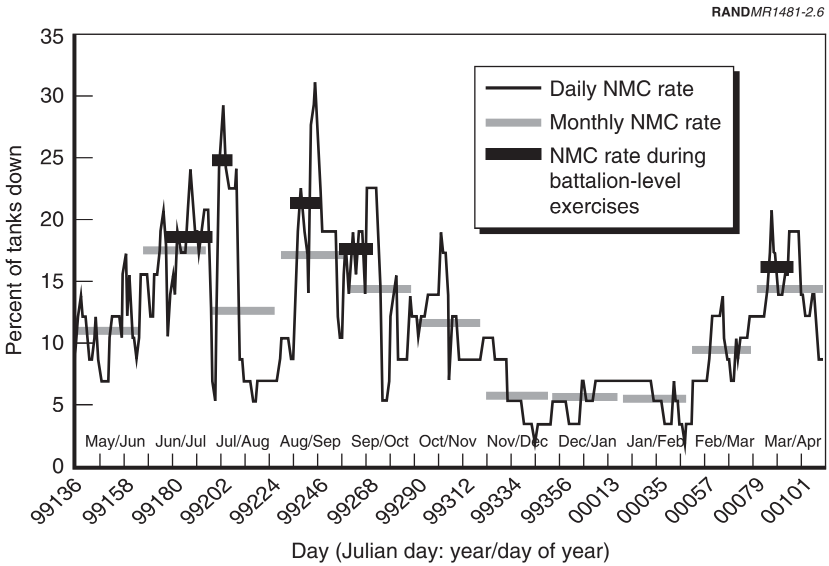
[3]Based upon the number of systems they have and the length of the reporting period, most units determine the number of days on which they can have a particular type of equipment down and still achieve the equipment readiness goal for the reporting period. Then each day they track the number of "bank days" remaining. Based upon that number, they can then calculate the "days to bust" if their equipment readiness stays at the current day's rate.



NOTE: One armor battalion’s tanks (based on daily deadline reports).

Figure 2.6—Measuring Combat or Training “Pulse Availability” Would Give a Different Picture of Capabilities

important as the Army moves to the “pulse” concept.[4] An emphasis on NMC rate peaks could not be “gamed” in the same manner (it could be gamed, however, by not reporting NMC events, which can also occur in the current system). Today, everything—the logistics system and weapon system development—usually looks fine, because units generally find a way to hit 90 percent ER for critical systems. And as long as they hit 90 percent (or 75 percent as appropriate), they are usually satisfied. In effect, leaders tend to manage the metric. They react when “bank days” or days to bust get low instead of finding ways to systematically avoid the problems in the first place.

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[4]In the pulse concept, units would be self-sufficient for the duration of a combat pulse, which would be a period of continuous operations. Pulses would be interspersed by refit periods during which deferred and anticipatory maintenance would be performed and during which replenishment would occur.

Emphasizing NMC rate peaks would put much different kinds of pressure on the system. The only way to avoid peaks is to reduce the failure rate during exercises (or actual deployed operations) or to very, very quickly complete repairs. For example, unless the repair process is exceptionally fast (i.e., one day or less), regardless of the maintenance resources you have, if 20-plus percent (for example) of your force fails in two days, you will temporarily have a high NMC rate. Visibility of high NMC rate peaks would put pressure on developers to provide more reliable equipment, on units to perform better preventive maintenance checks and services (PMCS) and scheduled services, and on the Army to fund prognostic technologies that enable units to shift exercise or combat pulse failures to pre-exercise "anticipatory" repairs (similar in intent to PMCS and scheduled services). This would not relieve pressure on the logistics system, though. When failure spikes do occur, you want them to start from a position of maximum readiness so that the NMC rate peaks will be as small as possible. And of course you want the repairs completed as quickly as possible—ideally before the next group of failures occurs and quickly enough to return items to mission capable status during a combat pulse.

Perhaps most important, different types of goals can sometimes be achieved in different ways. For example, if units always received parts in exactly seven days, they would almost never have to worry about not achieving monthly targets of 90 percent or 75 percent in peacetime, even during months of fairly high OPTEMPO. However, this would do little to affect the NMC peaks or the NMC rates during pulses that we have illustrated in this chapter. Take, for example, a seven-day combat pulse or exercise. To affect the NMC rate during the pulse, repairs must be completed inside the envelope of the combat pulse or exercise. So getting a part in seven days would not help during the pulse. Only those repairs for which parts could be obtained locally, either through local stockage or controlled exchange, could be completed.

This does not mean, however, that getting all parts in seven days would not be extremely valuable. This would enable an organization to quickly replenish its stocks, thereby enabling it to achieve effective local stockage with little depth of stock.

A BROADER LOOK AT EQUIPMENT READINESS

Daily and pulse NMC rates begin to provide a more accurate picture of how effectively the Army can sustain its equipment in the field from what one might call the performance or results approach. A more complete picture of the readiness of the Army to sustain equipment might combine this with another approach that assesses the readiness of the resources and capabilities necessary to generate equipment sustainment capability. A few key factors would be stockage capabilities and readiness (retail and wholesale), maintainer readiness (number, skill mix, and training levels)—which is basically already a part of personnel readiness reporting—and distribution effectiveness.

METRICS SHOULD ALSO REVEAL THE "WHY" BEHIND EQUIPMENT READINESS

Measuring daily equipment readiness would improve the Army's ability to know how ready its equipment was at any given point in time, and measuring exercise ER or daily NMC rate volatility would help the Army better assess its projected equipment sustainment capability during missions. However, these measures serve only to describe performance and to help detect the presence of trends in ER. The next level, as reflected by the "diagnostic" USR goal, is a need to know why ER is what it is so that it can be improved. What are the drivers of ER, and how should resources be allocated?

To successfully diagnose ER, the Army must understand how failure rates and the responsiveness of the logistics system to those failures contribute to ER. Decomposing ER into its two basic components—how often things fail, or the failure rate, and how long they are down when they fail, or the broke-to-fix time—provides this information. This is illustrated in Figure 2.7. ER is simply one minus the NMC rate, which (in the limit) is the product of the failure rate (defined in terms of clock or calendar time) and the average broke-to-fix time.

Current Army measurement systems provide monthly ER numbers, but they do not preserve the number of equipment failures or the number of days that each item was down—bringing us back to the aggregation of information to reduce memory and communication requirements. Therefore, the Army might know that a battalion's

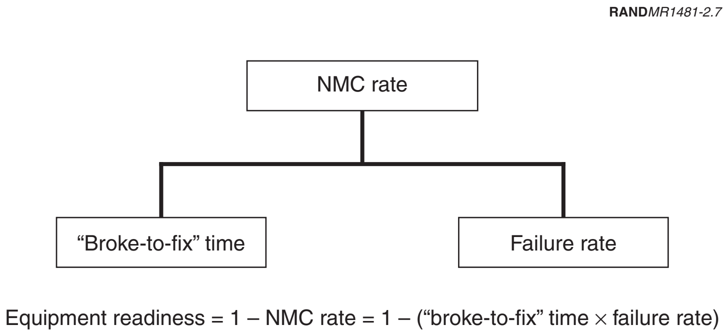

Figure 2.7—The NMC Rate Is a Function of the "Broke-to-Fix" Time and the Failure Rate

tanks were down 170 days during the previous month, but not whether there were 10 failures down for an average of 17 days or 34 failures down for an average of 5 days. In the first case, we would want to know why the equipment was down so long. Where were the delays in the logistics system? In the second case, we would want to know why the equipment failed so often. Is there a problem with design reliability, repair quality, or preventive maintenance?

To discern this information, the Army needs new metrics for diagnosing ER, starting with failure rates and total "broke-to-fix" time. The VM initiative—which brings to the military process innovations that have proved successful in the commercial sector—has confirmed the importance of well-designed metrics.[5] Only with the right metrics have Army logisticians been able to diagnose and dramatically improve process problems and then evaluate the effectiveness of those improvement efforts.

New metrics have enabled VM teams to target and measure improvements in individual processes, such as the wholesale order fulfillment process, but not overall equipment readiness. While the two are obviously connected, the connection is not always simple.

[5]For an overview of Velocity Management see John Dumond et al., *Velocity Management: The Business Paradigm That Has Transformed U.S. Army Logistics,* Santa Monica, CA: RAND, MR-1108-A, 2001.

Today there is no way to measure whether, for example, a reduction in wholesale requisition wait time (RWT)—which measures the effectiveness of the wholesale order fulfillment process—flows through the system to produce an equivalent improvement in equipment readiness. An unanticipated reaction or deterioration in some other process produced by changes in behavior could counteract the gains. To ensure that gains in logistics processes actually improve ER, the Army needs a well-defined, integrated system of ER metrics that provide visibility into the underlying processes. These same metrics would also facilitate critical new insights into the reliability of weapon systems, and they would provide consistency for defining and enforcing the aggressive reliability and sustainability targets envisioned for such systems as the Interim Armored Vehicle (IAV) and the Future Combat Systems (FCS). Today, unless it comes through special data-collection efforts, failure rate and reliability information is not available after fielding to provide feedback to the acquisition community. Overall, better ER metrics would help the Army achieve its new vision by guiding process improvement, recapitalization, and acquisition efforts.

Better metrics would also help focus and prioritize the various efforts intended to support the Army transformation. Without links between acquisition and recapitalization program goals, logistics processes, and ER, it is difficult to know which efforts will enable the Army to leverage its limited resources to produce the greatest improvement. For many reasons, then, the Army needs metrics that allow it to determine which efforts are driving progress toward ER goals and that illuminate why or why not progress is being made.

The types of questions we would like to answer seem basic:

- What is the operational readiness rate of the Army's equipment in field operations?
- How do alternative maintenance structures affect equipment readiness?
- What is the "pulse reliability" of current forces?[6]

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[6]Pulse reliability is defined as the probability that an end item can make it through an entire combat pulse without requiring external logistics assets—either spare parts not carried on-board or non-crew-level maintenance. Combat pulses are envisioned to be

- How long does it take to return a fighting force to a high state of equipment readiness following an operation?
- What process improvement or expenditure of resources would produce the biggest gain in equipment readiness?
- Has improved wholesale RWT improved ER? If not, why?
- How much will improving the effectiveness of local inventories improve ER?
- How do wholesale backorders affect ER?
- How much will speeding up direct support repairs affect ER?
- Do unit practices influence equipment failure rates?
- How does recapitalization affect ER?
- What component parts drive ER?

Today it is very difficult, if not impossible, to answer these critical operating questions confidently or quickly. Answering them often requires conducting special studies that draw data from multiple sources but yield inferences rather than definitive conclusions. This is because the Army has no mechanism for "drilling down" into ER results to understand what drives readiness. In contrast, many private sector corporations have instituted activity-based costing systems designed to assess the contribution of each process and organization to overall operational results. These systems provide visibility into how each process and organization affects the bottom line. They allow managers to understand where the problems and opportunities are, which process improvements are paying off where it counts, and where additional leverage is possible.

The Army should have an analogous mechanism to link its process measurements to ER, in many respects the bottom line of equipment sustainment, and thus enable measurement of how logistics and failure prevention processes affect ER.[7]

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anywhere in duration from 72 hours to 2 weeks. Pulse reliability must be measured against a given combat pulse duration.

[7]By "failure prevention processes" we mean all those processes that affect the failure rate. These include the weapon system development and design processes, end item

This type of measurement capability requires the development of an integrated set of metrics that "conserve" time: that account for and attribute every second of downtime to a process, and that isolate the effects of processes on the NMC rate. Such a framework is illustrated in Figure 2.8, which builds on the fact that the NMC rate is the product of the failure rate and the broke-to-fix time. Metrics should account for all time at all process echelons (each of which is represented by a layer in the hierarchical tree) in the overall broke-to-fix process and allocate it to the most appropriate process. In other words, the time accounted for by all of the boxes in a layer, each of which represents a process, should equal the total average broke-to-fix time. For example, the weighted average of organizational and support-level repair times equals the average broke-to-fix time, and the sum of the average organizational maintenance and supply times equals the average organizational repair time. Likewise, all the component failure rates together should account for the total end item

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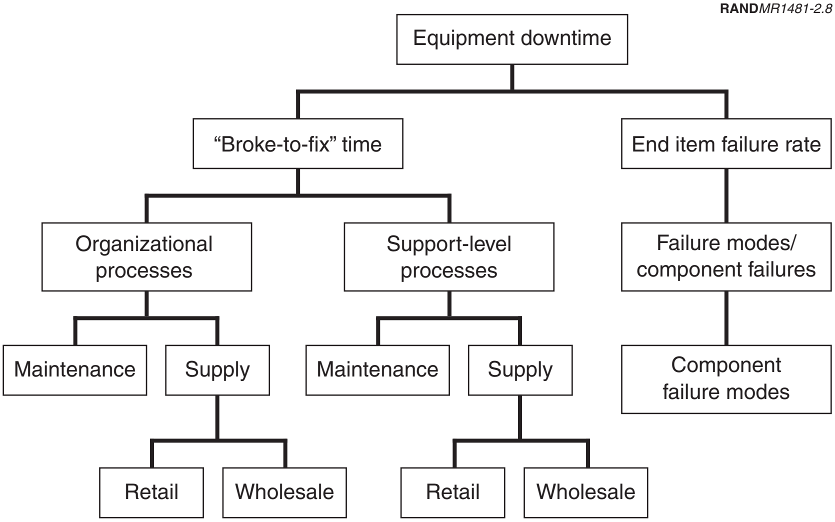

Figure 2.8—Metrics Should "Conserve" Time and Measure All Processes

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manufacturing, spare parts manufacturing, component repair, end item repair, preventive maintenance, scheduled services, operator use of equipment, and aging.

failure rate. A complete decomposition would continue decomposing each process into its component processes until the bottom layer consisted only of root-level processes. In practice, one should drill down until reaching sufficient detail—in other words, until unearthing a root cause—to determine an appropriate course of action.

CLOSING THE MEASUREMENT GAP

This, then, is the conceptual framework that the Army should endeavor to incorporate in future information systems. Information systems should be able to:

- Provide as near real-time equipment readiness as possible.
- Assess how effectively the Army is able to maintain operational equipment in different situations.
- Signal ER problems.
- Provide very fast, seamless identification of what is driving equipment readiness capabilities and what should be changed to produce improvement.

Chapter Three

A NEW PICTURE OF EQUIPMENT READINESS

The EDA is a first attempt at employing this framework and providing these metrics and capabilities. Although it is not a complete solution, it offers the opportunity to field these capabilities quickly using existing Army data in a way that provides significant new management information. Long-term efforts should be aimed at addressing measurement shortfalls that arise from incomplete data capture by current systems.

The EDA will give the Army insight into equipment readiness similar in effect to the insight that activity-based cost systems give corporations into bottom-line costs. It aims to increase the Army's understanding of how processes influence equipment readiness and, ultimately, to ensure that today's process improvements work together to achieve the maximum possible improvement in ER. It allows managers to look inside ER results in order to understand how logistics processes, equipment usage, and equipment reliability all combine to influence the whole. The EDA converts existing data into a rich source of metrics that can support Army-wide analysis and improvement efforts. For example, VM Process Improvement Teams (PITs)—Army-wide teams that work to achieve VM goals—can use the EDA to evaluate the impact of improvement efforts on ER and to set customer-driven goals.

