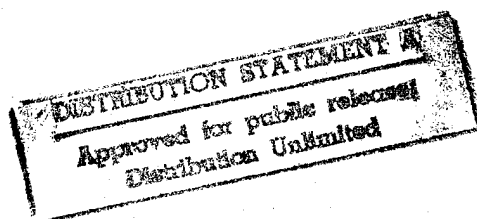


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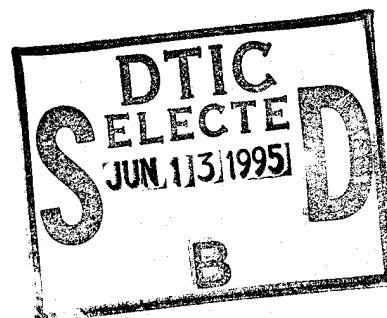
Precision-Guided Logistics

*Flexible Support for the
Force-Projection Army's
High-Technology Weapons*

Marc L. Robbins, Douglas W. McIver



Arroyo Center



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This report documents the final results of the Arroyo Center project, "Improving Combat Capability Through Support Alternatives." This project, sponsored by the commanding general of the Combined Arms Support Command, has been advising the Army on new concepts for supporting its increasing inventory of advanced high-technology weaponry. The report analyzes alternative support concepts for one subsystem, the Apache helicopter Target Acquisition and Designation Sight/Pilot Night Vision Sensor (TADS/PNVS), based on recent experiences in Operations Just Cause, Desert Shield, and Desert Storm. It also includes findings from a RAND study of high-tech support operations at the United States Army Aviation Center and School, Ft. Rucker, Alabama, sponsored by its then-commander MG Ellis Parker. Finally, it draws together many of the results generated from seven years of study and previously documented in the project's earlier reports:

- R-3673-A, *Evaluating the Combat Payoff of Alternative Logistics Structures for High-Technology Subsystems*, M. B. Berman, D. W. McIver, M. L. Robbins, and J. Schank, October 1988.
- R-3793-A, *Supporting Combined-Arms Combat Capability with Shared Electronic Maintenance Facilities*, William G. Wild, May 1990.
- R-3768-A, *Developing Robust Support Structures for High-Technology Subsystems: The AH-64 Apache Helicopter*, M. L. Robbins, M. B. Berman, D. W. McIver, W. E. Mooz, and J. Schank, 1991.

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INTRODUCTION

What should the Army's logistics system of the 21st century look like? With theaters, threats, missions, and resources available all unknown, the Army must look for new solutions to the Army's force-projection role. How must logisticians accommodate themselves to a world of radically changed weapons, doctrine, threats, and forms of operations? This report argues that just as technology and new concepts have revolutionized combat operations, so too must logistics be revolutionized to make it leaner and more responsive.

To help identify alternatives that will make the logistics system more capable of meeting this revolutionary challenge, the report examines the three operations the Army has been recently involved in—Operation Just Cause (OJC) in Panama and Operation Desert Shield (ODS) and Operation Desert Storm (ODSt) in Southwest Asia. Although these operations were substantial successes, in both logistics and, of course, combat terms, there is the question of how robust the logistics support the Army provided its deploying forces was. For example, what if the uncertainties of war had increased the stress on logistics? This study explores the robustness inherent in the Army's current logistics concept by analyzing the consequences of extending the three recent missions in challenging ways:

- What if the fighting had lasted longer in OJC?
- What if fighting had broken out early in ODS?
- What if the operating tempo of ODSt had been more demanding?

Our intent is to determine whether the Army can rely on the logistics structure in possible future operations and, if not, to determine what capabilities the Army should demand of its future logistics systems.

Because the Army's mission poses particular problems for its new high-technology weapon systems, the "what-if?" analysis focuses on these systems and examines the flexibility of current support concepts for maximizing high-technology weapon system capability in the face of demanding conditions. To make the analysis more manageable, the analysis concentrated on the Apache attack helicopter's Target Acquisition and Designation/Pilot Night Vision Sensor (TADS/PNVS), an all-weather,

round-the-clock targeting and navigation aid. Not only is the TADS/PNVS a critical part of the Apache, there is also a comprehensive set of wartime data available, which, in turn, makes it useful for the “what-if?” analysis.

HOW TADS/PNVS IS SUPPORTED

Support of the TADS/PNVS system is based on removing, replacing, and repairing its 26 line replaceable units (LRUs). LRUs are removed and replaced at the flight line by mechanics belonging to aviation unit maintenance units (AVUM). These LRUs are then evacuated back to aviation intermediate-level maintenance units (AVIM), located either at division or corps level. Repair of TADS/PNVS LRUs there can begin only after testing and diagnosis, which is performed on a sophisticated set of automated test equipment, the Electronic Equipment Test Facility (EETF).

Depot-level work is provided in two ways. The most demanding work takes place at the main Martin Marietta depot facility in Orlando, Florida, or at rework facilities operated by subcontractors. Other types of depot work are provided by the forward repair activity, or FRA, which consists of forward-located repair facilities that can both provide very fast turnaround or certain types of depot-level repairs and handle overflow from intermediate repair facilities.

SUPPORTING SMALL-SCALE CONTINGENCIES: THE CASE OF OJC

Apaches in OJC: Operation and Support

Eleven Apaches participated in OJC, providing attack and surveillance support. During the intense fighting of the first six days, operating tempos were in the range of two hours per aircraft per day; afterwards, operating tempos dropped to an average of a half an hour per day.

OJC did not present a large problem for the Apache’s TADS/PNVS subsystem. During the intense, six-day period of fighting, the spares on hand were roughly adequate; demands were far less in the succeeding period.

What If the Intense Portion of OJC Had Lasted Longer?

An intense OJC that lasted two or three times longer than those first six days might have put unsupportable demands on the logistics system. To evaluate this, we performed a simple Monte Carlo simulation in which the level of logistics demands (although not their exact mix) were duplicated for a second and third period.

The analysis results show that had intense fighting in OJC gone on longer, there would have been more than a 50 percent chance of four or more of the 11 Apaches being not fully mission capable (NFMC) and only a scant chance that two or fewer aircraft would be the only ones made non-mission-capable.

The main reason for this significant drop in Apache availability would be shortfalls in resupply. Order and ship times (OSTs) to Panama, 12–17 days in peacetime, increased

by a third during OJC. And even attempts to expedite especially critical items (those grounding aircraft) only reduced those OSTs to 14 days.

Solution Directions

For a short, no-notice operation like OJC, where speed and secrecy are of critical importance, relying on deployed repair capability or precisely calculated and easily available spares packages will likely not be sufficient. The core need for such operations must be for highly responsive resupply from outside sources.

Smaller operations, especially those relying heavily on high-tech weapon systems with precision-guided munitions, will be less mass-oriented; these fast-moving operations will put a premium on responsiveness. Therefore, the Army must modify the resupply system to fit the needs of particular operations (e.g., moving critical supplies through more informal channels, such as phone/fax/email delivery of requisitions to special operations centers, and direct delivery of items from any convenient source, including the production line or the home base).

SUPPORTING MID-SCALE CONTINGENCIES: THE CASE OF ODS

Apaches in ODS: Operations and Support

By early September 1990, four battalions of Apaches (along with other forces) were in Southwest Asia to help deter an Iraqi advance. The "what-if?" analysis here, which examines the implications of combat beginning September 15, focuses on these four battalions in theater.

What If Fighting Had Erupted in ODS?

In answering this question, we assumed a scenario in which Iraqi armored forces crossed the Iraq/Kuwait border into Saudi Arabia, a scenario that would place a heavy burden on the Apaches. The analysis assumes a steady-state tempo of three operating hours per day for the 72 Apaches.

We modeled logistics support for TADS/PNVS using RAND's Dyna-METRIC capability assessment model. The analysis shows that difficult logistics problems would likely crop up at the three-hours-per-day operating tempo, with an immediate drop-off in weapon system capability: over 20 percent of the Apaches are not fully mission capable (NFMC) only five days into the operation, climbing to a high of 56 percent by day 30.

Two things contribute to this outcome. First, there is a spares imbalance between units. Not all units are equally resourced when they arrive in theater, and the resources each unit has may not be well-matched to the operational demands put on it.

A second contributor to the outcome is slow resupply from the United States (CONUS). In ODS, the Army used standard practice for prioritizing delivery of spare

parts, and by all accounts this system worked no better in Southwest Asia than it did in Panama. For the group of highest priority requisitions, only about 12 percent met the OST objective of 12–17 days overseas; the average OST was 45 days.

Solution Directions

One solution to the spares imbalance problem is to enhance the local units' ability to exploit spares in the theater but not in their possession. In particular, tools the Army is developing that can aid "cross-leveling" supplies of spares across units show promise; these include Total Asset Visibility (TAV) and Objective Supply Capability (OSC). TAV seeks to provide the Army with near-real-time visibility of the assets it owns, uses, or stores, while OSC seeks to exploit TAV's visibility capabilities by enabling the supply system to check for availability laterally within the theater and to provide units with accurate requisition status.

Analysis using a model-based simulation of how OSC/TAV might help showed an improvement in weapon system availability by as much as 8 percent in overall fleet availability. More important, in-theater cross-leveling smoothed out the uneven availability across units; on D+10, for example, all units had roughly the same availability, whereas units without this capability showed differences of almost 200 percent in non-mission-capable systems.

In terms of the slow resupply problem, larger, ODS-like operations, unlike OJC-like operations, cannot rely on "customized" support, where supply clerks or civilian representatives can call their needs directly back to CONUS. They require a more formalized system, much like what we saw during ODS and ODSt in Desert Express, a fast-response airlift system for resupplying extremely high priority items. Desert Express achieved mean OSTs of somewhat over 15 days, a distinct improvement over the 45–60 days characteristic of the standard system.

Even faster OSTs could be achieved if problems of in-theater requisition processing and in-theater movement of critical items are overcome. Innovations like OSC may play a vital role in reducing such delays, making OSTs for express deliveries of under ten days possible. A Dyna-METRIC analysis of an ODS case with an improved Desert Express-type fast resupply of ten or fewer days showed that overall NFMC rates for Apaches might drop below 20 percent in this type of operation.

SUPPORTING LARGE-SCALE CONTINGENCIES: THE CASE OF ODSt

Apaches in ODSt: Operations and Support

As noted earlier, some 274 Apaches were deployed to Southwest Asia in 15 units. Operating tempos for that deployed fleet tended to be low, at least according to doctrinal levels of operating activity assumed for the European theater. Flying hours per day for the Apaches ranged from 0.6 to 1.1 hours per helicopter per day during the war.

To support that tempo, a richly endowed theater support structure was built over the six months of deployment and theater development. TADS/PNVs spare parts stocks, worth \$48 million, were placed at unit, intermediate, and theater-level locations. Eight EETFs (in seven intermediate maintenance units) and one FRA were deployed into the theater.

What If Operating Tempos Had Been Higher in ODSt?

In answering this question, we "replayed" ODSt with four different operating tempos: an actual ODSt operating tempo (0.75 operating hours/aircraft/day); a doubling of that (1.5); a tripling (2.25); and a quadrupling (3.0). We also assumed a standard support structure in that we did not include some of the adaptations actually employed in supporting the TADS/PNVs during ODSt.

Availability rates of Apaches, and of the TADS/PNVs subsystem, were exceptionally high in Operation Desert Storm. Not fully mission capable rates were on the order of 3 percent in the actual fighting, a level roughly matched in Dyna-METRIC runs attempting to replicate the actual scenario. Yet if higher tempos had been required, the Army's standard concept of support would not have been robust enough to deliver required weapon system availability. At a doubling of tempos (to an average of 1.5 hours per system per day), NFMC rates would increase to 15 percent; a tripling of operating tempos would increase that rate to over 50 percent, while a quadrupling might put more than 60 percent of the fleet at risk of becoming non-mission-capable.

Our analysis suggested four main causes for the inability of the standard support system as deployed to Southwest Asia to handle higher operating tempos.