HOW THE EDA WORKS

The EDA works by compiling a day-to-day history for every reported deadlining event[1] that requires a supply or maintenance action before the deadlined system can be returned to mission capable status. It creates these histories by piecing together and integrating data elements from several functional Standard Army Management Information Systems (STAMIS). From these histories, the EDA produces metrics that measure total end item repair times or broke-to-fix times and equipment failure rates (in terms of calendar time), as well as several other measurements not currently available, such as repair time at the organizational level. These metrics allow the EDA to "see" into all ER processes, creating a systems view that can detect whether improvements in root-level processes, such as wholesale RWT, propagate throughout the system to affect equipment readiness, or whether reactions in other processes "consume" the improvements.

The systems approach allows the Army to see the effects of process interactions. For example, when maintenance personnel perceive that the supply system is not sufficiently responsive to their needs, they may bypass that system to get a part. These maintenance "workarounds" become visible with the EDA data. The EDA also measures time lost when additional parts are ordered by maintenance personnel late in the repair process (perhaps because the diagnosis was made incorrectly the first time, there was an ordering error, or the standard diagnostic procedure requires progressive maintenance). In the first case, supply problems may be hidden because of the efforts of maintenance personnel to get the parts they need. In the second case, maintenance problems that cause added repair time can masquerade as supply problems.

ROOT-LEVEL SOURCE DATA

The source data for ER history reside in the Army's organizational and support maintenance STAMIS: the Unit Level Logistics System

[1]A deadlining event is defined as an end item failure that causes the end item to be NMC.

(ULLS) and the Standard Army Maintenance System (SAMS).[2] The unit or organization that owns and operates the equipment (called the "organizational level") records deadlining end item failures in ULLS, at which time the repair is assigned an Organizational Work Order Number (ORGWON). Any direct support maintenance action required on that equipment will be assigned an additional support Work Order Number (WON), which is indexed to the ORGWON. All ORGWON and WON information (including all parts requisition data) is transmitted daily to the division's (or other higher headquarters such as a corps support group) SAMS-2 computer, where all the information for each end item is indexed to the ORGWON.

Two SAMS-2 files serve as the basis for the EDA. The SAMS-2 "aho01i file" (01) compiles maintenance information on all currently open ORGWONs for deadlined weapon systems. Such information is updated daily and includes, besides the ORGWON itself, individual equipment identifiers (serial and bumper numbers); deadline or inoperative dates; associated support WONs and their statuses; evacuation and return times to and from each level of support; and the current statuses of repairs. The SAMS-2 "aho02i file" (02) contains all open parts requisitions for deadlined equipment, indexed to the corresponding ORGWONs found in the 01 report. This file shows each open requisition by document number and includes the national stock number (NSN) requisitioned, the quantity required, the level of maintenance (organizational or support) that ordered the part, and the status of the requisition.

SAMS-2 combines the data on the 01 and 02 files to produce what is called the daily deadline report, commonly referred to as the O26 print (it is the aho26i file in the SAMS-2 system). Division, brigade, and battalion commanders and their staffs use this report for daily management of ER. It lets them know what equipment is down and what immediate actions are necessary to improve the current ER posture.

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[2]ULLS is the maintenance and supply management system used at the organizational level. SAMS has two levels: SAMS-1, which is used to manage maintenance and supply actions at the direct and general support (GS military units only) maintenance level, and SAMS-2, which is a materiel management center (MMC)–level (e.g., division MMC, or DMMC) management system that provides an integrated view of all organizational and support maintenance ongoing in the superordinate MMC's organization.

While this is a valuable day-to-day management tool and a potentially rich source of information on the status of Army equipment, it has a life span of just one day, so it can be used only for real-time analysis and management of currently deadlined equipment. Information stays in the files only while action must be taken. Once a part is received or work is completed, there is no reason to continue to track it from an execution management standpoint. Under current Army standard operating procedures, each day's set of 01 and 02 reports overwrites the previous day's, and the replaced information is lost. Open requisitions stay in the 02 file only until the requisition is filled. Likewise, an open deadlining ORGWON stays in the 01 file until the equipment is brought back to mission capable status, at which time the entire record is removed from the 01 report. Once these records are closed and removed from the reports, no historical record remains of organizational repairs, and the linkages between parts and organizational repairs and between support-level and organizational-level WONs are lost.[3]

Building Repair and Failure Records

The first step in building the EDA is to save the data that are currently overwritten each day. The EDA essentially creates a stack of records from the first to the last day of each repair by linking the daily files together through ORGWONs and weapon system identifying information (unit identification code (UIC), bumper number, and serial number), which is illustrated in Figure 3.1. Once a repair is complete, the EDA tallies total repair time by counting the number of days the job was open, and it cuts through the stack of records to pick off key data that represent significant events over the course of the repair.

Using the Request Order Number (RON) for each required part enables linkage of supply data archived in the Corps Theater Automatic Data Processing Service Center (CTASC) document history files in

[3]SAMS-1, the support maintenance shop management system, does create closed work order files, which preserve historical information on each repair. These files are used to populate the Army's Work Order Logistics File (WOLF) at LOGSA, which provides support-level repair process metrics. The WOLF is part of the Logistics Integrated Database (LIDB).

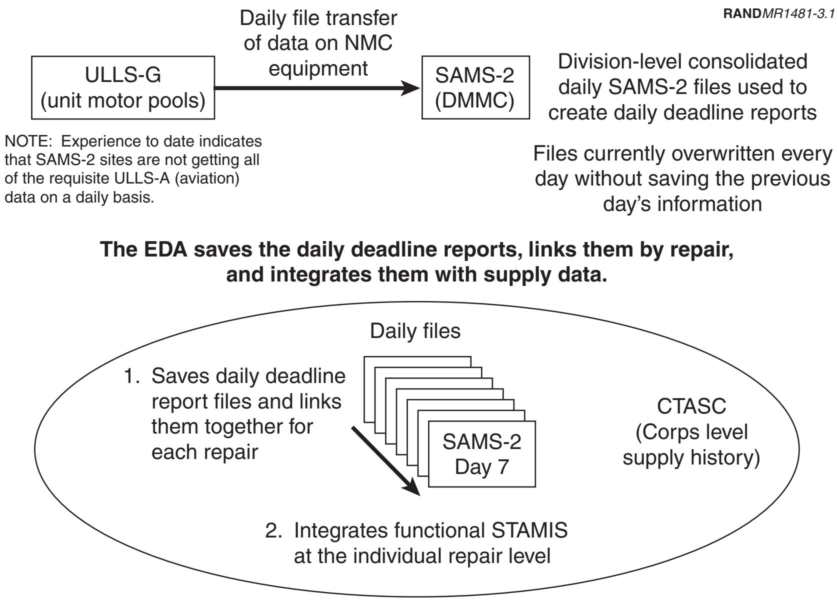

Figure 3.1—The EDA Generates a Complete Broke-to-Fix Record for Each Failure from Daily Records

the Standard Army Retail Supply System–Army/Corps Level (SARSS-2A/C) computers. From CTASC data, the EDA identifies the issue date of each part to each maintenance organization from their supporting Supply Support Activities (SSAs). Earlier RAND research in support of the VM stockage determination Process Improvement Team (PIT) devised and programmed logic for using the CTASC data to determine the source of supply for each requisition, such as whether the deadlining part was filled from the Authorized Stockage List (ASL), as a referral from another SSA, directly from a maintenance shop, or from the wholesale system.[4] This logic also measures

[4]This research resulted in the Army's CWT measure and its diagnostic metrics, which have been implemented in the ILAP. The logic employs the Army's RON/DON logic in reverse. When a unit enters the need for a part in ULLS, ULLS generates a Request Order Number (RON). The RON is sent to the supporting SSA, which fills the request if the item is in stock. If not, the SSA creates a Document Order Number (DON), which is used to requisition a part from another source of supply—either another SSA or a

the length of each process segment in the supply chain for each part. Integrating this source of supply and process segment information enables the EDA to show the contribution of each supply source—ASLs, on- or off-post referrals, local maintenance shops, on- or off-post laterals, or wholesale—to ER.

The linked daily deadline files joined with the CTASC data allow the construction of a detailed history of every repair across all echelons of repair and supply. To complete the data picture, the EDA combines unit property book information with repair histories to calculate failure rates as well as NMC rates.[5]

A NEW CONSTRUCT FOR REPAIR RECORDS

Figure 3.2 provides an example of a detailed repair record for an actual tank repair. The repair record was created by linking the daily deadline reports and combining them with CTASC document history data. The long bar at the top indicates that the tank was deadlined for 19 days, during which time there were three major repair segments: diagnosis and parts ordering, awaiting parts (AWP), and the actual fix process when the parts were applied. After the initial diagnosis, parts were ordered on day 2, and the tank was AWP until day 18. The tank was then fixed (all parts applied) and returned to mission capable status one day later. The figure also shows the day on which maintenance ordered each part, when the part was issued, and the source of supply.

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wholesale source. This is called the RON/DON process. RONs are filled by the SSA in order of priority and age. So a DON created in response to a low-priority RON could be used to fill a higher-priority RON with a later request date. The first RON would then be filled by the DON created in response to the second RON (or some other DON depending upon the activity between the SSA and its customers). DONs also are used to consolidate RONs submitted in the same time period for the same part by an SSA's various customers. By employing the RON/DON logic, the CWT computation algorithm attempts to determine which DON satisfied each RON and so identify the actual source of supply for each customer request. This is also the method used to decompose the Army's customer wait time metric for process analysis. In addition to RON/DON type requests, there are also dedicated RONs in which the RON itself flows through the supply system to the appropriate source of supply.

[5]The unit property book contains the official inventory records of organizations with regard to unit-owned equipment.

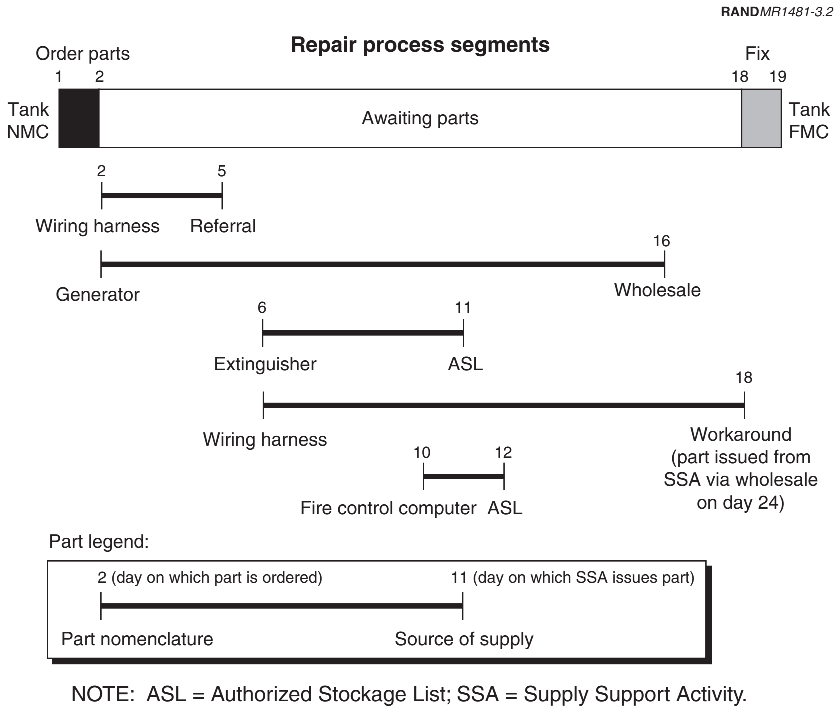


Figure 3.2—The EDA Creates Cross-Functional Repair Records Across Echelons

Overlaying the requisition information provides rich detail. For example, a wiring harness was ordered on day 2 and was supplied via an on-post referral, which was issued from the SSA on day 5. Each day on which parts were ordered represents the start of an "order cycle." Thus there were three order cycles, beginning on days 2, 6, and 10. From interviews with maintenance personnel, we know that the second wiring harness was ordered after the wrong one was received the first time. The extinguisher was ordered late because it was not determined right away that the part was needed. And the tank's fire control computer was provided to another tank, which the Army calls "controlled exchange" and is one type of workaround.

The causes of these multiple order cycles are typical of the reasons we have documented in general: requisitioning or part delivery problems, diagnostic problems, progressive maintenance, and controlled exchange. Of further note, the second time the wiring harness was ordered, maintenance personnel decided that they could no longer afford to wait for an issue from supply and satisfied the need through a workaround on day 18, which allowed completion of the repair. Note that the part was issued by the supply system six days later, on day 24.

The EDA logic, by combining supply and maintenance information at the requisition level, detects that a workaround probably occurred to procure the wiring harness and complete the repair. In effect, the wiring harness workaround reduced the total broke-to-fix time by six days. The fire control computer exchange did not cost this tank any downtime, and may have saved a couple of days on the other tank repair.[6] However, each workaround creates additional work that could be a limiting factor with regard to repair throughput in situations in which repair demand is very high.

By grouping these detailed histories, the EDA produces both repair process and failure rate metrics at any level of aggregation—from an individual tank through the entire Army fleet. And by providing in-depth visibility into the total broke-to-fix repair process, it helps identify the true cause of downtime (e.g., by separating AWP into two distinct components—the number of order cycles and their length, which respectively measure process quality and supply chain responsiveness—the EDA more accurately identifies the source of AWP than simply thinking of it in terms of part wait time).

CONSTRUCTING EXERCISE AND UNIT HISTORIES

In addition to enabling the construction of detailed repair records, the EDA enables reconstruction of detailed unit exercise histories. For example, consider Figure 3.3, which depicts an armor battalion that went through a three-week combined gunnery and maneuver exercise in preparation for a National Training Center (NTC) rota-

[6]Note that the potential savings were very limited in this case, because the part was available in the local ASL.