Shortfalls in Critical Spares. Surprisingly, there were sufficient spares on hand to cover demands for most of the TADS/PNVs LRUs even if tempos had been tripled. However, there would have been large shortfalls for a small number of LRUs, which, unfortunately, are the most expensive ones. This suggests that increased stockpiles of spares would not be a cost-effective solution to supporting higher operating tempos.

Inefficiency of Intermediate Repair. Even though ODSt had substantially more than doctrinal levels of intermediate repair in theater, this abundance would not have sufficed during intense operations. Our simulation of intense operations, based on performance data from ODSt itself, shows that intermediate repair units relying on EETFs for testing and diagnosis would have been able to convert no more than 25 percent of the carcasses it received back to serviceable status, despite a programmed capability to repair over 75 percent of the carcasses.

Lack of Prioritizing Capability at Critical Repair Facilities. Given the above problem at the EETFs, the analysis strongly suggests that the FRA would be overwhelmed with work. Our analysis indicates that in a higher operating tempo scenario, the FRA would be able to work on no more than 50 percent of the carcasses arriving during the operation. Without means of ascertaining combat unit needs, the FRA would likely waste effort repairing and shipping items that would fill spares stockpiles but that would not directly return weapon systems to full mission capability.

Slow, Unresponsive Movement of Critical Items Through Intratheater Distribution System. The standard system of moving spare parts through the theater (before the initiation of the Camel Flight program, an adaptation made well into Operation Desert Shield) was neither especially rapid nor sensitive to the special needs of high-tech spares. As a result, items from the FRA had to compete with all other items sent forward, which led to transportation times of about six days. The lack of a dedicated, or at least assured, in-theater distribution system would also complicate the retrograde¹ of critical items for rapid repair and forward shipping.

Solution Directions

To address these problems, we propose a concept for a type of support structure that is not now in Army policy. This integrated theater support concept adopts some of the successful adaptations made in ODS and ODSt, offers some new ideas, and proposes some ideas the Army is considering but has not yet adopted. The concept has four principal elements.

Consolidation of Intermediate Repair in a Theater Support Facility. We believe the Army should consider a move to a two-echelon structure for supporting high technology. In this structure, which we call the consolidated repair facility (CRF), remove and replace operations would occur forward, and removed components would be evacuated to a more centralized facility in which operations like the FRA and EETF are collocated. While this approach may seem radical to combat commanders believing in unity of command, we believe the concerns are outweighed by the system's advantages, which include higher productivity of a higher-skilled workforce, better allocation of workload across repair resources to avoid overloading some test stands while others are underburdened, greater overall test stand availability through reduced demand for movement and ability to cannibalize stands to support other test stands, and consolidation of workload in one location (or set of locations) to combine the benefits of batch processing repairs and prioritization.

Dedicated Intratheater Lift. One of the more interesting adaptations during ODSt was the Camel Flights aviation parts distribution system designed to expedite the forward movement of serviceables and the retrograde movement of carcasses from the units to the FRA and other repair resources located in the rear of the theater. Such fast transportation is a cost-effective alternative to buying the expensive high-tech spares that long pipelines require and is much cheaper than the costs of forgone combat capability.

Fast CONUS Resupply of Critical Parts. The Desert Express-type of formalized, quick-reacting operation would play a valuable role in larger contingencies like ODSt. It would be especially useful because some repair, especially that at depot level, cannot be moved to the theater; in-theater repair of LRUs requires having the right shop replaceable units (SRUs), which are difficult to stock in the right numbers;

¹Retrograde is an Army term for rearward movement of spare parts.

and the test equipment itself may require expedited delivery of its own spare parts to maintain mission-capable status.

Weapon System Sustainment Management. Substitution of centrally controlled repair and responsive transportation for expensive spares puts a premium on the use of information by logisticians to meet commanders' needs. The logistician must have up-to-date information on field status and possible future needs. Because that information is complex, it is vital that the logistician have available tested decision support tools to assess courses of action and influence execution of logistical actions.

Benefits of an Integrated Theater Support Structure

To test the value of the proposed support structure, we replayed the ODSt scenario comparing the base case with one that includes elements of the new support concept. The results show that where before at the highest tempos, Apache NFMC rates might exceed 60 percent by the end of the operation, under the new support concept, NFMC rates are sustained at no more than 25 percent at the most demanding operating tempo; for all lesser cases, the number of Apaches down for TADS/PNVs would not exceed 10 percent.

And because of the inefficiencies of the current support concept, the integrated theater support structure can actually provide the higher performance at lower costs. Using a zero-based costing of the two TADS/PNVs support structures, including spares, intermediate repair, FRA, in-theater transportation, and information systems, the integrated support concept could actually provide savings of as much as one-third, with the major cost savings coming in the reduced need for EETFs.

CONCLUSIONS

In looking across the alternatives for supporting the three operations described above, we see a common underlying philosophy that stands in contrast to much of the previous practice of Army logistics. We call this philosophy "precision-guided logistics," or PGL, because it is intended to do for logistics much the same thing that precision-guided munitions (PGM) did for combat operations: marry technology and information to new doctrine and types of command and control to yield far greater support at substantially less expenditure of resources.

The PGL concept derives from four fundamental principles:

- **Substitute information and speed for mass** to increase the responsiveness and robustness of logistics support, even at reduced cost.
- **Emphasize fungible resources**, such as responsive repair and transportation, rather than static resources, such as stockpiles of spare parts.
- **Recognize time as the enemy** by making retrograde, repair, and forward distribution far more responsive.

- **Configure support to the operation** by creatively designing support packages for the various types of operations along the possible spectrum, by writing them into doctrine, and by practicing them in peacetime, and **reduce the tail** by making deployed elements as productive as possible.

Although adopting the PGL philosophy will entail many changes in current practice as well as the specifics of logistics doctrine, the concept is based squarely on the core characteristics underlying Army logistics doctrine as enunciated in FM 100-5: anticipation, integration, continuity, responsiveness, and improvisation.

PGL demands *anticipation* instead of open-ended surge, arguing, for example, that logistics planners must consider what support packages should be created to support what types of missions. PGL calls for *integration* of all parts of the logistics structure, seeking, for example, to tear down the stovepipes that lead, at best, to local efficiencies but may do little to accomplish the final goal. In the view of PGL, *continuity* means that the system should be robust, that, for example, units that do not have needed supplies must be able to get them the quickest way, such as from neighboring units. *Responsiveness* is the true heart of PGL: delivering the right thing to the right place at the right time. And, finally, in the PGL world, *improvisation* implies remaining flexible by substituting information and integrated control for the static solution of spare parts stockpiles.

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This research could not have been completed without the help of our colleagues at RAND. Principal among them is Stan Bentow, who acquired, processed, and gener-

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ACRONYMS¹

AMC	Army Materiel Command
APOD	Air Port of Debarkation
APOE	Air Port of Embarkation
ASL	Authorized Stockage List
ATCOM	Aviation Troop Command
AVIM	Aviation Intermediate Maintenance
AVSCOM	Aviation Systems Command
AVUM	Aviation Unit Maintenance
CAB	Combat Aviation Brigade
CCP	Consolidation and Containerization Point
CCSS	Commodity Control Standard System
CENTCOM	Central Command
CONUS	Continental United States
COSCOM	Corps Support Command
CRF	Consolidated Repair Facility
CRP	Central Receiving Point
DAAS	Defense Automated Addressing System
DISCOM	Division Support Command
DLA	Defense Logistics Agency
DOL	Directorate of Logistics
EETF	Electronic Equipment Test Facility
EOB	Electro-Optical Bench
EOC	Emergency Operations Center
EUCOM	European Command
FAD	Force Activity Designator
FLIR	Forward-Looking Infrared
FMC	Fully Mission Capable
FORSCOM	Forces Command
FRA	Forward Repair Activity
HARS	Heading and Attitude Reference System
IFTE	Integrated Family of Test Equipment
IHADSS	Integrated Helmet and Display Sight System
IM	Item Manager

¹Acronym definitions for the components of the TADS/PNVS system are given in Table 2.1.

KKMC	King Khalid Military City
LAR	Logistics Assistance Representative
LIF	Logistics Intelligence File
LIN	Line Item Number
LRU	Line Replaceable Unit
MEP	Mission Equipment Package
MMC	Materiel Management Center
MMFF	Martin Marietta Fault File
MMFSS	Martin Marietta Fielded System Status
MMRF	Martin Marietta Runtime File
MRO	Materiel Release Order
MSC	Major Subordinate Command
MSRA	Materiel Systems Readiness Activity
MWO	Modification Work Order
NFMC	Not Fully Mission Capable
NICP	National Inventory Control Point
NMCS	Not Mission Capable, Supply
NRTS	Not Repairable This Station
ODS	Operation Desert Shield
ODSt	Operation Desert Storm
OJC	Operation Just Cause
OSC	Objective Supply Capability
OST	Order and Ship Time
RBM	Readiness-Based Maintenance
RPD	Requisition Priority Designators
RX	Reparable Exchange
SAILS	Standard Army Intermediate Level Supply System
SARSS	Standard Army Retail Supply System
SRU	Shop Replaceable Unit
SUPCOM	Support Command
TADS/PNVS	Target Acquisition and Designation Sight/Pilot Night Vision Sensor
TAMP	Theater Aviation Maintenance Program
TAV	Total Asset Visibility
TOE	Table of Organization and Equipment
TP	Transportation Priority
TPS	Test Program Set
UIC	Unit Identification Code
UMMIPS	Uniform Military Movement and Issue Priority System
UND	Urgency of Need Designator
USAREUR	United States Army Europe
WOLF	Work Order Logistics File

What should the 21st century Army's logistics system look like? It is clear what it will *not* look like: the mass-driven large infrastructure built mainly to serve a single theater against a known foe. With theaters, threats, missions, and resources available all unknown, the Army must look for new solutions for providing logistics support to the force-projection role of the Army. How must logisticians change what they do to accommodate themselves to a world of radically changed weapons, doctrine, threats, and forms of operations? This report argues that just as technology and new concepts have revolutionized combat operations, so too must logistics be revolutionized.

THE NEED FOR A REVOLUTION IN LOGISTICS IN A CHANGED WORLD

Combat operations—their philosophy, concepts, and doctrines—are being transformed by high-tech weapon systems, precision-guided munitions (PGMs), high-mobility platforms, and near-real-time information gathering systems. But only the most modest steps toward a parallel revolution in the philosophy, concepts, and doctrine of the logistics support structure that undergirds the fighting edge of the nation's armed forces have been taken. Increasingly, the way we fight and the way we support that fight are out of sync, like a high-velocity bullet train tearing along tracks built for 19th century trains.

The transformations of the past few years only make the need for such a revolution in logistics more telling, but they would have been required whether or not the Soviet Union was still a threat. High-tech weapons and the fluid movement of AirLand warfare as they emerged in tandem in the 1980s first created the need for a leaner and more responsive logistics system. With the collapse of the standard threat scenario, that need is now all the greater. Today a CONUS-based, force-projection Army cannot rely on mating up with a mature theater support infrastructure; more often than not warfare will be “bring what you need.” Short mobilization periods and short but intense operations—where the goal is not only rapid victory but minimal casualties—imply a logistics system with no wasted effort or materiel. While a “just-in-time” concept of logistics may not be feasible for the Army—and given the uncertainties of warfare, might not even be desirable—the U.S. Army can no longer hope to overwhelm its enemies, as it did in World War II, with sheer mass.

THE RELEVANCE OF RECENT EXPERIENCE

If indeed war is the great auditor of armies, the U.S. Army has been heavily audited in recent years. Twice, in Operation Just Cause in Panama and then in Operation Desert Storm, the Army has been called on to fight; in addition, during Operation Desert Shield, it executed a demanding deterrence mission before the actual fighting in Southwest Asia.

These three operations were the “coming out party” for an Army equipped and trained in the past decade to fight the Soviet foe. They marked the first appearance in combat for the Army’s new high-technology weapon systems and tested the Army’s doctrine and practice of supporting high technology.

The three operations also tested the Army’s ability to support operations along a spectrum of mission types. They called upon the Army to send a relatively small force rapidly to execute a short mission; to deploy larger, more powerful forces over a somewhat longer period with the mission of deterring a powerful foe; and, finally, to send massive forces over an extended time with the intent of carrying out sustained, large-scale combat.

As a whole, the three operations were stunning successes. Not only did the U.S. forces achieve overwhelming victories, but they did so rapidly and at relatively little cost. Logistically, as well, the success was substantial. Previously untested by the demands of major combat, the logistics community overcame a multitude of challenges—undeveloped theaters, little time to prepare (as in Panama), massive force sizes to support (in Southwest Asia), and extremes of environments—to deliver high combat capability in support of the commander’s objectives.

This logistical success came in large part from the impressive effort by well-trained and highly motivated Army logisticians, both green-suit and civilian. It also derived from the large investment in logistical resources made by the Army over the course of the past decade. Finally, success of this sort was achieved by the nature of the wars fought, for typically combat was initiated at times of America’s own choosing, and neither the length nor the tempo threatened to overwhelm the logistical system.

Saying this is to take nothing away from the substantial achievements of the U.S. Army. But from an analytical point of view, we are faced with a question. What if conditions had been different? What if the stresses on the system—time to deploy, length, and intensity of the operation—had been greater? Could we be sure that the level of logistic achievement would have been the same? Furthermore, could we have the same confidence that the logistics structure of the future, operating from a much shrunken resource base, would perform as well?

In short, is the logistics structure that helped secure victories in Central America and Southwest Asia the one the Army can rely on in possible future operations? If not, what capabilities should the Army demand of its future logistics system?

STUDY OBJECTIVE AND SCOPE

This report examines those questions. It extrapolates from these recent cases of combat to explore the robustness inherent in our current logistics concept, especially as applied to the Army's ever more critical high-technology weaponry, and then it attempts to offer some alternatives to make the system more capable in the face of tomorrow's challenges.

To do so, we perform a series of "what-if?" analyses for a particular weapon system based on the Army's recent experiences in Just Cause, Desert Shield, and Desert Storm. The study explores the robustness of the logistic support by "extending" these three missions in challenging ways.

- What if the fighting had lasted longer in Operation Just Cause?
- What if fighting had broken out early in Operation Desert Shield?
- What if the operating tempo of Operation Desert Storm had been more demanding?

The Army's mission poses particular problems for its new high-technology weapon systems. Thus, we narrow our attention to these systems and examine the flexibility of current support concepts for maximizing high-technology weapon system capability in the face of demanding conditions.

These high-technology weapons will become even more important in the force-projection environment: they deliver far more combat power per pound deployed, and as around-the-clock weapon systems they act as powerful combat multipliers. But with high unit costs of the weapon systems, their spare parts, and the sophisticated maintenance equipment to support them, the pressure on the logistics structure to exploit resources to maintain the highest availability of these systems will be much greater in the future.

To make this analysis manageable, we looked at one example of new Army high technology, the Apache attack helicopter's Target Acquisition and Designation Sight/Pilot Night Vision Sensor, or TADS/PNVS. A critical part of the most sophisticated weapon system in the Army's main maneuver units, TADS/PNVS ably demonstrates the capabilities and challenges involved in using high-technology weapons in force-projection operations.

An additional reason for selecting TADS/PNVS is the availability of a comprehensive set of data on its wartime experiences, which we believe is unmatched for any other weapon system in the Army. Using this data set and supplementary sources of data, we were able to fill out a detailed picture of how this system was used in combat, what its support demands were, and how the logistics system responded to those demands at every echelon of support. This gave us an excellent springboard for attempting the "what if?" studies.¹

¹Appendix B discusses the Martin Marietta data systems.

Such comprehensive data systems do more than just make the analyst's job easier. As we argue here, better exploitation of scarce resources calls for greater visibility of the state of the world, including asset availability, emerging demands, and knowledge of logjams in the process. The TADS/PNVS data systems we use in this study are also, we believe, a prototype for the more transparent, comprehensive, and easy-to-use information systems that the Army must adopt to plan for and execute the future support mission.

APPROACH

To make valid extrapolations of this sort demands both reliable data capturing the basic truth of the state of the world and proven analytical techniques. In this study, we employ a set of analytical tools fitted to the needs of the specific problem. In the more elaborate and demanding analyses (of the Desert Shield and Desert Storm cases), we use the Dyna-METRIC capability assessment model, developed and enhanced at RAND over the past decade.²

Using a multi-echelon technique for recoverable item control, Dyna-METRIC reflects wartime uncertainties and dynamics in an integrated logistics structure with repair and supply at different echelons. Dyna-METRIC represents component support processes as a network of pipelines through which reparable components flow as they are repaired or replaced in a single theater. Using the sum of all pipeline segments, Dyna-METRIC determines the complete probability distribution for the number of parts in repair and on order. Combining such distributions for all components provides an estimate of weapon system availability.

The model has been developed to capture as much of the complexity of the real world as possible, reflecting variable removal rates, the existence of removals for no fault, controlled substitution, probabilistic transportation times, and choices among support strategies, such as "first come, first served" and prioritization of repair and distribution.³

ORGANIZATION OF THE REPORT

Chapter Two presents a brief overview of the TADS/PNVS subsystem of the Apache and its support concept. The next three chapters form the heart of the analysis, taking in turn each of three recent operations—Just Cause, Desert Shield, and Desert Storm. In each of the three chapters, the nature of the operation and the Apache role in it are discussed, along with the support concept for TADS/PNVS. Then, a "what-if?" question is posed for each of those operations, through which we seek to understand analytically the robustness of the Army's support concept for its force-projec-

²Appendixes C and D lay down the Dyna-METRIC input parameters for the Operation Desert Shield and Desert Storm analyses.

³For a general introduction to Dyna-METRIC, see K. E. Isaacson, P. Boren, C. L. Tsai, and R. A. Pyles, *Dyna-METRIC Version 4: Modeling Worldwide Logistics Support of Aircraft Components*, RAND, R-3389-AF, May 1988; for the most recent changes to the model, see K. E. Isaacson and P. Boren, *Dyna-METRIC Version 6: An Advanced Capability Assessment Model*, RAND, R-4214-AF, 1993.

tion mission. We next discuss possible pitfalls in high-technology support in the more stressful cases, and follow that with consideration of alternative support concepts geared more specifically to fit the needs of different types of contingencies.

Chapter Six briefly summarizes the results of the previous three sections and lays out the kind of logistics capabilities the Army needs for the different types of missions examined. Finally, Chapter Seven provides some general statements on the direction that strategies for support of Army weapon systems must take, especially for the new and forthcoming high-tech ones. Based on the analytical results of the previous chapters, Chapter Seven takes a wider view of the principles that should underlie Army logistics operations and how these principles follow from the basic doctrine that guides the Army. Borrowing loosely from the revolutionary innovation of precision-guided munitions, the chapter concludes by emphasizing the need for a support philosophy based on the idea of "precision-guided logistics."

HIGH TECHNOLOGY IN THE ARMY: APACHE TADS/PNVS

THE HIGH-TECH REVOLUTION

"High technology" can encompass many different things, including microelectronics, sophisticated composite materials, advanced explosives, and so on. In this research, we adopt a fairly narrow definition of high technology to refer to the complex, integrated, primarily electronic systems used for such functions as target acquisition and fire control in modern weapon systems. With the revolution in small size, capability, and reliability of electronic microcircuits, the number of components in a box has grown exponentially, allowing complex signal processing and startling capability. For this study, the most distinguishing characteristics of the high-technology revolution in weapon systems are the great combat leverage the high-technology system brings to weapons; the integrated nature of the high-technology systems in that failures in the system lead to substantial degradation in operational capability; difficulties in diagnosing and repairing complex, integrated systems, with concomitant requirements for sophisticated test equipment and highly trained personnel; the very high unit costs of high-technology components, often measured in hundreds of thousands of dollars; and the small weight and volume of these items, making them a trivial burden on the transportation/distribution system.¹

High technology is becoming an ever more important substitute for mass, especially for a contingency-based Army. The increasing capability of these high-technology systems will allow the Army to reduce its need for deployment and sustainment lift and to better adapt its forces to maneuver on unknown battlefields having varying terrains. Thus, better targeting systems in tanks are increasing the probability of kill with a concomitant reduced need for masses of tank ammunition (and tanks); even more striking is the case of precision-guided munitions like the laser-guided HELLFIRE missile.²

¹For more detail on these points, see the predecessor studies of this ongoing work: M. B. Berman, D. W. McIver, M. L. Robbins, and J. Schank, *Evaluating the Combat Payoff of Alternative Logistics Structures for High-Technology Subsystems*, RAND, R-3673-A, 1988; and M. L. Robbins, M. B. Berman, D. W. McIver, W. E. Mooz, and J. Schank, *Developing Robust Support Structures for High-Technology Subsystems: The AH-64 Apache Helicopter*, RAND, R-3768-A, 1991.

²In a rather direct contrast of "dumb mass" with light and smart new technology, the Army is moving toward using aircraft radar and stealth technologies to help defeat missile threats to its armored ground systems. By using new missile jammers, the Army can obviate the need for increased armoring of its tanks, which may make future extremely light systems, such as the 15-ton Lightweight Contingency Vehicle,

This chapter describes the Apache attack helicopter Target Acquisition and Designation Sight/Pilot Night Vision Sensor, or TADS/PNVs, perhaps the most sophisticated subsystem to enter the Army's inventory. TADS/PNVs, itself based on 1970s technology, represents the wedge of ever more sophisticated technology certain to become a standard part of Army weapon systems. As such, it demonstrates many of the logistical issues facing the Army as that service moves into the world of high tech.

When TADS/PNVs was introduced in the Apache in the mid-1980s, it marked a quantum leap forward in Army combat capability. TADS/PNVs is an all-weather, round-the-clock targeting and navigation aid. It uses forward-looking infrared (FLIR), television, and direct-view optics to aid flying and weapon employment no matter the conditions or amount of light. The TADS subsystem helps detect, find the range of, and designate targets for all weapon systems, but primarily for the main antiarmor weapon, the laser-guided HELLFIRE missile. The PNVs aids the pilot in navigation. Both TADS and PNVs can be viewed on screens in the cockpit or they can be slaved to the pilot's or copilot's helmet display system, where head movements can command the direction of the TADS/PNVs optics. Figure 2.1 pictures the Apache with the TADS/PNVs and some of its main components.

Figure 2.2 shows a blowup of the TADS/PNVs system, laying out in detail the major components of the system. The TADS/PNVs contains 26 line replaceable units (LRUs). Table 2.1 provides basic information on these 26 TADS/PNVs components, including the acronyms by which they are commonly known (and which will be frequently used in this report), removal rates, and recent unit acquisition costs.