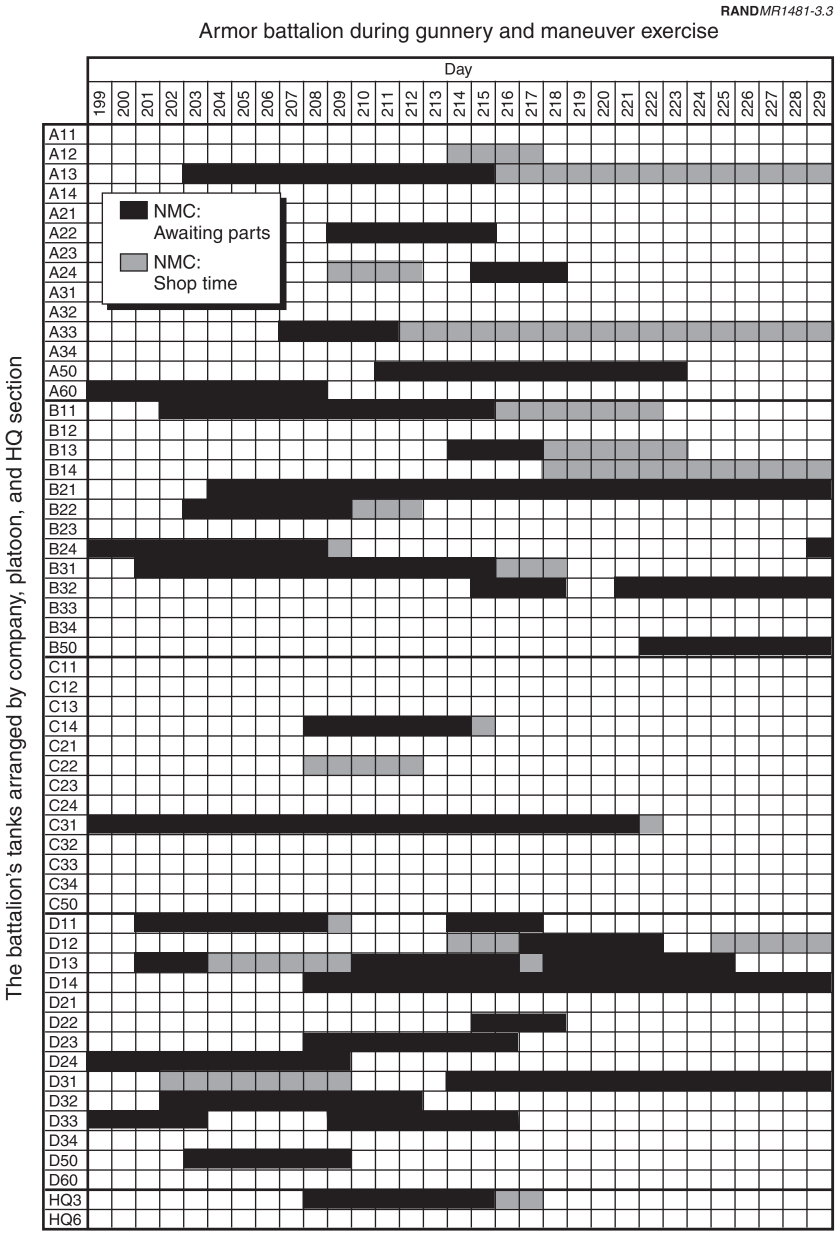


Figure 3.3—Example: Detailed Unit and Exercise History

tion. The 58 tanks in the battalion are arrayed by company, platoon, and headquarters section on the left axis, and each box to the right represents one day.[7] Shading represents a deadlined tank; the lighter shading indicates at least one open deadlining requisition for which maintenance was awaiting parts, and the darker shading indicates that all necessary reported deadlining part needs had been satisfied.[8]

Many interesting patterns are apparent. For example, the data indicate that 76 percent of the deadline time in the exercise came from AWP. For many repairs, once all of the parts were available, the repair was completed either that day (no dark boxes at the end of the repair) or just one day later. However, several repairs have substantial shop time, which could indicate problem diagnoses, difficult repairs, or situations in which repairers job-ordered a broken component directly to maintenance, avoiding a supply transaction and thus the possibility of measuring AWP time. Also, it is clear that Delta (D) Company suffered the most failures and Charlie (C) Company the least. As many as 9 of Delta Company's 14 tanks were down on one day, and all four tanks of its 1st Platoon were deadlined for four straight days. This rich level of detail should help leaders improve equipment sustainment performance by identifying where to look to find the sources of problems.

At a higher level of aggregation, the EDA provides information that can be used to identify fleet-level issues as logistics response problems (high total repair time), failure rate problems, or both. EDA

[7]The numbers on the left axis of Figure 3.3 are called bumper numbers—the identifying numbers units use for each vehicle. The Army employs standard numbering sequences across similar types of units. An Army of Excellence Division armor battalion has four tank companies, A to D, with fourteen tanks each and a headquarters company with a two-tank headquarters section. Thus, bumper numbers begin with A, B, C, D, or H. The first number indicates the platoon or a headquarters section tank, 1 to 3 being platoons, 5 being the company executive officer's tank, and 6 being the company commander's tank (3 at the battalion headquarters section level stands for S-3 and 6 for the battalion commander). The second number identifies the tank within a platoon, 1 being the platoon leader, 2 being the platoon leader's wingman, 3 being the platoon sergeant, and 4 being the platoon sergeant's wingman.

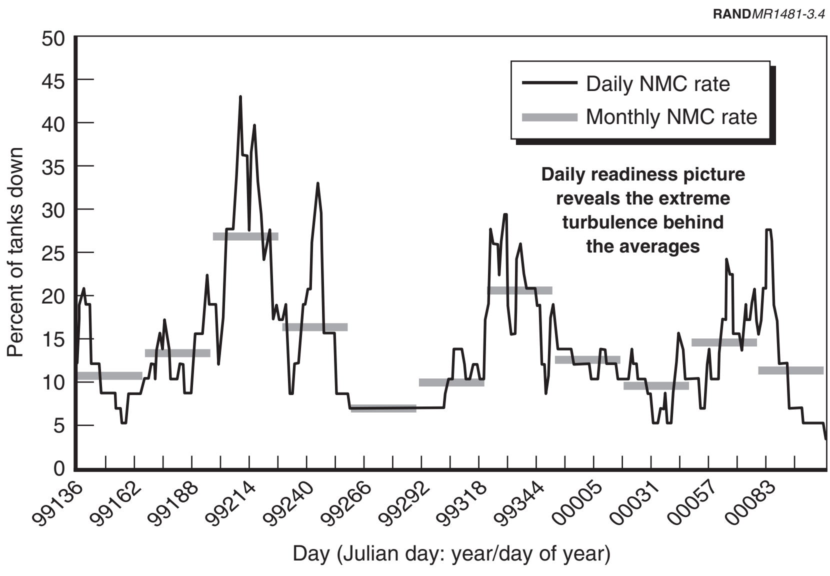
[8]The NMC-AWP and NMC-shop times indicated in Figure 3.3 roughly correspond to the Army's official NMCS and NMCM metrics. The difference is that NMC-AWP ends when the SSA has issued all the parts, whereas NMCS time typically ends when the maintenance shop has picked up and receipted all the parts. We allocate the pickup and receipt time to maintenance rather than to supply.

diagnostic metrics could then be used to determine the root causes of these problems.

By saving information about downtime in a structure that preserves the start and stop time of each deadlining event rather than just the accumulated downtime over a period, as the current reporting system does, the EDA can provide a richer, more complete picture of equipment readiness performance.

EXERCISES BECOME APPARENT IN THE RICHER PORTRAYAL OF EQUIPMENT READINESS

As depicted in Figure 3.4, the EDA data archives can be used to examine daily NMC rates. As in the NMC rate figures cited in Chapter Two, the horizontal bars represent monthly NMC rates for the



NOTE: One armor battalion over 11 months.

Figure 3.4—A Richer Portrayal of Equipment Readiness

tanks of one armor battalion, which combine days during which training and equipment usage is occurring with those when equipment is sitting idle in the motor pool. For example, in the last month displayed in the figure, the monthly NMC rate was 11 percent. At the beginning of the month an exercise caused the NMC rate to spike to 28 percent, reflecting this unit's typical experience in extended high-OPTEMPO situations. By the end of the month the NMC rate had fallen to just 4 percent.

From process improvement and capability assessment perspectives, it would be valuable to know how the unit's equipment performed when it was in use and how well the logistics system responded. The daily NMC line reveals this picture, with the spikes clearly indicating the effect of equipment usage. The spikes represent sharp declines in equipment readiness over one- to three-week training periods, followed by slightly slower recoveries to a high level of equipment readiness (although it rarely dropped below 6 percent NMC). Even minor exercises cause NMC rate spikes, and several major home-station exercises caused this battalion's equipment readiness to dip to 75 percent or less. To determine whether or not this battalion's tanks are ready to go to war, one probably should not look at data that has aged by more than a couple of days. And to determine how effectively the battalion could sustain tanks in a high-OPTEMPO situation, one should look at the exercise periods characterized by the high peaks in the NMC rate.

By isolating spikes in NMC rates, we can examine performance in high-OPTEMPO situations. Figure 3.5 depicts the daily equipment readiness profile of tanks and Bradleys during nine major armor and mechanized infantry battalion home-station training exercises that took place over several months in the two divisions. Most of these exercises lasted about two weeks, although one was shorter and two lasted three weeks. The sharp upward slopes indicate the inability of the repair process to keep pace with the failure rates. In each case, the battalion fleets hit NMC rates of 25 percent or greater on at least one day. Once the exercises ended, the steepness of each of the downward slopes during recovery is indicative of each battalion's repair times. Of further note, the battalions started the exercises with 5 to 10 percent of their fleets already NMC, so they did not have initial buffers for the first few failures. Thus, every battalion hit the 10 percent NMC threshold by the second day of each training event.

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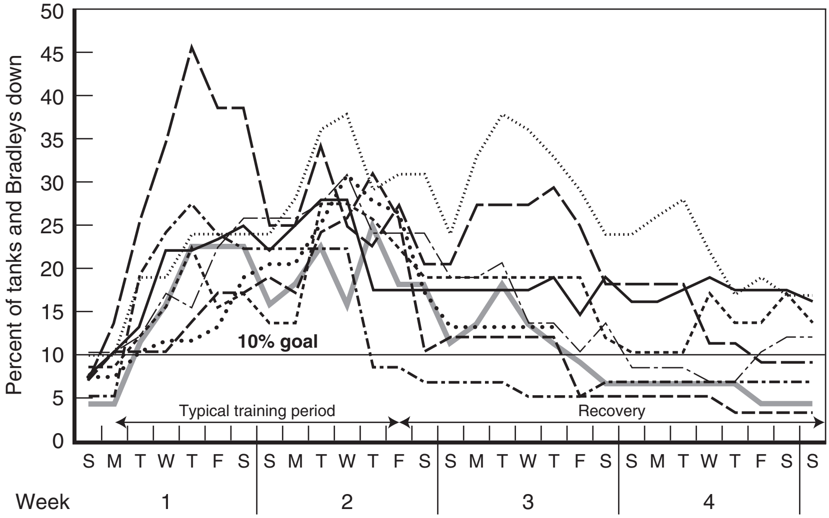
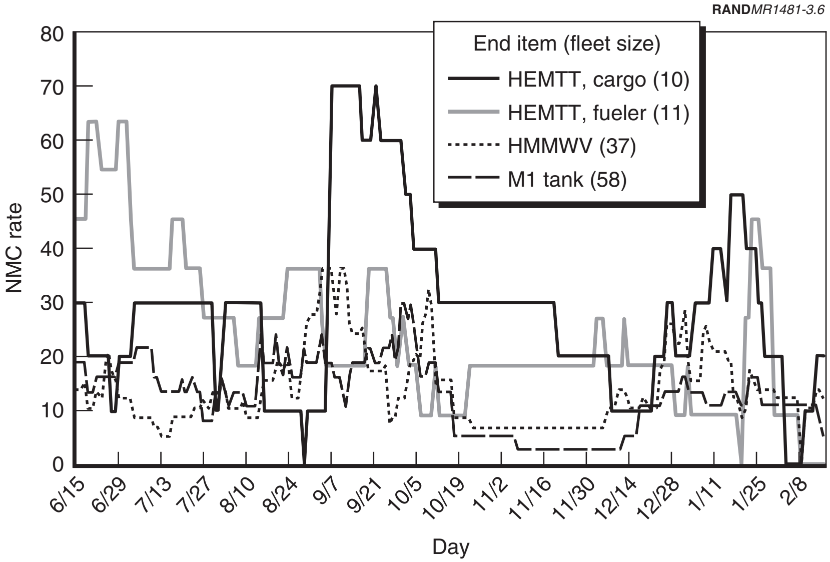


NOTE: Armor and mechanized infantry battalions during major maneuver and gunnery exercises.

Figure 3.5—Equipment Readiness During High-OPTEMPO Periods

The extreme turbulence in equipment readiness is not limited to tanks and Bradleys. The EDA also indicates problems with the daily equipment readiness profiles for other equipment. In fact, lower-density systems sometimes exhibit even higher NMC rate peaks and greater ER volatility, as exhibited in the example in Figure 3.6.



NOTE: One armor battalion over 8 months.

Figure 3.6—Example: Daily NMC Rate Turbulence Across Several End Items in an Armor Battalion

Chapter Four

USING THE EDA TO GAIN INSIGHT INTO FAILURE RATES

In the next two chapters, and with two case studies, we will show how the EDA can be utilized to provide more detailed insight into equipment sustainment performance. First we will look at failure rates, and then at total repair times.

THE EDA DIAGNOSTIC TREE

Figure 4.1 shows a prototype EDA diagnostic tree that allows a quick comparison of any combination of units, fleets, or time periods within a database. The tree provides a hierarchy of metrics that enables one to easily drill down from NMC rates to root-level sources of downtime. Each box or metric is decomposed into its immediate components, which are each in turn decomposed into their components, creating a picture that reflects the structure and processes of the logistics system. The top row in each box is the first combination of unit, end item, and time period—in this example the tank fleet for armor battalion (BN) A from October 1999 to December 1999—and the second row is the second combination, or armor BN B's tanks over the same time period.

The diagnostic tree is built to be as arithmetically decomposable as possible using just addition and multiplication. That is, each layer in the tree can essentially be built by adding or multiplying the metrics one level below. The layers account for all downtime, so if one metric changes, it is possible to see if time merely shifted between processes or if overall time was reduced. The overall percent of tanks NMC comes from two components, the average total end item

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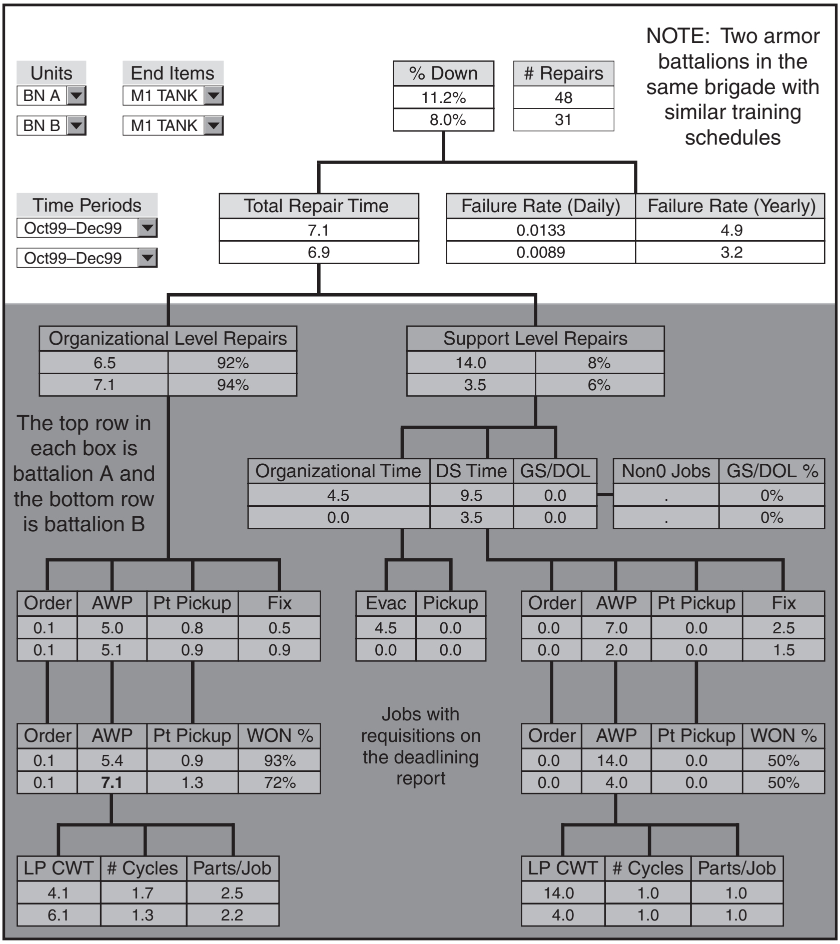

Figure 4.1—The EDA Diagnostic Tree

broke-to-fix time and the failure rate (expressed in failures per system per day), and it is roughly equal to the two multiplied together.[1]

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[1]End item broke-to-fix time multiplied by failure rate usually will not perfectly match percent down because of time truncation and mismatched population issues. For a given time period, we count systems that failed during the period for calculating the

CASE STUDY ONE: A FAILURE RATE PROBLEM

The two armor battalions in this example are in the same brigade and had similar training schedules during the three-month period shown. The NMC rates experienced by the battalions are at the top of the tree. In this case, there is quite a substantial difference in the two, with BN A having 40 percent more downtime (11.2 percent for BN A versus 8.0 percent for BN B). The EDA gives the Army a new tool to drill down into this difference and determine why it exists, something that would be very difficult to do using currently available data.