OPERATIONAL CONCEPT

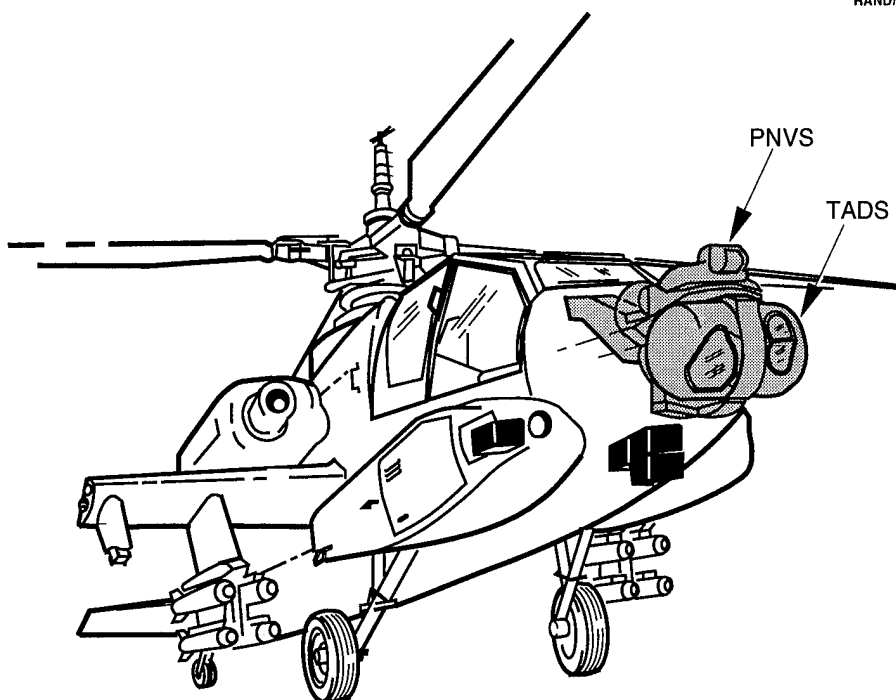
TADS/PNVs is perhaps the major subsystem of the mission equipment package (MEP) of the Apache helicopter, acknowledged as the most advanced attack helicopter in the world. Eighteen Apaches, along with scout helicopters, are fielded in an attack helicopter battalion (AHB). Several AHBs form a combat aviation brigade, or CAB, and are part of a division's or corps's maneuver brigades. Typically, there will be one to three AHBs in a CAB, although more may be attached for specific operational conditions (as happened in Operation Desert Storm).

The Apache's main mission is antiarmor; that is, to destroy enemy tanks and other armored vehicles. Apaches may serve as their own reconnaissance scouts, or they may be assisted by special OH-58 scout helicopters.

The Apache was developed to help defeat a major Soviet armored invasion of central Europe. Its AHBs and attendant support organization were structured and sized to help it accomplish that mission. As such, it was expected that the Apache would be able to endure a punishing operational tempo. Indeed, in the fierce fighting antici-

more survivable and effective in short-warning contingency operations. See "Electronic mail: Army borrows aircraft radar, stealth technologies to shield ground vehicles," *Army Times*, August 17, 1992, p. 28.

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SOURCE: *Target Acquisition and Designation Sight (AN/ASQ-170), Pilot Night Vision Sensor (AN/AAQ-11) Familiarization Course*, Martin Marietta Orlando Aerospace, June 1985.

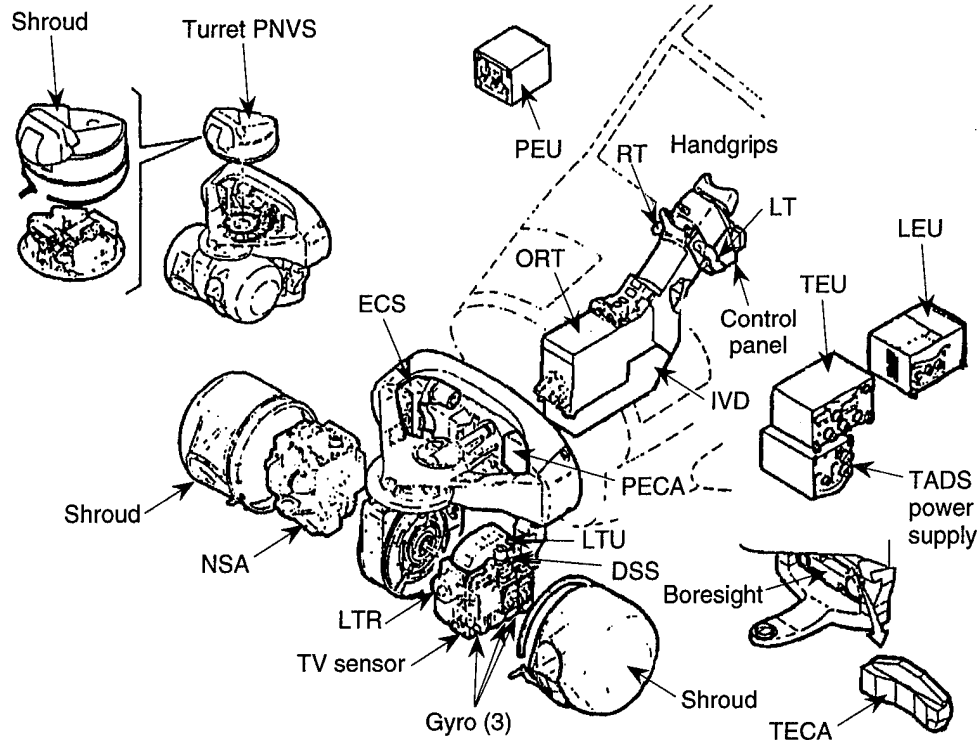
Figure 2.1—The Target Acquisition and Designation Sight/Pilot Night Vision Sensor (TADS/PNVS) of the AH-64 Apache Attack Helicopter

pated for central Europe, it was expected that a battalion of Apaches would have to maintain an operating tempo of over four hours per day for each of its 18 aircraft over the first 30 days of the war.³

That mission has now for all intents and purposes disappeared; no doctrine now details the operational tempo expected of the Apache in future contingency operations. While the tempo actually needed may be far less than the previous doctrine called for (as we shall see in the Desert Storm case), there is no certainty about that. The only certain thing about contingency operations is their total unpredictability—the logistician must be able to handle the most extreme demand and hope that that does not come to pass.

³*Aircraft Mission Profile Data for the Attack Helicopter Battalion (01385J420 and 01385L200)*, U.S. Army Aviation Center, Ft. Rucker, AL, 1988.

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NOTE: See Table 2.1 for acronyms.

SOURCE: *Target Acquisition and Designation Sight (AN/ASQ-170), Pilot Night Vision Sensor (AN/AAQ-11) Familiarization Course*, Martin Marietta Orlando Aerospace, June 1985.

Figure 2.2—TADS/PNVS Components

SUPPORT CONCEPT

Figure 2.3 presents in highly schematized form the general outlines of the current support concept for TADS/PNVS, including spares, intermediate maintenance, and depot-level repair.

Supply

TADS/PNVS is supported by standard Army stockage doctrine, featuring Authorized Stockage List (ASL) allocations of spares at the unit level, and wholesale spares at the national or theater level that can be distributed to units on an as-needed basis. Requisitioning of wholesale spare parts is done through standardized procedures, whereby supply personnel in the theater enter requisitions in the retail system (the Standard Army Intermediate Level Supply System, or SAILS), after which they are transmitted to CONUS (continental United States) and entered into the wholesale requisition-processing system (the Defense Automated Addressing System, or DAAS). From there, requisitions are distributed to the relevant item manager (IM) at

Table 2.1
TADS/PNVS LRUs, Removal Rates, and Costs

		Removal Rate ^a (per 1000 hr)	Unit Cost ^b
AND	Alphanumeric display	0.11	\$16,590
ADG	Azimuth drive gimbal	1.79	17,560
BSM	Boresight module	0.93	25,275
CPA	Control panel assembly	0.98	25,103
DSSA	Dayside sensor assembly	1.17	139,917
DSSH	Dayside sensor shroud	0.30	22,711
ECS	Environmental control system	0.32	11,373
GCCA	Gyro circuit card assembly	1.17	12,280
IVD	Indirect view display	2.03	52,048
LEU	Laser electronic unit	0.63	29,058
LHG	Lefthand grip	0.29	2,609
LTR	Laser tracker/receiver	0.56	32,263
LTU	Laser transceiver unit	1.06	72,948
NSA	Night sensor assembly	3.69	184,046
NSSH	Night side shroud	0.42	48,944
ORT	Optical relay tube	1.01	80,333
PECA	PNVS electronic control amplifier	0.38	15,406
PEU	PNVS electronic unit	1.28	48,533
PSSH	PNVS shroud	0.50	45,993
PTUR	PNVS turret	4.97	200,160
RHG	Right hand grip	0.32	2,357
TECA	TADS electronic control amplifier	1.73	26,771
TEU	TADS electronic unit	3.74	100,903
TPS	TADS power supply	1.33	50,606
TTI	TADS turret interface	1.94	186,096
TVS	Television sensor	0.99	41,441
	Total	33.64	

^aRemoval rates are from Martin Marietta Fault File System, 1988–1990.

^bUnit costs are from Army Master Data File (AMDF), 1993.

the various commodity commands of the Army Materiel Command (AMC), who ascertain availability of spares while taking into account the priority of the requisition, prior to tasking the depot or other supply location for shipping the item. Dispensation of certain critical and expensive parts is accorded closer control. These items belong to the Aviation Intensely Managed Items (AIMI) program, are maintained under wholesale control even if physically located at the installations, and have strict supervision over their release.

Maintenance: Division and Corps

Support of the TADS/PNVS system is based on removal, replacement, and repair of the components shown in Figure 2.2. Removal and replacement of LRUs take place at the helicopter by mechanics belonging to aviation unit-level maintenance units (AVUM) associated with the aviation units themselves. These LRUs are then evacuated back to aviation intermediate-level maintenance units (AVIM), located either at the division support command (DISCOM) or the corps support command

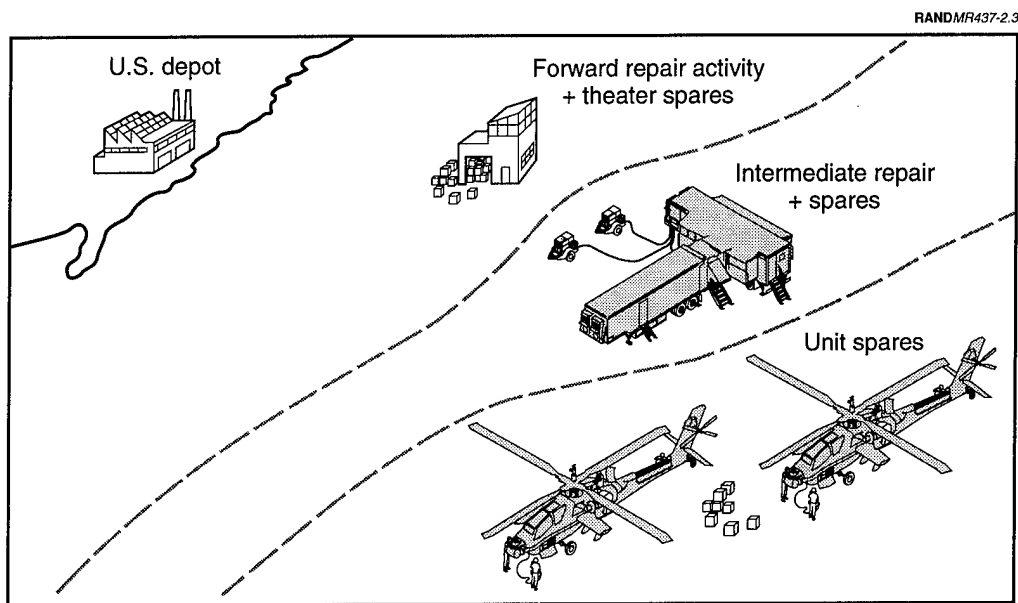


Figure 2.3—Simplified Support Structure for TADS/PNVs

(COSCOM).⁴ Repair of TADS/PNVs LRUs at that level can commence only after testing and diagnosis on a sophisticated set of automated test equipment, the Electronic Equipment Test Facility (EETF). The EETF, pictured in Figure 2.4, is housed in two 35-ft vans, one containing the test equipment work stations and the other the various adapters (test program sets [TPSs]) needed to configure the equipment to test different LRUs.