Moving to the second tier of metrics instantly reveals whether this disparity resulted from a difference in logistics response or failure rates. It is clear that it came almost entirely from a difference in failure rates, with BN A's tanks failing at a rate 50 percent higher during this period (a rate of 4.9 to 3.2 failures per tank per year). (Failure rates are presented in terms of the average number of failures per system per day and also as the average number of failures per system per year.) Average repair times, at 7.1 and 6.9 days, were virtually the same.

HIGH FAILURES DURING GUNNERY LED TO HIGHER FAILURE AND NMC RATES

Figure 4.2 illustrates that an annual gunnery qualification exercise accounted for much of the difference in failures between the two battalions over the course of the three-month period. The graph depicts

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end item failure rate and systems whose repairs were completed in the time period for calculating total repair time. These populations most likely will not match completely, especially if we are dealing with a short period, say failure rates and repair times over a month or even a quarter. A system may be deadlined during the month but its repair may not be completed until the next month (and so we would not count its repair time in our repair cycle time calculation). Similarly, a system may have its repair completed this month but have been deadlined the previous month, so we count its repair time but not its failure toward calculation of the failure rate. Our calculation of percent down does not use failure rates and average repair times. Instead, it is the actual percent down calculated by dividing the number of deadlined system days by the total system days in the period (system days is the product of the number of systems and the number of days). The longer the period we are measuring (such as a year), the more likely that the multiplication of repair time and failure rate will match the calculated percent down, because the two populations will more closely match.

the battalions' NMC rates for tanks by day over the course of the gunnery and the subsequent two weeks for a total of 30 days. BN A's tanks—the solid line—clearly experienced much more downtime during the gunnery, especially during the first week when its NMC rate spiked to 45 percent. The first step in preventing this from happening again is to learn why the difference occurred. With the second level of the EDA tree, we can compare repair times and failure rates to see if there is a potentially glaring logistics problem in BN A or its support structure, or to see if there is a "failure" problem. Figure 4.1 showed that the average repair times for both battalions was about seven days, ruling out logistics support as the source of the difference. In this case, a difference in failure rates accounted for the difference in NMC rates, with 33 failures for BN A versus 21 for BN B over a three-week period. The number of failures for each battalion each week is also shown in Figure 4.2, exposing a substantial difference in the first week (18 failures for BN A out of 44 tanks, including 17 tanks failing in BN A in just the first four days, not shown, versus 10 for BN B).

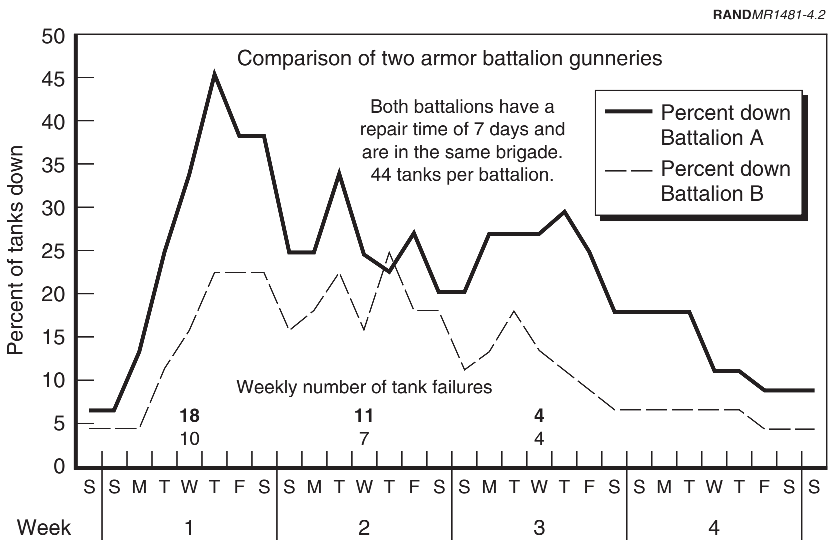

Figure 4.2—A Gunnery Example: Daily Tank Failures and NMC Rates for Two Armor Battalions in the Same Brigade

Examining the repair history for the period reveals that the difference in failure rates came primarily from excessive electronic component failures in BN A's tanks—primarily related to fire control components—as compared to BN B's. BN A ordered a combined total of 28 image control units, fire control computers, thermal receiver units, and laser range finders during gunnery versus just three for BN B.[2] Other types of parts were ordered in more similar quantities. Either BN B found ways to get fire control components without requisitioning parts, or BN A had a much greater incidence of such failures during the gunnery.

The pattern of failures is sometimes as informative as the frequency of failures in trying to understand how reliability affects operations. When we examine BN A's failures in more detail, we see that all seven thermal receiver units (TRUs) were ordered over a three-day span at the start of gunnery. This raises questions. Were these existing problems that had gone undetected? If so, were the systems checked sufficiently in the motor pool? Or were the problems hard to detect until the system was actually put into use? Did they occur as the result of a lengthy inactive motor pool period? Perhaps more important, what are the implications of this pattern? What are the consequences for deployment, whether with a unit's own equipment or with equipment that is in position when the unit arrives? Should this initial spike be expected?

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[2]To determine this, we augmented the EDA data with additional CTASC data. The EDA includes only those parts reported on the deadlining report. We added high-priority requisitions that were in CTASC during this period but not on the deadline report to those that were. This absence of part requests on the deadline report can occur when units do ASL walkthroughs, because the part need could be identified and satisfied after the ULLS closeout for SAMS transfer on one day and prior to the closeout on the next day. Thus, such a part would never appear in the SAMS-2 daily deadline report. Also, it is possible for units to not designate a deadlining demand as deadlining in ULLS and SAMS. This is a manually controlled field for which the automation operator has to enter "yes" or "no." For example, ULLS allows an operator to enter a high-priority part request (issue priority group 1) for a deadlining fault and then answer "no" when asked by ULLS if the part is an NMC part (and then the operator can also answer "no" when asked if it is an anticipated NMC part). We find that high-priority requisitions with a required due date (RDD) starting in N (not mission capable) or 999 (not mission capable for OCONUS units) are typically designated as NMC in ULLS and SAMS, but not always. Similarly, RDDs with a Julian day only (no preceding letter) or starting in E (expected to be NMC) are generally not designated as NMC in ULLS and SAMS, but again not always. Those requests with a blank RDD seem to be a mix of the two populations just discussed.

This is as far as the data alone can take us to diagnose BN A's high NMC rates. Thereafter the tough work of walking the process begins, looking at the process in more detail by taking an in-person look at procedures and interviewing personnel. But at least now, with the EDA data, BN A knows where the investigation should begin in order to learn what caused the difference in NMC rates. When it analyzes its processes, the battalion should try to answer why it suffered an excessive number of fire control–related tank failures at the start of gunnery. Process walks and on-the-ground analyses should try to answer such questions as: Did the battalion not conduct effective preventive maintenance checks and services? Were there any usage factors specific to BN A? Do the tanks themselves have reliability issues as compared to BN B's?

ARE SOME TANKS "LEMONS"? DO SOME CREWS DISPROPORTIONATELY CAUSE FAILURES?

In the previous example, looking at the performance of individual tanks and crews over time may produce additional insights. Another way to use EDA data is to take a fine-grained view that enables analysis at the individual tank level to identify possible problem tanks—those that fail with excessive frequency and disproportionately contribute to lost ER whether because of crew factors, poor repair quality, or excessive wear.

Figure 4.3 depicts the downtime history of the four tanks in one battalion that failed most frequently. Each darkly shaded portion of the horizontal bars represents one failure, and the length of the dark shading indicates the duration of the downtime. For a frame of reference, the time periods of the unit's major field exercises are superimposed over the graph using light shading enclosed by solid lines spanning all four bars. In a span of nine months covering just four major field exercises, these four tanks failed five to seven times each, with three of the four being down for extensive portions of the four exercises.

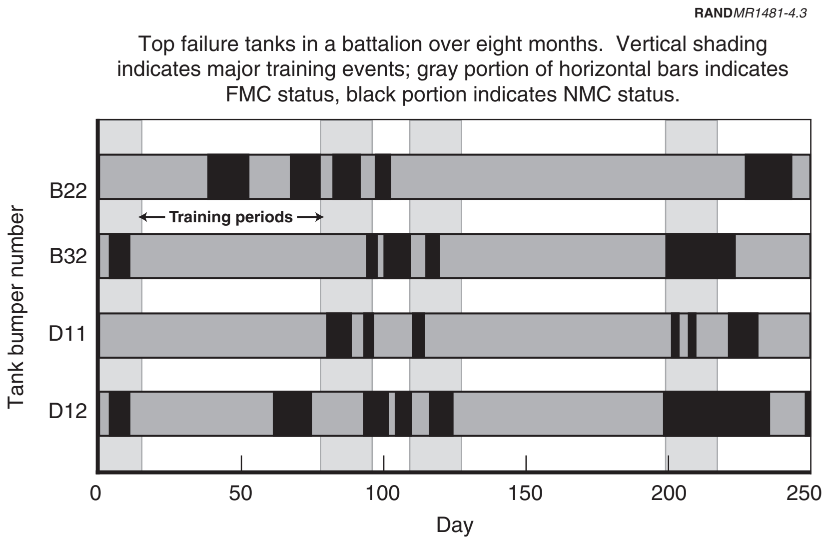

Figure 4.3—Identifying Problem Weapon Systems or Crews

Table 4.1 is an extract from a division report done at the level of bumper number, showing the top 10 tanks in terms of the number of failures over the course of a year.[3] Detailed analysis of the failures for a given tank in conjunction with a thorough inspection could reveal whether the repeated failures are the result of a worn tank, a recurring problem that is not getting fully resolved through maintenance actions, crew usage issues, or low PMCS quality.

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[3]Such a ranking would be more meaningful if it were based upon a measure of activity such as failures per kilometer. Exploratory research linking monthly usage from the Army Maintenance Management System (TAMMS) Equipment Database (TEDB) at the individual tank level to EDA data is promising, but missing usage data is a concern. This is also of broader concern to the Army, because it affects total reported training miles for each unit and the Army as a whole. Training miles are used to calculate operating cost rates and in external Army reporting as a measure of the Army's actual versus planned training.

Table 4.1

Extract from a Division Tank "Lemon" Report, 12 Months

Bumper	Unit	Days NMC	Failures	Percent Down	Cumulative Failures	Cumulative Failures as % of DIV Total (317 tanks)
D12	BN A	108	9	29.5	9	1.3
A21	BN B	108	8	29.5	17	2.5
B22	BN A	110	7	30.1	24	3.5
A24	BN B	76	7	20.8	31	4.6
D11	BN A	41	7	11.2	38	5.6
A11	BN A	110	6	30.1	44	6.5
A22	BN C	61	6	16.7	50	7.4
A60	BN B	51	6	13.9	56	8.2
C11	BN A	49	6	13.4	62	9.1
B11	BN C	33	6	9.0	68	10.0

IDENTIFYING THE PARTS THAT DRIVE READINESS

Today the Army does not have information that provides clear, direct information on how the supply system affects readiness. The EDA data can be a valuable tool in helping to better identify parts that are driving readiness and determining whether the key drivers are high removal rates or supply problems.[4]

For example, the EDA could be used to produce a list of the parts that appear on the deadline reports for a division over the course of a year. Such an EDA-based report is shown in Table 4.2. It ranks tank parts by the number of times they appeared on the deadline report

[4]Other sources of data exist and are better for determining total spare parts consumption. CTASC data contain all retail-level demands, both those for immediate use and those for replenishment of local stocks. This information can be accessed using ILAP. The Central Demand Database (CDDB) maintained by LOGSA also contains all demands. The Army's Operating and Support Management Information System (OSMIS) provides wholesale parts demand information in terms of usage and end item density.

Table 4.2

Which Parts Drive Readiness?

Ranked by orders (30% of total)

Nomenclature	N	Total Days	Average Days	UPrice
Starter, engine, gas, turbine	38	201	5.3	$753
Switchboard, fire control	31	259	8.4	$134,269
Transmission, hydraulic	30	340	11.3	$190,032
Wheel, solid rubber tire	27	336	12.4	$463
Final drive and container	26	118	4.5	$3,453
Control, remote switching	20	81	4.1	$34,320
Distribution box	19	252	13.3	$40,021
Elec unit, fire control comp	19	144	7.6	$130,355
Manual drive assembly	19	81	4.3	$2,809
Electronic components assy	18	118	6.6	$30,696
Elec unit, fire control comp	17	116	6.8	$130,355
Generator, eng accessory	15	246	16.4	$7,301
Electronic components assy	15	158	10.5	$36,853
Power control unit	15	86	5.7	$11,284
Cable assy, special purpose	15	79	5.3	$196
Pump, axial pistons	14	136	9.7	$5,405
Sight unit	13	69	5.3	$111,068
Display, optoelectronic	12	85	7.1	$48,349
Power supply	11	66	6.0	$34,768
Control, indicator	11	35	3.2	$2,518

Ranked by number of deadlining days (30% of total)

Nomenclature	N	Total Days	Average Days	UPrice
Transmission, hydraulic	30	340	11.3	$190,032
Wheel, solid rubber tire	27	336	12.4	$463
Switchboard, fire control	31	259	8.4	$134,269
Distribution box	19	252	13.3	$40,021
Generator, eng accessory	15	246	16.4	$7,301
Shaft assembly, straight	10	218	21.8	$1,138
Starter, engine, gas, turbine	38	201	5.3	$753
Housing, bearing unit	5	161	32.2	$891
Electronic components assy	15	158	10.5	$36,853
Elec unit, fire control comp	19	144	7.6	$130,355
Pump, axial pistons	14	136	9.7	$5,405
Bracket, mounting	8	126	15.8	$28
Final drive and container	26	118	4.5	$3,453
Electronic components assy	18	118	6.6	$30,696
Elec unit, fire control comp	17	116	6.8	$130,355
Valve, linear, directional contr	9	102	11.3	$3,173
Parts kit, seal repl, mec	5	101	20.2	$209
Washer, key	5	98	19.6	$3
Thermal imaging system	10	97	9.7	$77,063
Engine, gas turbine, nonaircraft	7	96	13.7	$521,775

NOTES: For one heavy division, deadlining requisitions for tanks, 12 months. This table undercounts tank engines because most were handled through maintenance-to-maintenance transactions in this division during this period, preventing their appearance on deadline reports.

N: number of orders for the part on the deadline report. Total Days: deadlining days for the part across the division over 12 months. Average Days: average customer wait time for the part (days on the deadline report). UPrice: unit price of the part.

(top panel) and the total number of days they appeared on the deadline report (bottom panel), thus contributing the most to lost readiness. Either a high number of orders, poor supply support, or both will cause a part to appear on the bottom list. The first part listed in the bottom panel of Table 4.2, the tank transmission, represents a critical reliability concern. The part below it, the roadwheel (wheel, solid rubber tire), is on the report primarily because of a wholesale backorder problem that caused local stocks of this high-wear item to be depleted.

We should note that this information does not account for all deadlining demands. It reflects the part removals that are on the deadline report, not all removals that create a deadline condition. Parts acquired from prescribed load list (PLL) stock at the unit level or from bench or shop stock at the support level do not trigger the creation of a customer request and therefore do not appear on the deadline report tied to a job. These are known gaps in supply transaction data that also affect the Army's ability to fully measure customer wait time. Similarly, maintenance-to-maintenance transactions do not trigger supply transactions, preventing them from appearing on the deadline report. Also, some same-day ASL walkthroughs are not posted to the deadline report because they are open less than 24 hours.[5]

Still, this information should provide valuable feedback that the Army Materiel Command (AMC) and the Defense Logistics Agency (DLA) could use to help identify high-leverage points to improve customer support. In the long term, this type of information should prove useful in evaluating part reliability and prognostic efforts that would have the greatest effect on improving ER. In fact, the Tank-Automotive and Armaments Command (TACOM) has been using data of this nature from the prototype EDA database for fleet recapitalization analyses.

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[5]Total deadlining time is much more complete, though, because most of the methods for procuring parts that do not result in a deadlining requisition as described in this paragraph do not result in much deadlining time. If something is holding an item down for a significant length of time, it will generally be on the deadline report. The one exception is maintenance-to-maintenance transactions.

Chapter Five

USING THE EDA TO GAIN INSIGHT INTO THE REPAIR PROCESS

We saw in the previous chapter that the EDA provides insight into how failure rates affect ER. By creating several new metrics that fill gaps in measuring the total repair process, the EDA also has the potential to provide significant new insight into the repair process.

CASE STUDY TWO: A REPAIR TIME PROBLEM

Figure 5.1 reintroduces the diagnostic tree that we saw in Chapter Four, but with different data. This tree compares the tank fleets of two armor battalions in the same division but in different brigades. In the entire four-month period for both battalions, BN D's downtime was almost 50 percent greater than BN C's: 11 percent versus 16 percent. Using the EDA, we quickly see that both battalions experienced about the same number of failures during this period. The difference in their downtime, therefore, was a function of the difference in total end item repair time: 11.4 days versus 8.2 days on average.

Without the enhanced data collection the EDA provides, not even the top-level difference in repair times is visible, let alone the detailed differences. The Army would know only that BN D has a severe readiness problem. In fact, without the EDA data, this unit and its division support command (DISCOM) were unable to isolate the cause for the difference in performance, despite intense efforts to improve BN D's equipment readiness. Thus, the primary response was to implore the maintenance personnel to work harder, which, as we will see by the end of the study, did not address the root causes of the problem.

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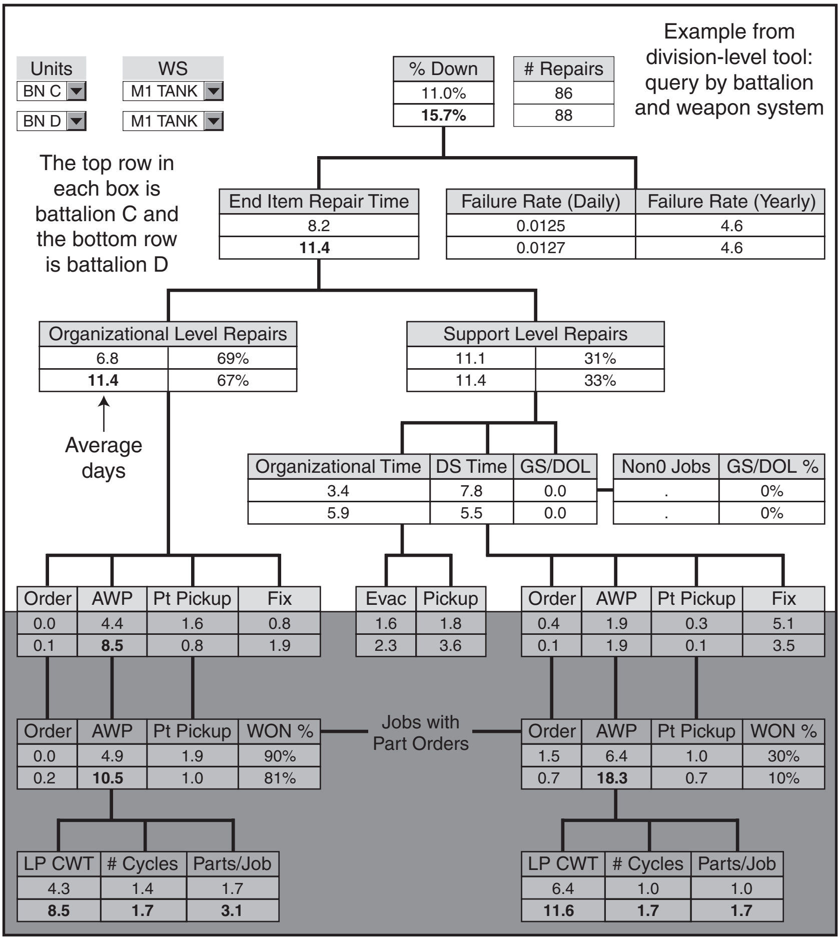

Figure 5.1—The EDA Diagnostic Tree Decomposes Repairs by Echelon of Maintenance

However, by decomposing the total repair time into repair levels and process segments as depicted in the diagnostic tree, the EDA can help identify why the total repair times are different for the two battalions. We see in the third row of boxes in Figure 5.1 that total end item repair time is decomposed into its two components: the average time for jobs in which all the work was completed at the organizational level (6.8 days for BN C versus 11.4 days for BN D) and the average time for jobs evacuated to direct support (11.1 versus 11.4 days). The difference in repair time comes from a difference in organizational-level repairs, which accounted for most of the tank repairs for these two battalions (69 percent and 67 percent respectively). This information would enable the battalion and logistics personnel in its parent brigade and division to investigate what actions should be taken to improve the capabilities of BN D's equipment sustainment processes.

Next we will look at the different segments of the repair process. Then, because of its importance to the example in Figure 5.1, we will focus on further decomposing the organizational repair time.

THE SEGMENTS OF THE REPAIR PROCESS

Figure 5.2 illustrates how the EDA decomposes repairs into maintenance levels and process segments. The height of each bar roughly represents the proportion of deadlining repairs executed at each level and the length of the process segments roughly represent their relative proportions in the average total repair time.

The top bar divides organizational level repairs into four process segments:

- Diagnosing the problem and ordering parts
- Getting the needed parts from the supply chain (AWP)
- Picking up the parts from SSA and receipting them
- Fixing the problem once all necessary parts are on hand (including both awaiting maintenance time and actual time in work).

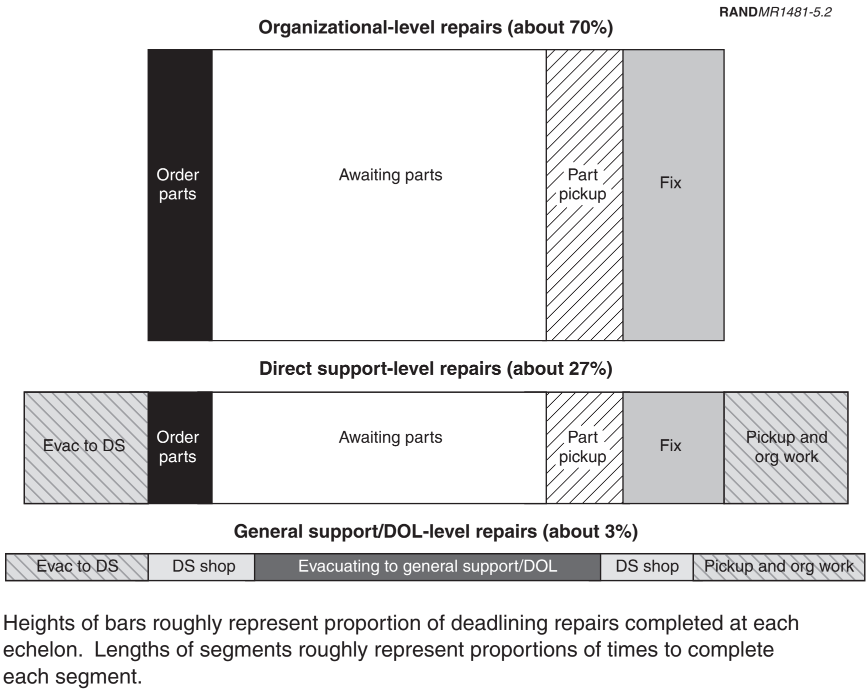

Figure 5.2—Segments of the Repair Process

Repairs that require direct support (DS) maintenance are very similar; additional process segments come only at the beginning and end of the repair, evacuation to DS and pickup from DS.[1]

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[1]Measurement of evacuation and pickup times is not a "clean" measurement. Before evacuating an end item or after picking one up, organizational maintenance could also perform work. With the currently available data, however, we cannot distinguish organizational work time from either evacuation or pickup times. Therefore the technically correct name for these metrics is organizational time prior to evacuation and organizational time after pickup. Further, on jobs with both organizational and support-level work, the EDA only allocates time to the support-level metrics. Otherwise, "simultaneous" work would result in double counting of time, causing the decomposition of repair time to be inconsistent with the total time. This is in line with the purpose of the EDA, which is to diagnose ER and repair time. Creating consistent organizational repair metrics from all of the jobs completed entirely at the organizational level provides sufficient data to diagnose organizational-level repairs and allows the use of all support-level data to diagnose support-level repairs.

For repairs evacuated to the general support (GS)/Directorate of Logistics (DOL) level, the EDA records the time spent at GS/DOL and separates it from DS time. But since deadlined end items are rarely evacuated to this level, GS/DOL time has not been decomposed. If this process turns out to be an issue, one could then use GS WOLF data or DOL EMIS data to isolate the problem.

In Figure 5.2, we defined awaiting parts time as the elapsed time between when a part is ordered and when it is issued. However, the calculation of AWP time is often more complicated. Total time for awaiting parts may be composed of several "order cycles." A first round of diagnosis and parts ordering may be followed by a second or third or even more cycles of parts ordering. Sometimes these order cycles are completely separated, and sometimes they overlap.

This occurs for many reasons. Mistakes in the first diagnosis may be revealed only after the first group of parts is received. The maintenance may be progressive in that additional faults are uncovered after a first set of faults is repaired. Requisitions may be "lost" or incorrectly entered, requiring them to be submitted again. Parts may be removed from one system through controlled exchange to bring another deadlined system back into service, requiring another round of parts ordering. A received part may be defective. And so on.

Measuring awaiting parts time (AWP) alone does not lend itself to process analysis and improvement, because it consists of both how long it takes the supply system to provide parts and the additional time produced by multiple cycles. To enable the Army to better understand how each affects readiness, the EDA records the length of each order cycle and the number of cycles for each repair. A key point of emphasis is that it measures each order cycle from the common document date until supply issues all the parts in the order cycle. This is what matters to maintenance; maintenance personnel usually cannot begin work until they have all the needed parts. We call the length of an order cycle the last part customer wait time (LP CWT). Traditionally, supply metrics treat each requisition separately, which is appropriate when using supply metrics to analyze and improve supply processes. LP CWT instead shows how well the supply system is working from a customer's perspective and how important it is to total repair time.

With process metrics created from decomposing repair time into its four component parts, and further decomposing one of those—AWP—into order cycles, LP CWT, and the components of part-level CWT such as the Authorized Stockage List (ASL) fill rate or wholesale RWT, we can drill down to find out how each process affects repair time. This capability can support both local and Army-wide process improvement efforts. It can also provide a critical decisionmaking tool by helping the Army understand the ER benefits of potential initiatives.

THE "WHY" BEHIND BROKE-TO-FIX TIME

Now that we understand how to decompose the repair process segments, we can use the EDA to learn why BN D's broke-to-fix time was so much worse than BN C's. The organizational repair segments (on the left side of the diagnostic tree in Figure 5.3) capture the repair phases described previously. The segment times reveal that the difference in organizational repair time came primarily from AWP time, with BN D's 8.5-day average wait almost twice as long as BN C's 4.4-day average wait. Information on the time spent awaiting parts is presented twice in the tree: first, showing times across all repair jobs, and second, showing the times for just those jobs with requisitions reported on the deadline report.

The first row maintains the arithmetical integrity of the diagnostic tree and allows us to determine which process would most improve ER. Yet because many jobs have no requisitions and thus zero AWP time, the overall average AWP time may not accurately reflect AWP time problems when there *are* requisitions submitted.[2] So at the left of the tree we again show AWP time performance, but only for work orders that went to the supply chain for materiel. These numbers exclude the "0-time" AWP records (and thus 0-time order and parts pickup records) for work orders without requisitions. With the no-part work orders removed, the AWP times increase to 10.5 days and

[2]Jobs may not have requisitions on the deadline report, because the requisitions were not coded in ULLS as deadlining, all parts were on-hand in the PLL (which does not trigger a supply request posted above ULLS), all parts were procured locally, or the job did not require any parts. As described in an earlier footnote, parts ordered against deadlining faults in ULLS are not automatically coded as deadlining in the system.

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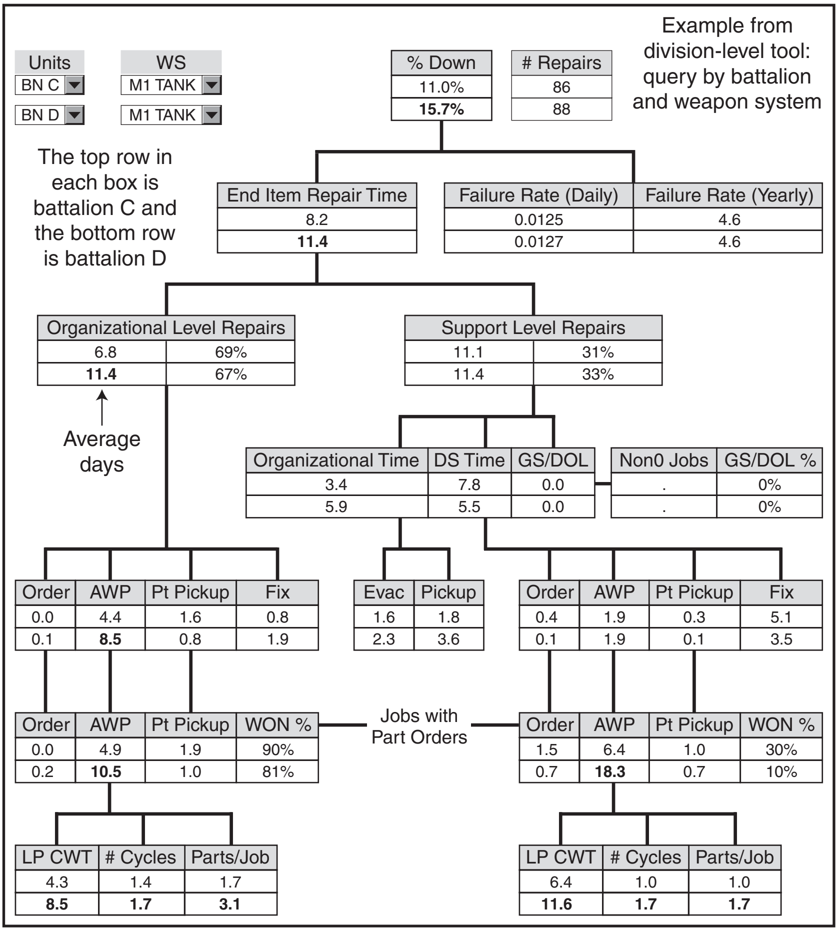

Figure 5.3—The Diagnostic Tree Provides a Complete Picture of Equipment Readiness

4.9 days respectively. The increase is greater for BN D, because it had a lower percentage of jobs with parts on the deadline report, at only 81 percent versus 90 percent for BN C. This second set of numbers is more appropriate for diagnosing AWP problems.