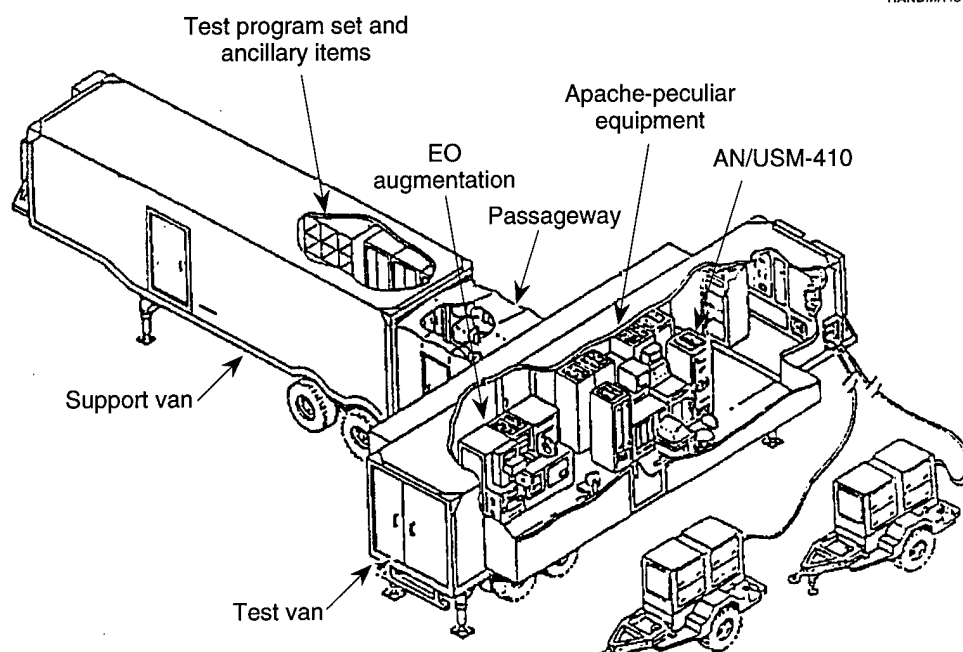
Although TADS/PNVs is a major part of the EETF diagnostic load, the EETF supports other parts of the Apache mission equipment package as well. The TADS/PNVs LRUs form about half of the total workload passing through the EETF; other parts of the workload come principally from the fire control computer, the integrated helmet and display sight system, and various indicators and control panels.

The EETF is typically operated as part of a standard Army Table of Organization and Equipment (TOE) unit, manned by military personnel. Army doctrine calls for one EETF to support 54 Apaches.⁵ The EETF will typically be located in the COSCOM for heavy corps; divisions supported by these COSCOMs have their removed LRUs evacuated directly from the division to the corps for diagnosis and repair. Divisions belonging to the light corps (the XVIII Airborne Corps) possess their own EETFs, located at the DISCOM; consequently, TADS/PNVs LRUs for these divisions will be sent back from the unit to the division-level AVIM for diagnosis and repair.

⁴FM 1-500, *Army Aviation Maintenance*, April 1985, p. 1-4.

⁵Program Manager, *Advanced Attack Helicopter, AH-64A Materiel Fielding Plan for USAREUR Units*, United States Army Aviation Systems Command, St. Louis, MO, July 10, 1987, p. 37.

RANDMR437-2.4



SOURCE: U.S. Army.

Figure 2.4—Electronic Equipment Test Facility (EETF)

A van-mounted EETF carries a procurement cost of roughly \$10.4 million. Yearly operating and support costs are estimated to be in the range of \$1 million. EETF operations require six E-5 military personnel, costing about \$210,000 per year, with additional training needs averaging about \$31,000 per year. Thus, EETF costs include initial expenditures of \$10.4 million (leaving aside upgrades) and a recurring cost of \$1.2 million per year.⁶

Depot-Level Repair

The Army has decided that depot-level repair of TADS/PNVS will continue by contractor for the lifespan of the system. TADS/PNVS was developed as a separate prime contract in the Apache program by the Martin Marietta Aerospace Corporation; Martin Marietta has been the provider of depot-level support since early fielding. Depot-level repair is provided in two ways. The more demanding work (for example, repairing television tubes or lasers) or work requiring a greater infrastructure investment is accomplished at the main Martin Marietta depot facility in Orlando, Florida, or at the rework facilities operated by subcontractors.

⁶U.S. Army Aviation Logistics School, Ft. Eustis, VA, *EETF Relative Life Cycle Costs*, September 12, 1989. All figures are in FY88 dollars.

Another innovative option is the forward repair activity (FRA), previously known as the special repair activity (SRA). It consists of dispersed, forward-located, depot-level repair facilities able both to provide very fast turnaround of certain types of depot-level repairs and to handle overflow from intermediate repair facilities. The FRA concept was developed by the TADS/PNVs Program Management office to assist in the early fielding of the Apache; it has since been institutionalized as part of the Apache support concept.⁷ The FRA is a very small facility with minimal overhead; typically, it has 10 to 12 technicians and only two or three other personnel handling administration, clerical, and supply responsibilities.

The FRA relies on simpler technology than the EETF. The most sophisticated part of the test equipment is a hot mockup/aircraft simulator, a full-up TADS/PNVs system used to screen incoming LRUs suspected of faults and to diagnose some simple faults. Aside from that system, the test equipment used is fairly standard (oscilloscopes and the like); instead of sophisticated software-driven automated testing, the FRA substitutes the specialized knowledge of its trained technicians.

FRA acquisition and operations costs compare favorably with those of the EETF. For an FRA test set (basically a single hot mockup and ancillary support equipment), procurement costs (including facilities) are about \$3 million. A single test set can support eight to ten technician specialists,⁸ each costing at a fully-burdened rate \$180,000 per year, for a total of \$1.4 to \$1.8 million per year.⁹

A SUPPORT CONCEPT IN FLUX

The concept described above offers no rigid rules for how TADS/PNVs should be supported in all types of operations. It was designed primarily with intense operations in Central Europe in mind, where much of the needed infrastructure would already be in place. The innovation of the FRA, for example, even though it is not yet doctrinal, could support TADS/PNVs in a European conflict since one of the four existing FRAs was located in Germany. EETFs as well were already forward-deployed, along with considerable numbers of spare parts.

With the passing of the threat in Europe, future theaters will be less likely to have a predeployed support structure; fighting units will have to take their support with them. With the substantial mass and complexity of the support resources, this would put a premium on reducing those support needs as far as possible and on making whatever was taken as effective as possible.

The Army now has had three recent experiences in supporting Apache and TADS/PNVs in force-projection operations. In the next three chapters, we turn to

⁷See Robbins et al., R-3768-A.

⁸In Operation Desert Shield/Desert Storm, the deployed FRA had ten technician-specialists and a single test set; toward the end of the operation, another test set package was deployed, joined by six more personnel.

⁹Robbins et al, R-3768-A, App. A. All figures are FY88 dollars.

the questions of what support strategy was followed, how well it worked, and what robustness it possessed in the face of uncertainty.¹⁰

¹⁰This study focuses on management of Class IX items (principally LRUs) and their effect on weapon system availability. We put much less emphasis on on-weapon system maintenance at the organizational level (such as removal and replacement of LRUs), not because it is not an important problem—it is—but because it is a different type of problem than managing high-technology LRUs. The latter requires understanding a distributed system of support, involving supply, off-weapon system maintenance strategies, distribution, and management of unintegrated elements of a logistic system. The problems of on-weapon system maintenance include onboard and flightline diagnostics and training and retaining manpower. Because these are qualitatively different concerns, we make no attempt to design a complete support concept, from the weapon system to the CONUS support base and back. But the problems of organizational-level support—such as high no-fault-found rates, undermanning, promotion of maintainers with technical expertise out of hands-on maintenance positions, underutilization of maintainers during peacetime, and so forth—are vital for the Army to address and resolve. On the former, see, for example, J. R. Gebman, D. W. McIver, and H. L. Shulman, *A New View of Weapon System Reliability and Maintainability: Executive Summary*, RAND, R-3604/1-AF, 1989; and on the latter, see SFC Dennis Cary, "Aviation Apprentice Mechanic Program," *U.S. Army Aviation Digest*, September–October 1991, pp. 15–17; and W. G. Wild, Jr., and Bruce R. Orvis, *Design of Field-Based Crosstraining Programs and Implications for Readiness*, RAND, R-4242-A, 1993.

SUPPORT ISSUES IN SMALL CONTINGENCIES: THE OPERATION JUST CAUSE EXPERIENCE

SUPPORTING SMALL CONTINGENCIES

The Army may be called in to execute missions at the “low end” of the operational spectrum—small, relatively brief, and short-notice operations. The model here is Operation Just Cause (OJC), not because the exact characteristics of OJC will be those of future contingencies of this type but because the actual OJC experience will elucidate some of the critical factors that may play.

Relevant Characteristics of Operation Just Cause for High-Technology Support

Operation Just Cause illustrates three critical characteristics that are relevant to high-technology support.

First, OJC was *small*. Although over 20,000 soldiers were involved in OJC, only a few high-technology weapon systems were deployed. Only 11 Apaches were deployed to Central America, less than two companies of the 1/82 attack helicopter battalion (AHB) of the 82nd Airborne Division at Ft. Bragg. Thus, support strategies necessary for a large-scale operation were not likely to be necessary in this more “tailorizable” operation.

Second, the operation was *brief*. Officially, OJC began on December 20, 1989, and ended January 31, 1990. The operation was essentially over, however, with the surrender of General Noriega on January 3, and, indeed, the most intense fighting was over within the first three days. The extreme abruptness of this mission dictated a different kind of support strategy than would be employed in a longer operation, like Operations Desert Shield/Desert Storm.

Third, OJC occurred with *short notice*. It is true that some forces had deployed earlier to Central America (elements of the 7th Infantry Division and six of the 11 Apache helicopters moved to Panama in mid-November). Nonetheless, the actual order to deploy the remainder of the forces was made with very little notice. Thus, there was only the shortest time available for preparing logistically for the operation (e.g., ordering and receiving spare parts).

The implication of the above is that support for OJC-type operations will likely be of a simple and austere nature, especially for high-tech systems. There will be no time for building mature theater support (to provide, among other things, much repair beyond the simplest possible),¹ nor will the deploying units be able to build up deployment spares packages. Units will be called upon to fight and be sustained with whatever support they can take with them or whatever they can receive from the CONUS sustaining base in the course of the operation. As the analysis below shows, absent a new support philosophy, this approach has some inherent dangers.

Apaches in Operation Just Cause

OJC marked the first use of the AH-64 Apache attack helicopter in combat. As mentioned above, 11 Apaches from the 1/82 AHB of the 82nd Airborne Division participated in the Panama invasion. The Apaches arrived in Panama in two stages. Six deployed secretly to Panama November 15–16 and were hidden in hangars at Howard Air Force Base. The remaining five left with the mass of deploying forces from Ft. Bragg on the night of December 19/20.