AWP time is further broken down into LP CWT and "cycles per job," along with another diagnostic metric—parts per job (in the lower left-hand corner of the tree). LP CWT measures the responsiveness of the supply chain to customer needs, and "cycles per job" measures the efficiency of the customer's diagnostic and ordering processes. The two multiplied together often roughly equal AWP.[3]

We see a very large difference in LP CWT or the supply support received by the two battalions, 4.3 days on average for BN C versus 8.5 days for BN D. Part of the higher LP CWT was likely caused by the higher number of parts per order cycle—1.8 versus 1.2 (not on the tree)—and, as we will see later, part of the higher LP CWT came from higher part-level CWT.[4] The more parts that maintenance personnel have to wait for, the more likely it is that one of the parts will take a long time to arrive. Later we will examine part-level CWT to better understand the difference in supply support received by the two battalions. BN D's order cycle rate, at an average of 1.7 order cycles per job, was also much higher. This order cycle rate means that 70 percent of the time when BN D ordered parts, it had to order parts again versus just 40 percent of the time for BN C. This higher rate exacerbated the effect of BN D's slower supply support, increasing AWP time by 20 percent over the LP CWT.

The right side of the tree decomposes repairs evacuated to DS-level support, which on average were about equal in length for the two battalions and accounted for one-third of all repairs. When we decompose the total repair time for these jobs into the three main

[3]Again, the relationship will not be perfectly multiplicative. If cycles are completely serial—that is, there is no overlap—then the product of LP CWT and order cycles will equal AWP time. If cycles overlap (i.e., there are new order cycles before all the parts ordered in earlier cycles are received), the product of the two numbers will tend to be larger than the actual AWP value. For example, BN A's organizational level AWP time averaged 4.9 days, with an average LP CWT of 4.3 days and an average of 1.4 cycles per repair. $1.4 \times 4.3 = 6.0$, which is much larger than 4.9, reflecting a high frequency of overlapping parts-ordering cycles. In contrast, BN B's DS work orders had an average AWP time of 18.3 days, relatively close to the product of 11.6 (LP CWT) and 1.7 (order cycles), which is 19.7, reflecting a tendency toward nonoverlapping or serial cycles. Thus far in our development of the EDA, these patterns seem to be relatively consistent: for most units, organizational cycles tend to overlap while DS cycles tend to be more serial.

[4]By part-level CWT we mean CWT measured across all parts ordered as opposed to LP CWT, which measures CWT for an entire group of parts in one order cycle.

components (organizational time, DS repair time, and GS/DOL time), we see that differences in the organizational times and DS repair times counteract each other to neutralize any overall difference. We also see that neither battalion had any tanks evacuated above DS-level maintenance during this period.

As illustrated in the process segment tree in Figure 5.1, the organizational time for support-level repairs consists of two components, time before evacuation and time after the item is ready for pickup. BN D's higher organizational time for DS repairs comes from longer time in both segments. Further detailed analysis of these repairs and process walks of the two battalions could determine why BN D's process is so much longer. Perhaps the tanks that were evacuated to DS also required organizational-level work while BN C's did not. Or maybe BN D simply takes more time to identify DS-level faults, to evacuate the tanks to DS, and to pick up the tanks.

For the DS repair time, we see that BN C's supporting DS shop has longer fix time than BN D's supporting DS shop. Further analysis using Work Order Logistics File (WOLF) data for these two shops, as well as process walks and interviews, could uncover the reasons for this difference.

Decomposing AWP for DS repairs reveals another situation where an opposing difference in two metrics caused them to cancel each other out. When we examine AWP for only those jobs with requisitions appearing on the deadline report, we see that AWP for BN D's supporting DS shop is much longer than that for BN C's. As with the organizational repairs, this comes from longer LP CWT and more order cycles. In this case, the order cycle effect for BN D is much larger, leading to AWP time of 18.3 days for jobs with requisitions—more than 50 percent longer than BN D's LP CWT.

The longer LP CWT result is consistent with the organizational repairs, because the organizational parts and DS parts for a battalion's repairs are ordered from the same SSA. It would be hard to conclude anything simply from the DS LP CWTs, though, because parts were reported on the deadline report for only eight and three DS repairs, respectively, possibly as the result of very robust shop stock. This is why the DS-level differences in supply support and cycles do not play a significant role in the overall total repair time story. The part needs for the other repairs were satisfied through bench stock, shop stock, or maintenance-to-maintenance transactions; or through same-day ASL walkthroughs; or through some other means, none of which produce requisitions. Potentially of note, the DS maintenance shop with better supply support also requisitioned parts through the supply system a greater percentage of the time.

The EDA diagnostic tree, then, provides a fairly complete picture of what happened for each battalion. We can see the relative importance of organizational and DS-level repair work and the relative contributions of the different process segments within each type of repair. Today, without the EDA, the only metrics in this tree that are available are overall ER, DS repair time (excluding the organizational time on both ends of DS repairs), GS/DOL time, and part-level supply metrics (not tied to individual deadlining repairs). These metrics are not linked together to create an integrated picture.

The difference in ER between the two battalions can be diagnosed further by examining part-level CWT, but first we explain the concepts of workarounds and customer wait time in more detail.

WORKAROUNDS

Without workarounds, the LP CWT for both battalions would have been longer. When maintenance and supply information are combined at the requisition level, interaction between the two becomes visible, making workarounds at least partially measurable for the first time. Figure 5.4 illustrates how EDA data is used to detect workarounds.

A workaround occurs when the requirement for a part is satisfied through means other than the standard supply chain channels. Through the EDA, we can see workarounds when they occur after a requisition has already been placed in the supply chain—that is, after the customer first tries to obtain the part through normal channels but then decides to use alternative means—or when they are a response to an unsuccessful part request. The first typically occurs because there are delays in getting the part through the supply chain. With pressure to get systems out of deadlined status, maintenance personnel pursue alternative means to get parts that take too long to

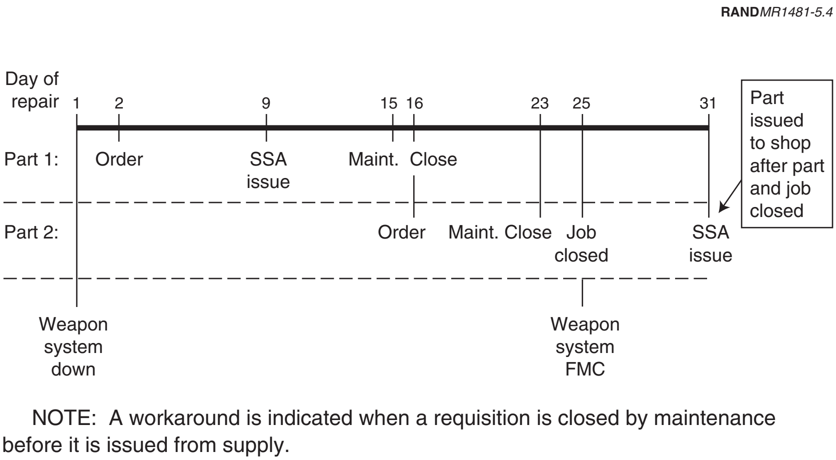

Figure 5.4—Maintenance Workarounds Shorten Total Repair Time

arrive. The chart illustrates this phenomenon with data from an actual tank repair. The first part was ordered on day 2, issued by the SSA to the unit on day 9, and removed from the deadline report on day 15. This is the standard sequence of events. A second part was ordered on day 16. Maintenance "receipted" it in ULLS and removed it from the deadline report on day 23, and the tank was brought to mission capable status on day 25. The part was issued six days later. This out-of-sequence series of transactions most likely signals the occurrence of a workaround. Given that the tank had already been down for 23 days, it is quite possible that the maintenance personnel worked offline to obtain the needed part to bring this long-deadlined system back to mission capable status. In this example, it cut eight days from the LP CWT of the second order cycle and at least eight days from the total repair time. Workarounds are also signaled when requisitions are not satisfied by the supply system at all and the part is not reordered.[5]

[5]This can occur for several reasons. The first is that the maintenance organization either fails to send an ULLS or SAMS request to SARSS or does so incorrectly. The second is that request is rejected for an error (e.g., obsolete part). The third is that a request is rejected for financial reasons. The fourth arises when a computing problem corrupts or deletes SARSS data and effectively deletes a record of a transaction. The

Through process walks, interviews, and attendance at maintenance meetings, we documented several ways that workarounds are executed. These are listed below along with the frequency with which they were reported or directed in one weekly brigade maintenance meeting.

- Controlled exchange[6] (5)
- "Scrounge," trade, use of "can" point, or borrow[7] (4)
- Local purchase (after submission of a still-open requisition)[8] (4)
- Local fabrication by component repair shops (3)
- Change diagnosis/repair method (e.g., use next-higher assembly) (1)

Workarounds create waste through excess work—both direct labor to procure the parts and indirect labor to manage the workaround process—and through the delivery of duplicate (and therefore excess) parts. Choosing to accept the costs associated with this waste, however, is a rational response to the need to meet equipment readiness

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fifth is that a workaround occurs and the unit cancels the request. These reasons can be categorized through the request status codes of no record, rejected, or cancelled (or the lack of the RON altogether in SARSS and CTASC document history files).

[6]Controlled exchange, also known by the terms cannibalization and cross-leveling, is defined as taking a part from one deadlined end item to complete a repair on another. Typically the donating end item is still waiting for one or more parts and the receiving item only needs the one part to become FMC. In theory, if the part is already on order for the receiving end item, it is used on the donor end item when it arrives from the supply system. Otherwise, a new requisition is created for the donor end item. The end result is that instead of having two deadlined items that need one part each, there is one FMC item and one deadlined item needing two parts. It should be recognized, though, that controlled exchange has other potential costs besides additional work. There is a potential risk of breaking the part being removed or causing a problem to the donating system. In addition, the exchange is not always well "controlled" and tracked in automated systems, which can lead to the generation of "excess" parts.

[7]Sometimes when maintainers requisition parts found to be unneeded later, they hold on to them for later use. In effect, this is off-the-books inventory. This inventory, along with any other parts available, is also known to be used for an "underground" supply system that operates off the record. "Can" points are locations at which "discarded" or excess end items are kept until they have been stripped of all potentially useful parts.

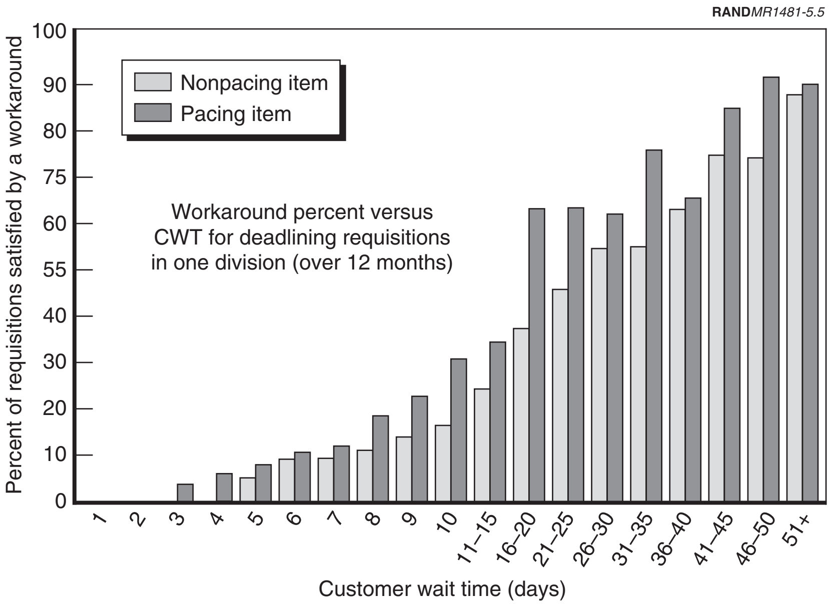
[8]Local purchases for both parts and part fabrication by job shops have been observed.

goals. The longer a system is down, the greater the costs, until the costs of further downtime exceed the cost of the workaround.

To the extent that this concept applies, maintenance personnel are doing the right thing when they employ workarounds. Downtime "costs" are transmitted via command pressure applied when units are in danger of missing targets and sanctions and further pressure placed when units actually fall short of goals. These targets may include formal Army-wide goals such as maintaining a monthly ER rate of 90 percent or above and locally driven goals such as not having repairs on the deadline report over 30 or 60 days. Informal targets could include things such as not having items on the deadline report for more than two consecutive weekly maintenance meetings (due to heavy command pressure at meetings).

As expected, the longer that maintainers have to wait for a part, the more likely they are to employ workarounds. Figure 5.5 plots the workaround rate (the height of the columns) versus customer wait time for all deadlining requisitions in one heavy division over one year, divided into requisitions for pacing and for nonpacing items.[9] For nonpacing items, the first workarounds appear at five days, and they increase fairly steadily to about 11 percent at eight days, 37 percent at 16-20 days, and about 90 percent at 51-plus days. For pacing items, the first workarounds occur at three days. They hit 11 percent at day 6, jump to 19 percent at day 8, go from 34 percent at 11–15 days to 63 percent at 16–20 days, and increase to about 90 percent again at 51+ days. Process walks, interviews, and observing meetings have revealed that maintainers sometimes do workarounds on their

[9]A pacing item is an official status accorded to certain types of equipment in each unit that are key to its capabilities and essential to its assigned mission (e.g., a tank in a tank battalion). They are accorded greater importance and weight than other equipment in required monthly equipment readiness reports. For ER reporting purposes, a unit's equipment is divided into three levels of importance: individual pacing items (Equipment Readiness Code (ERC) P), principal weapon systems and equipment (ERC A), and support items of equipment (ERC B/C). The unit's equipment serviceability readiness rating (R-level) is the lowest of the ratings for each individual pacing item or all reportable items together (ERC P, A, B, or C). The unit's equipment on hand readiness rating (S-level) is based upon the lowest S-level of each of the pacing items or all ERC A and P items combined. Thus "pacing items are subject to continuous monitoring and management at all levels of command." See Army Regulation 220-1, *Unit Status Reporting*, Washington, D.C.: Headquarters, Department of the Army, 1 September 1997, for more information on the treatment of pacing items.



SOURCE: Equipment Downtime Analyzer.