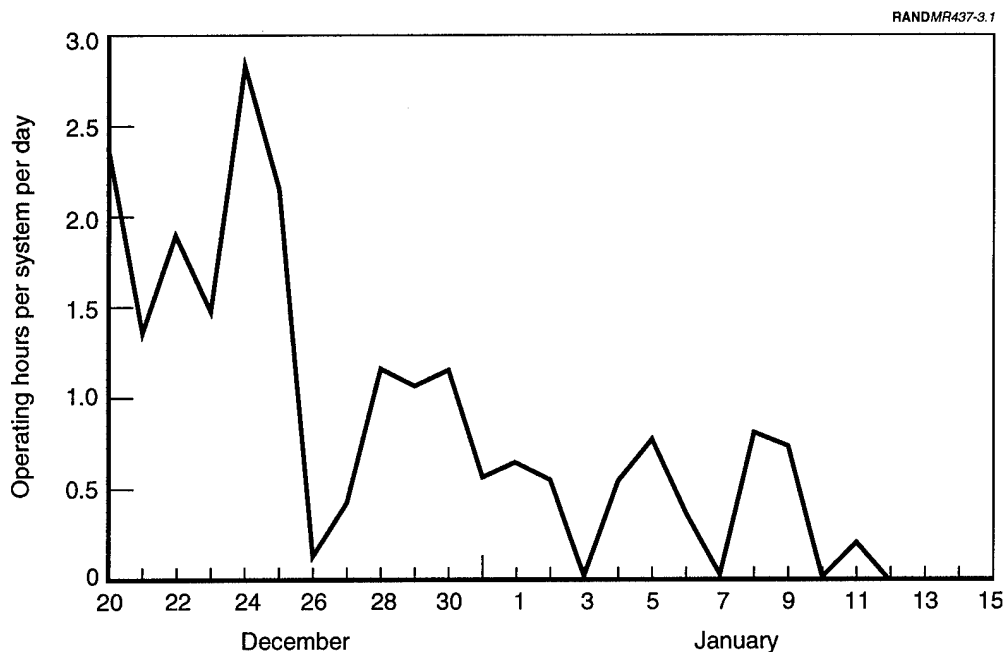
Given that this was a short-notice operation, there was little time to obtain spares from available sources. The earlier-deploying Apaches had carried only six lines of the AHB's ASL with them, and were supported as needed from the home base. For the December deployment, two nondeploying 1/82 aircraft were cannibalized to provide a second set of spares to buttress the ASL slice sent down; these 13 items were packed in a wooden crate and deployed with the rest of the forces. No AVIM capability for the high-technology portion of the Apaches (based on the EETF) was deployed; the aircraft would survive the mission out of spares they carried with them, items removed from non-mission-capable aircraft in the theater, and filled requisitions from the CONUS base. All unserviceable components were returned to CONUS at the conclusion of the operation for repair back at the home base or at the depot.

Apache Operations in Operation Just Cause

The deployed Apaches were active in many of the missions of Operation Just Cause, providing attack and surveillance support in the assaults on the Commandancia (General Noriega's headquarters) and Panamanian Defense Forces installations at Panama Viejo, Cerro Tinajitas, Fort Cimarron, and Rio Hato.² Figure 3.1 provides a daily plot of Apache operating hours in Operation Just Cause. It shows the flying tempo for the 11 Apaches over the first 24 days of the operation. Note that the most intense period of operation was in the first six days, when operating tempos (optempos) were in the range of two hours per aircraft per day; afterward, operating tempos dropped to an average of a half hour a day.

¹Although a substantial infrastructure existed in Panama, those facilities were not built to support the Apache, especially its electronics.

²Thomas Donnelly, Margaret Roth, and Caleb Baker, *Operation Just Cause: The Storming of Panama*, Lexington Books, New York, 1991.



SOURCE: Sample Data Collection.

Figure 3.1—Apache Operating Tempo in Operation Just Cause

TADS/PNVS Logistical Demands in OJC

We now turn to the logistical situation for the TADS/PNVS subsystem of the Apache helicopter. To do so, we will examine the balance of demands (or removed components), spares on hand, and spares available from other sources. There were 15 removals of TADS/PNVS components in Operation Just Cause, covering the period December 20–January 11, or 17 days. Most took place in the period of most-intense flying, the six-day period from December 20–25, when nine of the 15 removals occurred (or to be more precise, when faults occurred that led to these removals).³

In that period, the spares on hand were roughly adequate: for any one LRU there was at most a shortfall of one, meaning that at most one aircraft out of 11 might have been down for TADS/PNVS.⁴ In the low-intensity operations of the next 13 days, only six removals occurred, putting little pressure on local spares or on the requisitioning system. Thus, as far as TADS/PNVS was concerned, OJC did not present a large logistical problem—the logistic resources on hand were ample to the task.

³Removal data are from the Sample Data Collection operation at Ft. Bragg, NC. Table 3.1 shows removals for the six-day period.

⁴In fact, one aircraft, 85-25440, was not available and did not accrue any flying hours over the course of OJC. Presumably, it was available as a “supply bin” through cannibalization.

WHAT IF THE INTENSE PORTION OF OJC HAD LASTED LONGER?

As it was actually fought, OJC did not overly stress TADS/PNVS, at least in terms of spare parts demands. This is almost certainly because the operation was intense only over the first six days, with per-aircraft operating tempos of two hours per day.

This analysis explores “what if?” conditions in determining how robust the deployed support was and what shortcomings might need correction. What if the more intense operating tempos of the first six days had been required for another six days, or even another six days following that? What would have been the consequences for the Apaches of the greater demands flowing from a more sustained intense operation?

Analytical Method

We cannot know for sure what would have been the logistics demands of an OJC scenario in which high optempos were demanded for 12 or 18 days rather than the six days that actually occurred. To make the analysis simple, then, we shall assume that the number of demands in each succeeding six-day period would have been the same as in the first six days (that is, nine total TADS/PNVS removals, but not the *exact same* removals). Thus, we will consider cases where the deployed Apaches would experience 18 TADS/PNVS removals in 12 days of operation and 27 TADS/PNVS removals in 18 days of operation. With the support resources available to the Apaches, how would this number of removals have affected Apache availability?⁵

To explore this, we use a Monte Carlo simulation, in which the probability of any particular LRU being removed is a function of its peacetime removal rate (see Table 2.1). For example, the PNVS turret accounts for 15 percent of all TADS/PNVS removals in peacetime; in this simulation, we thus give the PNVS turret a probability of 0.15 of being among the 18 TADS/PNVS LRUs removed in the 12 days of our extended OJC. Since in a random simulation “bad luck” could cause a large number of a single LRU to be removed, resulting in a large number of not fully mission capable (NPMC) aircraft, we ran the simulation 100 times to develop a distribution of possible outcomes. (Of course, in the real world, an OJC would not be fought 100 times, and it is not impossible for that bad luck actually to occur.)

The number of removals generated in this extended operation (which we partition into three six-day periods) is then compared to the actual spares on hands. These deployed spares and working LRUs from aircraft that are already NPMC for some other TADS/PNVS LRU are the available sources of supply.⁶ From this information, it is a simple matter to determine how many aircraft would be NPMC after exhausting available spares and consolidating as many holes as possible through controlled substitution on cannibalized aircraft.

⁵In this report, all references to “Apache non-availability” refer solely to non-mission-capable status due to TADS/PNVS. For the purposes of analysis, we do not examine the rest of the helicopter.

⁶We do not consider resupply from CONUS here for reasons to be explained below.

Illustration of the Method

Table 3.1 demonstrates sample results from the simulation. It shows the 26 LRUs that constitute the TADS/PNVS subsystem. (The definitions of the acronyms are given in Table 2.1.) The deployed stockage available at the start of OJC is shown next to the actual removals in the first six days, December 20–25. It can be seen that a maximum of one Apache would have been rendered NFMC for TADS/PNVS, assum-

Table 3.1
Monte Carlo Simulation of Extended OJC—Sample Results

LRU	Initial Available Stock	Actual Experience 1st 6 Days		Simulation Results							
				Trial 1				Trial 2			
				2nd 6 Days		3rd 6 Days		2nd 6 Days		3rd 6 Days	
		Rem	Holes	Rem	Holes	Rem	Holes	Rem	Holes	Rem	Holes
AND											
ADG		1	(-1)		(-1)		(-1)		(-1)		(-1)
BSM				2	(-2)		(-2)				
CPA						1	(-1)	1	(-1)		(-1)
DS shroud						1	(-1)				
DSSA	1	2	(-1)	1	(-2)		(-2)	1	(-2)		(-2)
ECS											
GCCA		1	(-1)	1	(-2)		(-2)		(-1)		(-1)
IVD	1	2	(-1)		(-1)	1	(-2)	3	(-4)	1	(-5)
LEU	2									1	
LHG						1	(-1)				
LTR	1							1			
LTU	1										
NS shroud		1	(-1)		(-1)		(-1)	1	(-2)		(-2)
NSA	2	1				1					
ORC											
RHG											
TTI				1	(-1)	2	(-3)			2	(-1)
TECA	1							1			
TEU	1	1		2	(-1)		(-1)			2	(-1)
TPS	1										
TVS	2					1				1	
PECA	2									1	
PEU	1			1							
PNVS shroud											
PTUR	1			1		1	(-1)	1		1	(-1)
A/C NFMC ^a			1		2		3		4		5
Total holes ^b			5		11		18		11		15

NOTES: Rem = removals. Holes = cumulative missing LRUs across the deployed force.

^aEquals largest number of holes in column.

^bTotal of negative numbers in column.

ing that the maintainers practice controlled substitution techniques. This would have resulted in one NFMC Apache TADS/PNVs system with five holes in it.⁷

The table shows the results from two of the 100 Monte Carlo simulations. In each of the trials, OJC was "extended" by assuming equal numbers of spares removed in each of the succeeding periods (period 2 covers December 26 through December 31 while period 3 extends OJC hypothetically to cover January 1 to January 6). In each period, nine more TADS/PNVs removals were simulated by random number generation applied to the probability of removal, based on peacetime removal rates. The effect on aircraft availability is cumulative from the earlier period ending December 25.⁸

To understand how the table should be read, consider one LRU, the IVD. The deployed force carried one IVD spare. In the first six days of OJC, there were two removals of IVDs, leaving a net deficit (that is, holes in Apaches) of one IVD. With no repair or resupply, one Apache is NFMC due to the IVD (ignoring other LRUs for the moment). We then extend OJC hypothetically for twelve days, divided into two periods of six days each (periods 2 and 3). In Trial 1, period 2 had no more IVD removals, so there is still a deficit of one. In period 3, there is one more removal of an IVD, so the deficit (holes in Apaches for IVDs) increases to two. In Trial 2, we again begin with a deficit of one IVD from period 1. In period 2 of this second trial, there are three additional removals of IVDs, increasing the deficit to four, and in period 3, there is yet one more IVD removal, increasing the deficit to five. We would expect five Apaches to be NFMC due to IVD shortages; the actual number of NFMC Apaches would simply be the greatest negative number among all 26 LRUs in a given period for a trial; the number of holes consolidated on those NFMC systems is the total of negative numbers.

Overall Results of the Analysis

Table 3.2 shows the results of the Monte Carlo simulation representing 100 trials of repeated "intense OJCs" extended an additional six or 12 more days. It shows the probability of various outcomes in terms of NFMC (represented by the percentage of trial outcomes). In period 2 (i.e., if heavy fighting had extended to December 31), the most likely outcome would have been two NFMC Apaches due to TADS/PNVs. There is over a 40 percent chance of three or more of the 11 aircraft being brought down for TADS/PNVs.

⁷The number of NFMC aircraft is calculated by first subtracting the number of removals of a particular LRU from the available stock on hand. The number of NFMC aircraft is equal to the largest number of holes for a particular LRU. Thus, if there are three turret (PTUR) removals and only one spare, then there are two PTUR holes in aircrafts: at least two Apaches must be NFMC for PTUR. If another Apache has a different LRU, say an indirect view display (IVD), removed, it can be brought back to fully mission capable (FMC) status by cannibalizing the IVD from a helicopter missing a PTUR; thus, holes from other Apaches are consolidated on the cannibalized aircraft and the number of NFMC weapon systems will be equal to the greatest number of holes for a single LRU.

⁸Therefore, the variability in the process was limited to which LRU failed, rather than the total number of failed LRUs (which was assumed to be constant and even for each period).

Table 3.2
Monte Carlo Simulation of Extended Intense OJC
(100 trials)

Apache NFMC (out of 11)	Frequency of Outcome (%)	
	Period 2 (Dec. 26–Dec. 31)	Period 3 (Jan. 1–Jan. 6)
1	2	0
2	54	5
3	38	41
4	6	33
5	0	19
6	0	2
	100	100

If the fighting had extended to a third period of six days of intense operation (to January 6), the number of downed weapon systems would cumulate. There would be a greater than 50 percent chance of four or more of the 11 Apaches being NFMC for TADS/PNVS, and only a scant chance that two or fewer aircraft would be the only ones grounded for TADS/PNVS components.

In summary, had OJC gone on longer than anticipated, there might have been a substantial risk of losing weapon system availability.⁹

In the foregoing analysis, we assumed that the only sources of support were available spares and LRUs cannibalized from NFMC aircraft. As previously noted, repair for TADS/PNVS LRUs was not deployed to Panama. But a hidden assumption of the preceding analysis was that no resupply from CONUS would be received in a timely manner over the 12–18 days of intense operation. Is that a justifiable assumption?

Shortfalls in Resupply in OJC¹⁰

Table 3.3 indicates the apparent resupply problems during OJC. It shows, for aviation items only, resupply times for NMCS (not mission capable, supply) demands in the first three days of the operation and the order-and-ship time (OST) for non-NMCS items before, during, and after OJC.

⁹We repeated this simulation for the *first* six days of intense fighting in OJC to compare against what really happened. In this simulation, we again assumed nine TADS/PNVS removals against the same stock, utilizing cannibalization, but we let the simulation determine which LRUs would be removed. The results were similar to what actually happened: there was a 46 percent chance of one Apache being NFMC for TADS/PNVS (as actually happened) and a 48 percent chance of two Apaches being NFMC (there was also a 6 percent chance of three Apaches going down). Thus, the forces were relatively supportable for the six-day operation, assuming no total surprises (such as massive failures of one type of LRU that could not be anticipated from peacetime experience).

¹⁰The following is adapted from an unpublished manuscript by I. K. Cohen, D. B. Kassing, D. W. McIver, M. L. Robbins, H. L. Shulman, R. S. Tripp, and C. L. Tsai, "Ideas for Enhancing the Combat Support System for Regional Contingencies: Derived from the Operation Just Cause Experience," RAND, January 1991.

Table 3.3
Order-and-Ship Times for Aviation Items in OJC

NMCS Items Ordered in First 3 Days of OJC ^a		Non-NMCS Items Ordered Before, During, After OJC ^b	
Pipeline Segment	Processing Days		Total OST
In theater	0.5	Before (pre-Dec. 20)	18
NICP	0.5	During (Dec. 20-Jan. 3)	24
Depot	2.0	After (post-Jan. 3)	24
Ship to APOE ^c	3.4		
APOE	2.6		
Ship to APOD	0.5		
APOD	4.7		
Total OST	14.1 ^d		

SOURCE: LIF records provided by AMC's Logistics Control Activity.

NOTES: AMC = Army Materiel Command
APOD = Air port of debarkation
APOE = Air port of embarkation
LAR = Logistics assistance representative
LIF = Logistics Intelligence File
NICP = National Inventory Control Point.

^a27 NMCS items phoned into AVSCOM by LAR December 20-22.

^bObtained from E Company SARSS computer.

^cIncludes consolidation and containerization time.

^dTotal OST does not add to the sum of the segments because of averaging.

As a whole, resupply did not become more responsive during OJC. Instead of shortening in the crisis, OSTs actually increased an average of 33 percent during the operation itself, from 18 to 24 days.

Especially important items, where requisitions were made on the basis of a weapon system being NMCS, received expedited treatment, as discussed below. Still, OSTs averaged 14 days, so that an item ordered for a NFMC weapon system on December 23 was not likely to be received until around January 7. (There were 27 NMCS requisitions in the first three days of OJC; the range of OSTs was seven to 38 days.)

The stretched-out times for normal requisitions occurred for several reasons. To speed up the process, the Army instituted a new system of ordering spares for OJC—direct requisitions. Unfortunately, the new system probably increased delays. Computer glitches and lack of familiarity with the new system meant that records were not updated through the proper channels and often could not be reconciled; requisitions that could not be reconciled quite often were killed, which meant beginning the requisitioning process all over again.

Another reason for the stretched-out requisition times was inflated priorities. On the first day of the operation, supply personnel processed priority change requests for all outstanding requisitions. These requests upgraded all due-in requisitions to the equivalent of NMCS requisitions. In addition, the special OJC project code was placed on all requisitions in an attempt to obtain the absolute highest priority. As a

result, the standard system could not determine actual priorities and speed their delivery.

The logjam at the main air port of embarkation (APOE), Charleston Air Force Base, was partly a consequence of this, as well as a contributor to long OSTs. Similar delays were encountered at the air port of debarkation (APOD), Howard Air Force Base in Panama.

Instead of 24 days on average, true NMCS requisitions (as opposed to standing requisitions that were simply upgraded to NMCS status) were satisfied in much less time, on average 14 days. These truly high-priority requisitions were processed off-line. As an example, important requisitions were phoned or sent by fax into the AMC Major Subordinate Command (MSC) emergency operations centers (EOCs) by the logistics assistance representatives (LARs) beginning on the first day of the operation. The EOCs would then use the Commodity Command Standard System (CCSS) to establish materiel release orders (MROs) and transmit the MROs to the appropriate depot for processing. Also, to help expedite the requisition's processing, the EOCs would move the requisition to the appropriate MSC or other sources of supply, such as the Defense Logistics Agency (DLA). Between December 20 and January 12, AVSCOM processed 183 requisitions in this manner through the EOC.

Most of the requisitions were processed through the depot with little delay until they arrived at the Charleston APOE. For several reasons, all cargo did not move through the APOE as responsively as needed. In addition, once these critical shipments arrived in Panama, delays were encountered because the Howard APOD operations were saturated.

SOLUTION DIRECTIONS

For a problem like providing sufficient support to a system similar to TADS/PNVs, there are at least three possible solutions: deploy test and repair capability, provide more spares, or make resupply more quick and responsive.

Deploy Test and Repair Capability

Of the three, deploying test equipment is the least satisfactory. The two principal means of support for TADS/PNVs are the Electronic Equipment Test Facility (EETF) and the forward repair activity (FRA). As shown previously in Figure 2.4, the EETF is a large, cumbersome system, with two 35-foot vans, a generator, spare parts, and personnel. It requires a C-5A aircraft for deployment. The FRA as currently configured is not an easily deployable facility; in Operation Desert Shield it required more than a month for the FRA deployed in the theater to become operational. Given a short, no-notice operation, where speed and secrecy are likely to be of critical importance, it is not desirable to burden the fighting forces with this kind of support tail.

An associated problem is *when* in-theater repair would become necessary. As stated above, OJC had sufficient spares on hand, with cannibalization, to support the Apaches for six days; strains would appear in the second six days; and unacceptably

high numbers of downed systems would appear in the third period of six days. When in that period should the decision for deploying repair capability have been made? Given normal delays in preparing for and executing deployment, the decision might have had to be made before the operation itself began, that is, well before the need would be evident.

Provide More Spares

Providing more spares is a simpler alternative for shorter missions like OJC. After all, the weight and cube of the spares needed (or all spares that might possibly be needed) would be far less than deploying repair equipment. In part, this strategy was pursued in the actual OJC and would have been pursued in our extended "what if?" case. The ASL slice of the early deploying Apaches was in fact increased on December 20 by the addition of parts cannibalized from nondeploying aircraft. These proved sufficient for six days of high-tempo operations, but would not have sufficed for a longer mission, even with cannibalization.

Would it reasonably be possible to maintain high levels of availability simply by increasing the stocks of deployed spares? Our analysis strongly suggests it is not possible.

Table 3.4 gives some evidence of this. The results demonstrate the effect of substantial increases in the deployed spares kit. We assume for this analysis a doubling of all deployed TADS/PNVs spares, plus sending one spare for all LRUs where none was sent in the first place. This would represent an approximately 120 percent increase in the spares deployed (both from the ASL slice and the nondeployed aircraft cannibalized at Ft. Bragg).

However, such a massive increase in spares on hand would have at best a modest effect on sustainability achieved. Recall (from Table 3.2) that with spares as deployed in period 2, there would be a 44 percent chance of having three or more Apaches down for TADS/PNVs. With a more than doubling of spares, the simulation results suggest there would be about a 44 percent chance of having two or more Apaches down because of TADS/PNVs. In period 3 in the previous analysis, there would have

Table 3.4
Effect of Increased Spares Deployment on Apache
Availability in Extended Intense OJC

Apaches NFMC	Frequency	
	Period 2 (Dec. 26–Dec. 31)	Period 3 (Jan. 1–Jan 6)
0	1	0
1	54	8
2	38	43
3	5	29
4	1	18
5	0	3

been around a 50 percent chance of four or more Apaches being NFMC due to TADS/PNVs. With the increased stock, that would be reduced to about a 50 percent chance of three or more Apaches being NFMC because of TADS/PNVs. In short, more than doubling the stock levels would add only one more expected available weapon system.¹¹

Clearly, there is some level of spares deployed where the risk, as assumed in this simulation, would be quite low. But there are, of course, costs to this strategy:

- The sheer volume and weight of a large number of "just in case" spare parts would impose a penalty during a rapid and time-sensitive deployment.
- The dollar cost of providing immediate access to large pools of spares to any unit that might have to deploy would likely be more than the Army could or should bear.
- Even with a large spares package, there may still be surprises, where demand far exceeds what was anticipated, rendering the value of the larger spares package inconsequential.

This leaves the option of fast resupply of critical items.

Provide Fast CONUS Resupply

Overall OSTs in OJC were around 24 days, clearly too long for a fast-moving operation of this sort. Some shortcuts were used to minimize process times; as noted earlier, supply personnel and LARs managed to cut the OST time for critical (NMCS) items down to 14 days by using phones and fax orders. While this reduction was a substantial improvement, it would still not be satisfactory. Table 3.3 showed where the main delays for these NMCS items occurred: in the pipeline segments between the depot and APOE, at the APOE, and at the APOD. These segments of the ordering and shipping process clearly must be changed to make fast resupply an actuality.

Some evidence from OJC suggests these problems can be overcome and that OSTs on the order of one to two days can be achieved. The main elements of the solution are to seek out alternative sources of supply, use separate means of delivery, and ensure adequate communication so items can move smoothly.

In some cases, elements from the 82nd Airborne Division and the special operations group Task Force 160,¹² operating out of Ft. Campbell, were able to get faster access to critical parts by obtaining them from their home station rather than from supply depots. These units asked supply or maintenance people at the home station to ob-

¹¹This analysis assumed that LRU removal rates do not themselves vary. This, however, is actually not true. In fact, high-technology components have extremely high variability in removal rates, making prediction of spares needs extremely difficult. See Gordon Crawford, *Variability in the Demands for Aircraft Spare Parts*, RAND, R-3318-AF, 1988; M. B. Berman et al., R-3673-A, Sec. II; and Marc Robbins et al., R-3768-A, pp. 10-21.

¹²This special operations group also played a prominent role in OJC. It deployed specially modified MH-60s and MH-6s to the theater; much of the support for these helicopters took place outside of standard Army channels.

tain the material and place it on a scheduled flight, called the "Log Bird," operating out of the home base and supporting the deployed forces. Members of Task Force 160 requested what they needed by phone with their home unit. The home unit then notified the force in Panama about the specific Log Bird that had the requested materiel and the pallet number that contained the materiel. Each Log Bird was met by personnel from Task Force 160, and the materiel was quickly moved to the task force, with an elapsed time of only a day or two from the original phone request.

A similar process, though less successful, was also employed by elements from Ft. Bragg. Phone calls to the home station requested parts from off-the-shelf depot stocks or from cannibalization actions. These items were also palletized and shipped to Panama. However, several problems were encountered from this point on. From most accounts, the main problems stemmed from lack of documentation: when the pallets arrived in Panama, either the documentation identifying the contents of the pallet had been removed by inexperienced ground movement personnel or the documentation was not prepared in the first place.

Elements of an Improved Fast CONUS Resupply System

Each contingency will differ in its specific needs. For the small, fast-moving type of operation considered here, we believe a special type of fast resupply system for the most critical items should be established in policy and doctrine, and practiced in peacetime; it should comprise the following elements.