Figure 5.5—Through Workaround Rates, Maintainers "Communicate" What They Must Do to Achieve Equipment Readiness Goals

own initiative and sometimes as the result of direction such as that given during weekly brigade maintenance meetings. Typically, within a brigade there is a weekly meeting to review all the deadlined equipment on the O26 print. We have observed, and logistics personnel agree, that the meetings are primarily devoted to discussing the status of requisitions for needed parts. If it is reported that a deadlining part is backordered or has an extended estimated ship date, then it is likely that the leadership at the meeting will direct the execution of a workaround, if feasible, especially if an end item is a pacing item. We have also observed that if they have not been able to get good status (visibility of the stock status and/or estimated ship date), especially by the second weekly meeting, then a workaround is also likely to occur. The pressure to get pacing items fully mission capable coupled with such weekly meetings may explain the jumps at eight days and then at 16–20 days, when at least two meetings will have occurred. Preliminary analyses have also suggested that the workaround rate, besides customer wait time and end item criticality, is a function of what the owning unit is currently doing (e.g., NTC rotation, gunnery, or motor pool activity) and their current equipment readiness status (i.e., are they below the 90 percent goal, and how much below?).

Through their actions that produce the data in this curve, maintainers and logistics unit leaders are telling the Army how fast they need to get parts to keep equipment ready to the standards that their leaders and the Army's senior leadership demand. While wholesale CWT has improved dramatically over the last five years, almost 15 percent of deadlining customer requests filled by wholesale sources of supply (including backorders) are still satisfied by a workaround before the supply system issues the part to maintenance.[10] Some referrals also result in workarounds, because of excessive delay.

CUSTOMER WAIT TIME

The concept of "customer wait time" (CWT) was introduced previously, but not fully defined.

CWT is the elapsed time from the identification of a customer's part requirement until that need is fulfilled, no matter the source. Figure 5.6 depicts typical sources for filling customer needs and the main components of the order fulfillment process for each of the sources. CWT is measured from the document date (the earliest date the customer's need is captured) until the supply system issues the part to the customer (the maintenance shop). It then becomes the responsibility of the maintenance shop to pick up, receipt, and distribute the part to the appropriate mechanic.

The Army's supply chain satisfies parts requirements through sources at several different echelons of support. They can be satisfied locally by shop or bench stock (for DS work) or from the PLL (for organizational-level work) or from other local sources such as local purchase or through controlled exchange. They can be filled from

[10]The data suggest that the workaround rate was 50 percent or higher for deadlining requests filled by wholesale prior to the VM improvement of the wholesale order fulfillment process.

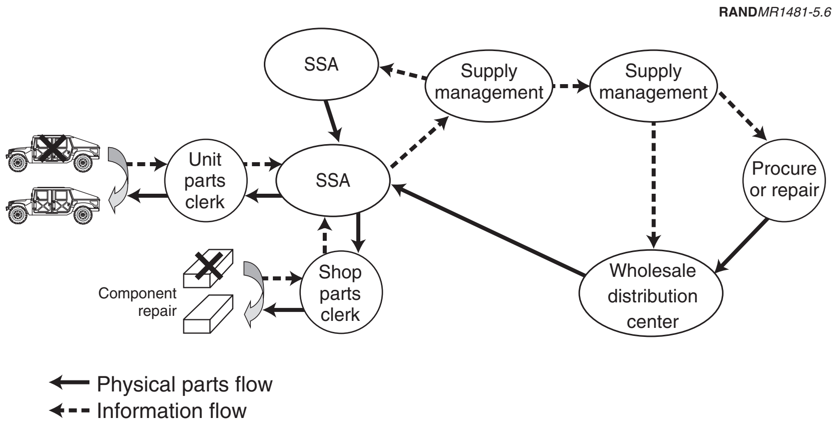


Figure 5.6—Overall Customer Wait Time Reflects a Mix of Performance from the Different Sources of Supply

the ASL inventory at the customer's SSA, by referral from another SSA, or by component repair at the customer's supporting DS organization. They can also be filled from wholesale sources, such as organic Department of Defense depots or from direct vendor delivery. If the part is not available through any of these sources, the customer will have to wait for the wholesale system to procure the item or repair a carcass, creating a wholesale backorder. Typically, the closer the source of supply is to a unit (from the perspective of organizational structure rather than geography), the shorter CWT will be. Fills from local inventory—whether PLL, bench stock, shop stock, or ASL—are the fastest. Every other source of supply has to be routed through the same information and delivery processes as ASL fills, and they require various additional processing steps, depending on the source.

Overall CWT metrics measure the length of this process regardless of the source of supply. To diagnose CWT, one can examine the percentage of requisitions filled from each source (which measures stockage effectiveness) and the fill times by source and process segment (which measures order fulfillment process performance for each fill source).

To continue the diagnosis of the difference in readiness between BN C and BN D, we decompose part-level CWT into its components to understand what is causing the difference in overall CWT.[11] In each set of bars in Figure 5.7, the left column represents BN C and the right column represents BN D. The set of bars at the far left compares total CWT for all deadlining tank requisitions for the two battalions. Each set of bars to the right shows the CWT for the source of supply named underneath the bars, and the numbers below each set of bars indicate the frequency with which customer needs were satisfied by the source. The shaded parts of the bars show the percentiles of the distribution of CWTs: the median (fastest 50 percent), the 75th percentile, and the 95th percentile. The dots in the bars indicate average CWTs.

The overall CWT numbers come from combining requisitions satisfied by all the supply sources. The mean total CWT is an arithmetic average of the individual source of supply CWT means, weighted by the number of requisitions filled by each source. For example, 14 percent of BN D's requisitions were filled from its SSA's ASL, with an average CWT of 1.8 days.

We can see several important results from this chart. First, we see that BN C enjoyed better supply support in two regards: higher fill rates for deadlining tank parts from its SSA (27 versus 14 percent) and better times for wholesale deliveries (e.g., 9.4 versus 11.9 days CWT). This likely reflects better retail-level order fulfillment processes in BN C's brigade, because processes above the brigade level should be identical for both. Since maintainers will typically do a workaround if feasible rather than wait on the arrival of a wholesale backorder, wholesale backorders (which are not included on this chart) play a relatively small role in satisfying deadlining requisitions.

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[11]We are measuring CWT from the maintenance perspective. This means that CWT ends when the SSA issues the part, making it available for maintenance to pick up, or when maintenance executes a workaround to satisfy the part requirement. Thus CWT measured from the maintenance perspective will be shorter than CWT measured from the supply perspective, which is how the Army is measuring CWT. "Maintenance" CWT also includes a larger population of requests, because it includes all deadlining requests whether they became successful requisitions in SARSS or not. "Supply" CWT measures only those requisitions that are successfully established in SARSS and that result in an issue. "Supply" CWT is appropriate for diagnosing stockage and distribution processes, while "maintenance" CWT is appropriate for understanding how well the supply chain is satisfying repair requirements.

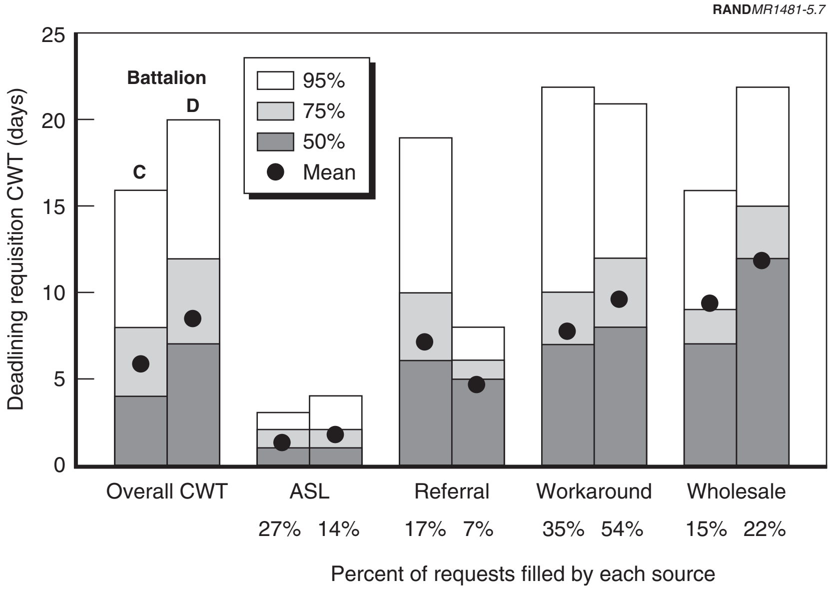

Figure 5.7—Lower ASL Fill Rate and Longer Process Times Produced Battalion D's Longer CWT

Those backorders that actually do satisfy deadlining requirements tend to be relatively short for wholesale backorders. As a result, only 1 percent and 3 percent of the two battalions' deadlining tank requisitions during this period were satisfied via wholesale backorders (the 1 percent rate is actually more typical), and they were issued in an average of just 22 days compared to median backorder times in the 100-day range. Overall backorder rates for deadlining tank requests in their division have run at about 5 percent.

Lastly, we see the importance of maintenance workarounds and the significant difference between these two battalions: 54 percent of BN D's deadlining tank requisitions were satisfied by workarounds, compared to "only" 35 percent of BN C's. These workaround rates were unusually high. This was probably for two reasons. First, tanks and Bradleys receive the most emphasis. Second, this was a period of relatively high OPTEMPO for both battalions, which puts more stress on ER rates, and exercises such as the gunneries they executed

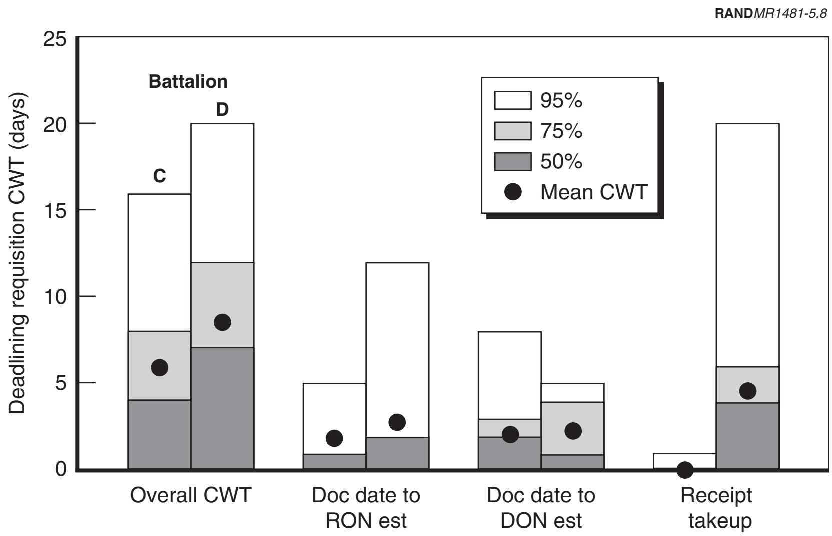

Figure 5.8—SSA Receipt Takeup Time Contributed to Battalion D's Longer CWT

further increase the urgency of fixing tanks. Also note that BN D was only able to get 21 percent of its parts through on-post sources—either its local ASL or on-post referrals.

In the previous discussion, we posited that the longer process times for the various fill sources were coming from longer retail-level order fulfillment processes in support of BN D. Continuing the drill-down into the data by looking at the portions of CWT under the control of the unit and its supporting SSA confirms this. The second set of bars in Figure 5.8 measures the time from creation of the request (document date) in ULLS to the time the data are transferred to SARSS (RON establish). BN D took one additional day, on average, to get its requests into the supply system. The third set of bars is a similar measurement for DON documents created when requests were passed to the wholesale system. In this case, both SSAs had similar performance in terms of document submission. The final set of bars measures receipt takeup, which measures from receipt (TK4 transaction) to master inventory record posting (MIRP). The SSA in support of BN D was taking markedly longer to complete the receipt process and make items available for issue.

Besides enabling the diagnosis of specific problems, the EDA data lend themselves to policy analysis. For example, the ongoing implementation of the Army's new retail inventory algorithm, commonly called dollar-cost banding, is proving that keeping parts stocked locally reduces CWT.[12] Theoretically, this should reduce total repair time, but the question is, by how much? With data from three organizations, we present an example EDA-based analysis that suggests the potential benefit is quite large.

In Figure 5.9, the left column of each pair shows the tank repair times for one Training and Doctrine Command installation and two active heavy divisions for repairs in which all the needed parts were available in the local ASL.[13] These bars contrast sharply with the columns on the right, which indicate repair times for those repairs needing at least one part not available within the local ASL (the ASL for a given brigade in the divisions), to include on-post referrals. The repairs requiring a part not available locally took an average of about 14 days longer at the TRADOC installation and 9 days in the two divisions. (Without workarounds, such as controlled exchanges, the differences would be substantially greater.) Shifting repairs from the right sets to the left sets would make a large improvement in overall repair time. Of course, this must be balanced against mobility and cost objectives, but ongoing efforts by the VM team to improve local stockage through the implementation of dollar-cost banding show that substantial local stockage improvement is possible with little or no increase in inventory value and without loss of mobility (number of containers or trailers necessary to hold the ASL).

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[12]Dollar-cost banding is an initiative of the VM Stockage Determination PIT that improves accommodation rates (the percentage of demands for which a part is authorized for stockage) by lowering the add-and-retain criteria for inexpensive, critical parts. It also improves satisfaction rates (the percentage of demands for parts authorized for stockage that are on the shelf when demanded) through the use of variable safety limits based upon demand patterns (the algorithm embedded in SARSS bases depth upon days of supply and assumes a uniform demand distribution).

[13]The percentage of repairs that got all needed parts from the local ASL is termed the work-order fill rate. This is a customer-oriented stockage effectiveness metric. This is akin to the term "order fill rate" in the private sector. The request level fill rate used previously with CWT is analogous to line fill rate.

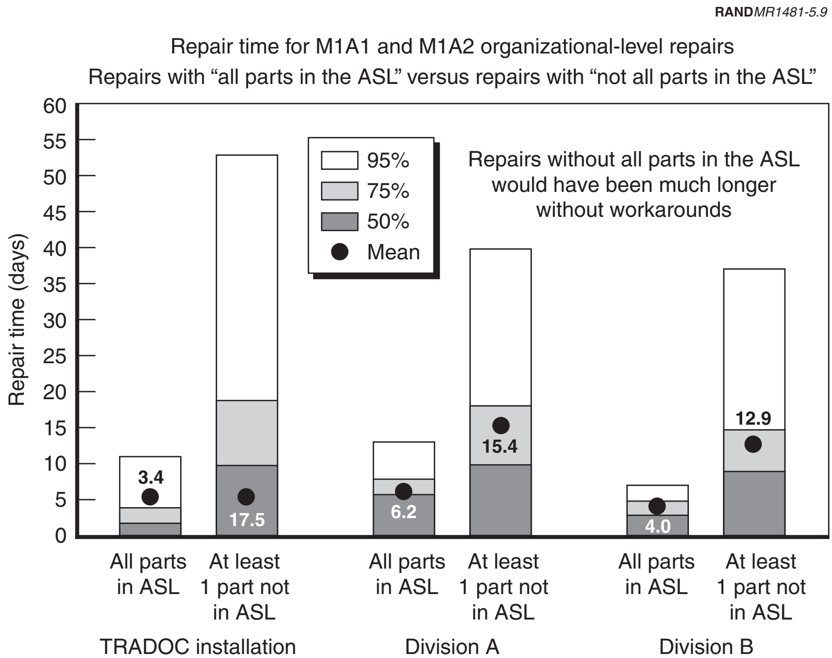

Figure 5.9—Effective Local Stockage Makes Repair Times Dramatically Shorter

We should note that when looking at the entire population of repairs in the two divisions, not just the tanks, the average time for repairs that had all the needed parts available locally was about 11 days. (The repair time for repairs in which one part is not available locally increases even more because the lower urgency of nonpacing items results in greater delays before workarounds are executed.) This suggests significant opportunity to improve the repair process through means other than just better supply chain support. In fact, the segment times for parts pickup and receipt, fix, evacuation to DS, and pickup from DS are typically much longer for nonpacing items than pacing items. This is most likely due to prioritization of resources and the special attention paid to repairs of pacing items to avoid the delays associated with nonoptimized processes.

Chapter Six

THE PATH AHEAD

DEVELOPING THE EDA

Today the EDA exists as a functional program, using live data, at RAND. To illustrate the power of the hierarchical ER metric framework, we have used examples in this document from a database populated with data from two heavy equipment divisions.[1] To fully develop the EDA concept and test its feasibility, RAND collaborated with the first of these heavy divisions to archive daily 01 and 02 files. Each working day, commencing in early May 1999, the division sent each set of SAMS files to RAND via e-mail. Concurrently, a team composed of participants from RAND, the heavy division, and the VM Repair PIT, developed a set of business rules (programming logic) for linking the daily records and dividing the repair histories into process segments. Based upon these business rules, RAND developed a program to process the 01 and 02 file archive to produce a history of each repair and repair process metrics. Major General Dennis Jackson, then commanding general of the U.S. Army Ordnance Center and School and head of the VM Repair PIT, provided oversight and support for these initial efforts.

In October 1999, a second division began sending data to RAND each day, providing an opportunity to validate the business rules and

[1]For the proof of principle, SAMS-2 data were received via daily e-mails from the two divisions, CTASC data were sent from the Corps computer, and property book data were downloaded from the secure Army Equipment Readiness Report Module (AREM) Internet site. AREM includes Continuing Balance System—Expanded (CBS-X) data and is maintained by the Logistics Management Institute.

confirm their broader applicability. Adding the second division also provided another opportunity to gain feedback on desired management reports.

EDA IMPLEMENTATION

In late 1999, after being briefed about the successful development of the EDA prototype based upon the data from the two divisions, the Army's DCSLOG (now the G-4), in conjunction with the Combined Arms Support Command (CASCOM) and the Ordnance Center and School (OC&S), began taking steps to make the EDA available for use throughout the Army.

The first action taken by the Army's DCSLOG to make implementation possible was to direct CALIBRE Systems, the company that developed and runs ILAP, to begin archiving the relevant SAMS files in order to begin the creation of an active Army EDA database (the information system architecture was already in place to accommodate the transfer of data from SAMS-2 to ILAP). CALIBRE initiated active-Army-wide archiving of the data in February 2000 for all data that are transferred from SAMS-2 to ILAP. Initial checks show that most, but not all, of the Army's major units are consistently transferring their data.[2] CTASC data were already being archived in ILAP, and CBS-X at LOGSA centralizes Army property book data.

Next, the office of the DCSLOG wrote an EDA Operational Requirements Document (ORD) for an interim EDA system to reside in ILAP. Based upon this ORD, HQDA approved funding to integrate the EDA into ILAP as part of the intended migration of ILAP into the Global Combat Support System–Army (GCSS-A) Management Module.[3]

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[2]The SAMS-2 data flow to ILAP is essential for EDA implementation. The Army should institute a policy directing this flow on a daily basis, and develop a reporting and feedback mechanism to ensure high-quality data flow. Connecting SAMS-2 computers to local area networks offers the opportunity to improve the reliability of the data transfer process, because an automated nightly upload process that transfers the data to ILAP can be programmed.

[3]GCSS-A is a new information system currently under development by the U.S. Army. It will replace, among other systems, ULLS, SAMS, and SARSS. The management module will provide management reports and enablers such as the daily deadline report and the EDA.

CREATING A SEAMLESS, INTEGRATED EQUIPMENT READINESS DATA ENVIRONMENT

In many ways, the EDA represents just a first step toward an integrated, seamless Army information environment that facilitates analyses and equipment readiness management. Ultimately many more types of data could and should be integrated, whether through a virtual database or data migration, to help further improve the Army's ability to understand equipment readiness. Below we discuss several possibilities for this kind of integration.

First, there are opportunities to integrate additional existing data about equipment and its usage so that additional failure rate analyses can be performed. Currently, EDA failure rates are based solely upon calendar time. But the Army also captures usage information at the individual end item level on a monthly basis, which is stored in The Army Maintenance Management System (TAMMS) Equipment Database (TEDB) at LOGSA. For ground equipment, usage is measured and captured in miles or kilometers; for aviation, items usage is in terms of operating hours. In support of other research at RAND, we have been able to successfully combine TEDB ground equipment usage information and EDA data at the monthly level by end item serial number to produce metrics such as the mean kilometers between NMC failures. By grouping parts into subsystems, we also produced similar metrics for subsystems. The final step would be to do the same for parts. Incomplete data capture of parts needed for deadlining repairs, though, limits the potential quality of subsystem-level failure rates and especially part-level failure rates. Additionally, to fully analyze failure rates, one needs to know more than just the miles driven for some systems. Mileage may be adequate for many noncombat vehicles, but for combat systems, rounds fired would also be a useful metric for analyzing failure rates. Currently, however, ammunition expenditures at the end item level are not captured and stored in a way that would enable integration of this data. Further, for systems in which doctrine calls for significant time in which a system is on and just idling in a static position—for example, tanks in a defensive position—both mileage and operating hours would be valuable. In addition to usage, the TEDB contains year of manufacture and overhaul information. When analyzing failure rates, it would be useful to be able to integrate this information. At present, though, there are significant amounts of missing data in these areas, in particular for overhauls.

Second, in illustrations of the EDA diagnostic metrics, we extended the drill-downs of repair time metrics to CWT and then to CWT diagnostic metrics such as the ASL fill rate, referral RWT, and wholesale RWT process segment metrics (e.g., order processing time). The complete set of diagnostic metrics means that we can isolate the effects of each supply process and echelon on equipment readiness. Future information systems should seamlessly enable this type of drill-down.

Third, in Chapter Two of this report we discussed the notion of measuring pulse availability. To implement such a measure, the Army would need to tie training execution with ER data. This could be done by integrating unit training schedules (updated after the training was actually executed to reflect changes in the plan) with the EDA data. Besides enabling the calculation of pulse availabilities, which would help the Army better understand capabilities to perform different types of missions at different levels of intensity, the tie-in of unit training schedules to the EDA would enable direct linkage of training activities to failures and logistics results. This would further improve failure rate analyses and help better determine the need for logistics resources, such as parts inventory, based upon the type and length of activity. Better linkages between parts requirements and events might allow units to better anticipate part needs for exercises and thus better tailor stock packages for either training exercises or deployments.

Today the Army has an automated training information system, the Standard Army Training System (SATS), that may have long-range potential for integration with ER data. The key is that it has standard codes and names for different types of training events. After cursory reviews of its use in two divisions, it does not seem that it is employed by units to a degree sufficient to provide data of high-enough quality to make its integration with the EDA meaningful in the near term, although a thorough review of the quality of the data in SATS should be conducted before making this determination. Critical questions would be: Are all training events recorded? Are the dates correct?

Once training events and the EDA are integrated, it would then become valuable to increase the fidelity of the data on the use of equipment, such as daily mileage reporting, so that usage during the training events could be isolated to the exercise. As digitization of the Army's equipment progresses, this type of frequent usage reporting may become feasible through automation, which could also improve the accuracy of usage reporting.

Finally, the Army might also want to tie equipment readiness to personnel readiness. For example, the EDA might help identify that a particular shop has unusually long shop time or has had severe order process problems. Automated linkages to personnel data could quickly tell managers whether this shop was facing a personnel shortage in terms of absolute numbers or particular skill sets. Combined with workload data, this would be useful in helping isolate the potential root cause of the problem. At a higher level, it might provide the basis for analyses that would provide valuable insights for the Ordnance and Quartermaster branches.

IMPROVING THE EDA THROUGH FUTURE ARMY INFORMATION SYSTEM DESIGN

As GCSS-A evolves, the Army should ensure that it includes "EDA-like" capability, although this could be provided through different data structures. That is, GCSS-A should include, but not necessarily be limited to, the proposed EDA metrics and the EDA metric hierarchy that produces an integrated, systems view of equipment sustainment. It is the EDA framework that is valuable and should be preserved, not necessarily the current metrics, which are limited by the data currently available or the current means of collecting the data.

The EDA and future derivatives would benefit greatly from improved data capture, and GCSS-A offers opportunities for improvements. Ideally, complete work order records would be generated at the organizational level, including a complete history across echelons.[4]

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[4]This is currently done by SAMS-1 for support-level work orders. It creates closed work order histories that are then archived in the WOLF database and used to produce support-level metrics. These metrics measure the time from support work order creation to close and allocate this time through process metrics, but they do not

Work orders for all repairs, deadlining or not, should be captured and saved, regardless of how short the duration. (Today, repairs that start and end between daily reporting cycles are not reported at all. These may include repairs completed immediately via controlled exchange from an already-down system.) This would allow an EDA-like system to operate from the closed work order records rather than by cutting through daily archives, and it would allow the inclusion of repairs that today do not make the daily deadline reports because they are of exceptionally short duration. All parts used on these work orders should be recorded in the work order history, including those filled by PLL, bench stock, shop stock, local purchase, controlled exchange, direct job orders to component repair activities, and ASL walkthroughs to generate a more complete mapping of part demands to repairs. In addition to parts, labor hour information should be captured for every repair. Capturing all parts and labor information at the work order level would enable the creation of complete end item failure and repair histories.

In terms of part receipting, two improvements would be of value. The first would be the transmission of a receipt acknowledgment from ULLS or SAMS to the supply system when receipts occur. This would be a more positive indication than the current EDA method of looking to see when part requests are removed from the deadline report. In addition, this would improve Army CWT metrics, which today, because of this data limitation, end when SSAs issue parts and not when customers receive them. The second improvement would be to not allow customers to "receipt" items unless an issue has occurred. Today there is nothing to prevent customers from "receipting" items (if they no longer need the item due to a workaround, for example) whether or not the item was actually issued or received. GCSS-A should allow them to close the record in ULLS or SAMS, as they do now. But it should also require that the unit enter a reason (the part was not needed, for example, or a workaround was accomplished in a certain way) when records for parts requests are closed before the SSA has issued the requested part. In addition, the request should be cancelled automatically.[5]

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account for organizational evacuation time and ORGWON time after the support work order close.

[5]Currently, valid part requests can be closed in ULLS without canceling the request, and workarounds are not directly tracked.

The next step in improving data capture would be to improve the precision of event reporting. Recording the time of events precisely, rather than just daily, would improve data fidelity. This becomes ever more important as the total repair time, and thus each process segment, becomes shorter. If repair times were to come down to the two- to three-day range, measuring several process segments in one-day increments would make little sense. This is already the case at NTC and in many other high-pressure situations in which units are able to achieve very short repair times due to increased work hours, increased productivity, and excellent parts support. A batch system updated once per day just cannot keep up with the pace of operations. Consequently, at NTC the Observer-Controllers note that typically the daily SAMS-2 deadline report has fairly low accuracy; usually many of the items on it have been repaired, and many items that are NMC are not on it.

What else should future Army systems record? Improved tracking of failures would be valuable in improving preventive maintenance checks and services, scheduled services, operator training, mechanic training, and product design. Tracking repeat visits of an end item for the same or similar problems would enable evaluation of repair quality at the end item level, and tracking component removals by serial number would enable evaluation of component repair quality and the identification of bad actor components.[6] Improved use of standard fault coding in conjunction with more complete identification of part requests with work orders would be valuable for engineering improvement efforts of current end items as well as for improving the reliability of future systems. For example, the dealers for automotive original equipment manufacturers (OEM) enter warranty work through a hierarchical fault-coding system, creating a database that the OEMs use to improve quality.

To also improve failure analyses, GCSS-A should capture complete scheduled service histories for each end item. This could be accomplished through the creation of work orders for services. This would provide data to further improve service schedules, and it could help identify situations in which scheduled service deficiencies are lead-

[6]Bad actors are defined as specific components that are apparently repaired yet keep indicating new failures and get removed and replaced.

ing to higher failure rates. Finally, it would be extremely valuable to record diagnostic errors for use in improving overall training programs, identifying maintainers or units in need of additional training, and identifying needed improvements in diagnostic technology.

The biggest data deficiency, though, is with aviation data. The data required for EDA analysis are not being entered in ULLS-Aviation (ULLS-A) for a variety of reasons. To employ the EDA for aviation, the Army must either resolve ULLS-A problems sufficiently to gain user confidence or adopt a replacement system that captures the requisite data.[7] Ideally, the GCSS-A module that replaces ULLS should correct the ULLS-Ground (ULLS-G) and ULLS-A deficiencies that have been identified. And the GCSS-A module should be fully accepted by both types of organizations (ULLS-G and ULLS-A). One standard system should work well for both organizations. Any type of data that would be good for aviation maintenance management should also be valuable for effective ground system maintenance management. Alternatively, systems currently in development by the aviation community as substitutes for ULLS-A could be evaluated as to whether they capture the full spectrum of desired data; if so, they could become an alternate source of data for EDA metrics.

CONCLUSION

The ultimate promise of the EDA and any future systems that expand on its basic framework is an enhanced capability to focus constrained resources where they will have the greatest effect on keeping equipment ready to fight, whether by preventing failures through improved equipment reliability and other activities, or by reducing repair time. By enabling logisticians and those engaged in the acquisition and recapitalization processes to examine which improvements are most likely to improve equipment readiness, the EDA should advance the Army's ability to sustain equipment readiness while reducing total support costs and enhancing mobility.

[7] The U.S. Army Aviation and Missile Command is currently developing a system to improve the collection and management value of aviation data called the Data Collection and Analysis Management Information System (DCAMIS).

Army organizations have already identified several ways to exploit the more precise and complete insight that the EDA allows. For example:

- The U.S. Army Materiel Command (AMC) could better identify systemic part and weapon system readiness issues and identify units likely to benefit from technical assistance.
- The Army could use the EDA to help make recapitalization decisions and to evaluate recapitalization effectiveness.
- VM PITs and Site Improvement Teams (SITs) could identify and diagnose new process improvement opportunities.
- Division support commands could use the EDA as a tool to enhance their analyses of ER results and to identify operating shortfalls.
- G-4 could use it to enhance supply and maintenance policy analysis.
- CASCOM could use it to improve analysis of options in doctrine and force development.

In some of these applications, the EDA will provide information not previously available that will improve the quality of decisionmaking. In others, it will create the potential to automate tasks that are now executed manually, producing substantial time savings. For example, some Division Material Management Centers manually compute average broke-to-fix time using the daily deadline reports. This time-consuming process can be executed in seconds with the EDA.

Several organizations are already making use of the limited prototype data available. A division is using the data to justify improved stockage through the estimated equipment readiness benefits. A division has used it to help identify end items for turn-in. A corps staff is using it identify repair process improvement opportunities, and to help justify changes in stockage. A major subordinate command of the AMC has used it to help develop recapitalization plans. The VM Repair PIT is using it to identify opportunities for improvement in unit maintenance operations.

At RAND, we are using the EDA to support other research efforts for the Army. These include determining the effects of age and other factors on failure rates and developing improved stockage strategies for low-density equipment in conjunction with the VM Stockage Determination PIT.

In all its applications, the EDA will provide new, valuable information intended to help people in the Army conduct better analyses and make well-informed equipment sustainment decisions.

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