Near-Real-Time Transmission of Requisitions. These requisitions should be separated from the mass of ordinary parts requests and submitted by phone, fax, or electronic mail (email), either by supply personnel or by LARs with current knowledge of weapon system status.¹³ The requests would be sent directly to MSC EOCs or, in certain circumstances, to home station personnel. If new total asset visibility systems are successfully fielded, then EOCs should become the clearinghouse for all such special requests, even if only for contacting the home station to release an item from the local ASL or through controlled substitution. The EOC would confirm that the formal requisition had been entered into the Logistics Intelligence File and query the theater if it has not; units must continue to make formal requisitions. Due care, of course, must be taken to ensure that the system is not abused. The importance of voice-to-voice contact for reducing frivolous use of this highest-priority system should not be denied; EOC personnel or in-theater LARs should make it a policy to ask specific questions about which weapon system was down for the requested part

¹³Current standard requisitioning systems, such as through SARSS, would be transmitted back to the NICP just as fast as, or faster than, by these means. However, these standard requisitioning processes do not as yet allow for specification of higher priorities than currently exist in the Uniform Military Movement and Issue Priority System (UMMIPS). Perhaps more to the point, there as yet exists no way of using these standard channels to rapidly move the highest-priority requisitions from the theater without the problem of priority inflation. For small operations, a more informal communication mechanism, along the lines described here, or like the Aircraft on Ground (AOG) requisitioning system used by the Aviation Troop Command (ATCOM) in Operation Restore Hope in Somalia, has a better chance of succeeding.

and about whether alternatives (such as other local supplies or cannibalization) would suffice.¹⁴

Avoid Clogged Shipping Ports by Using Alternatives. The EOCs were used quite effectively, as Table 3.3 shows, to get materiel release orders cut quickly. These expedited supply actions were frustrated, however, by the inability to get the materiel moved quickly through the Charleston APOE. As the table shows, delays through the APOE were a particular problem. Charleston was short-handed because one-sixth of its aerial port staff was transferred to other OJC activities. Then, early in the operation, Charleston was hit by unusually severe winter weather. Simultaneously, the port was overwhelmed by a sudden demand to send a large load (48 tractor trailers) of unpalletized packaged meals. As a result, by December 26 Charleston had some 457 tons of cargo on hand but not yet manifested for shipment, including 86 pallets that had been waiting for more than 48 hours.

In consequence of delays at this main APOE, the MSCs directed shipments from other airports, and deployed units used standard Log Bird flights carrying personnel from their home stations. Other APOEs (Travis Air Force Base, Memphis International, Monterey Peninsula Airport) were close enough to the sources of supply to cut off much of the intra-CONUS handling. Log Birds out of home stations, especially from Pope Air Force Base, adjacent to Ft. Bragg, were particularly useful. Log Birds were typically used to send extra personnel to the theater as the need arose; however, they had sufficient spare cargo capacity to allow shipment of critical items either from Ft. Bragg itself or materiel sent to Ft. Bragg by the MSCs.

Avoid Delays at the Air Port of Debarkation. Serious delays were also encountered once the materiel arrived in the theater, as shown in Table 3.3. In fact, the problem of APODs is more serious than that of APOEs, for there can be many of the latter but there are few of the former.

Howard Air Force Base served as the terminus for most resupply airlift into Panama. Howard was the normal destination for the airlift channel from Charleston. The aerial port staff at Howard was augmented by personnel from Charleston and other bases. When resupply operations went into high gear, some flights, mainly those carrying humanitarian aid, were diverted to Torrijos-Tocumen, the civilian airport for Panama City.

Despite augmented staffs and the use of two airfields, cargo handling at the Panama end of the air line of communication became a serious problem. Visibility over incoming cargo was patchy. Personnel newly arrived from CONUS were unfamiliar with both the local military structure and the civilian environment. Security problems prevented local national cargo handlers from reporting for duty for several days. Problems in using the road system delayed the movement of cargo off the airfield.

¹⁴This was characteristic of the AOG process in Somalia where ATCOM LARs created a separate communication channel between helicopter units in theater and the ATCOM Operations Center and AOG office back at the MSC in St. Louis. While this system worked very well at speeding and regulating the transmission of requisitions (though it played less of a role in accelerating the item through the rest of the pipeline), it was commodity specific; a future system must be able to cover all commodities and deal with all NICPs.

Although helicopter transport took up some of the load, incoming cargo began to accumulate at Howard's freight-handling facilities.

Problems also arose at the interface between the transporters and users. For the first five days, no cargo was delivered to the Army's central receiving point (CRP) in Panama because the roads had not been secured. However, the Army aerial port liaison officer soon set up a Joint Movement Control Center near the Military Airlift Command's freight-handling facilities. Their job was to identify incoming cargo and distribute it to the units that had requisitioned it. Representatives of the fighting units worked with the cargo handlers to locate, identify, and move their cargos onward.

This work was hampered both by the sheer volume of incoming shipments and the frequent lack of proper documentation on the individual packages and pallets. This was particularly a problem for smaller packages combined into "multipacks" and pallets. Individual items, such as helicopter parts, were often not identified until the pallets were moved from the airport and broken down.

Steps must be taken to ensure that critical items are not lost in the shuffle at the APOD. The most important step is a clear and effective system for identifying and prioritizing critical items for shipment. This system must include communication with the responsible actors in the theater to ascertain priorities and to keep them abreast of the progress of the high-priority part. Preferably, a fax, email, or phone call to the LAR or supply clerk alerting them of the part's imminent arrival on a specific plane (with the identifying information clearly laid out and consistent with what is actually on the pallet) would alert the theater for pick-up and delivery of the part using organic transportation (truck, helicopter, or so on, as the case demands).

The end result of such specialized priority support would be OSTs on the order of one or two days, as was achieved by Task Force 160 in OJC. This, it should be noted, would do little to reduce overall OSTs, which probably would remain around 20+ days. The point, however, is that ordinary requisitions are not absolutely required for sustaining weapon systems. A differentiation of workload that allows 20 days shipping for some items, and one day for others, is in fact exactly the kind of system the Army needs and should pursue for very fast moving operations like OJC.

SUPPORT ISSUES IN A MID-SCALE CONTINGENCY: OPERATION DESERT SHIELD

When American forces began deploying to Southwest Asia on August 7, 1990, no one could say with certainty when, or if, they would actually be involved in fighting. During the early days of the deployment, when only a light cover of U.S. air forces and light infantry were on the ground, the danger from an Iraqi armored incursion into Saudi Arabia was quite high; indeed, members of the 82nd Airborne Division on the ground referred to themselves as “speed bumps” in the Arabian desert. By early October, this “window of vulnerability” had closed; it was fairly clear that Iraq would not seize the initiative, and that the decision to commence fighting would remain with the United States and its allies.¹

In the contingency operations in Panama and Southwest Asia, the United States retained the initiative for commencing operations. However, this may not always be the case and, as the foregoing suggested, might not even have been the case in Southwest Asia. Had the United States been facing a leader who made decisions differently, Operation Desert Storm (ODSt)—the actual fighting—might have started much earlier, and at a time not so well-suited to American needs.

SUPPORTING MID-SCALE CONTINGENCIES

Operation Desert Shield (ODS) involved deploying a substantial force over a sustained period in which the probability of combat could not be estimated with complete confidence, at least in the initial period. It therefore presents a different problem from a small contingency operation, like OJC, where all combat and logistic support resources must be deployed almost simultaneously (and very quickly). Larger force deployments like ODS will of necessity be time-sequenced, and the local commander must establish priorities between support and combat resources.

The commander-in-chief of the Central Command (CENTCOM), GEN Norman Schwarzkopf, made just such a decision. To maximize combat punch early on, he deferred deployment of theater logistics forces and accelerated the arrival of combat

¹Department of Defense, *Conduct of the Persian Gulf War*, Final Report to Congress, April 1992, pp. 46-51.

units. These combat units would have to rely on organic supplies and equipment, initial combat sustainment, host-nation support, and afloat prepositioned supplies.²

This gamble paid off against the Iraqi foe. Future gambles may not be as successful. And future commanders will continue to face the problem of what to send first and in what sequence: combat teeth with little sustainment, or logistic mass to provide sustainment for a combat force possibly too small to prevail.

The task of the logistician is to make the commander's choice easier by helping him give priority to combat deployments while at the same time preserving sustainability. That is, the support concept for mid-scale contingencies has to be concentrated on providing maximum support with minimum resources in the theater; to the extent possible, it has to emphasize split operations. According to the split-base operations concept, materiel management support can be provided to the force, wherever it is located, through enhanced and secure communications. Typically, a materiel management center (MMC) will deploy modular packages of personnel and equipment; the rear MMC will continue to support the stay-behind force while simultaneously interfacing with deployed units to provide required support forward.³

ODS is a useful test bed for studying this kind of problem. The fact that deterrence succeeded, and no fighting occurred, should not prevent us from examining the potential consequences if combat had occurred. Had early fighting broken out, could the deployed forces have fought with adequate logistical support? Would the logistical resources on the ground, and the support concept in place, have been adequate to sustain high operational tempos in the punishing scenario required by the mission to stop the Iraqi invasion?

This chapter pursues a second "what if?" question. In Chapter Three, we addressed the question of what if the duration of the operation had exceeded what had been expected or planned for. Here we ask a different question: What if the war begins before we are "ready"? That is, to the extent that combat forces deploy before all logistic resources are in place (as was the case in ODS), what happens if fighting breaks out before the theater has developed to the planned doctrinal maturity?

Early Deployment of Apaches in ODS

Some 274 Apaches were deployed to Southwest Asia for ODSt, arriving in stages over six months. By early September, four attack helicopter battalions (totaling 72 aircraft) were in the theater. These four were part of early-deploying XVIII Airborne Corps units. They included the 1/82 AHB of the 82nd Airborne Division; the 1/24 AHB belonging to the 24th Mechanized Infantry Division, Ft. Stewart, Georgia; the

²DoD, *Conduct of the Persian Gulf War*, p. 43. See also LTG William G. Pagonis, *Moving Mountains: Lessons in Leadership and Logistics from the Gulf War*, Harvard Business School Press, Boston, MA, 1992.

³FM 100-5, *Operations*, June 1993, pp. 12-8, 9; see also LTG Jerry R. Rutherford and MAJ Daniel Sulka, "Making FM 100-5 Logistics a Reality," *Military Review*, Vol. 74, No. 2, February 1994, especially pp. 13-15. The authors write that "split-based operations are particularly useful for the early stages of a power-projection operation to conserve strategic lift or for supporting a smaller-scale operation in which a force may be more efficiently supported from a forward-presence or CONUS location."

1/101, of the 101st Air Assault Division (Ft. Campbell, Kentucky); and its sister AHB, the 2/229, stationed at Ft. Rucker, Alabama.

This "what-if?" analysis examines the implications of combat beginning September 15 and focuses on these four battalions ready for fighting at that date.

Support Resources

The planned deployment of forces to Southwest Asia envisioned building a large and mature sustaining base in what was basically a bare-bones theater.⁴ The TADS/PNVS support structure would be highly elaborate as well, as discussed in the next chapter. By September 15, however, only pieces of that support had begun arriving and being positioned. Five (of an eventual eight) EETFs arrived in Saudi Arabia between September 1 and October 8. On October 8, two were located at King Fahd International Airport and two were at Dhahran air base, while the fifth was still in port. The FRA was also arriving in the theater at this time. Although Martin Marietta, the contractor running the FRA, received notification to prepare for deployment on August 24, complications in arranging transport prevented actual deployment until September 5. Further problems in Southwest Asia delayed the FRA coming on line from its Abu Dhabi location until past mid-September. The FRA in theater made its first reparable exchange with theater forces on September 18; there remained problems in retrograde movement of items to the FRA and shipping serviceables forward.

Spare parts pools arrived slowly in the theater. The envisioned mature theater would have three echelons of spare parts, with unit ASLs, stocks at division main support battalions (MSBs) and at the corps, and a large stock of wholesale spares collocated with the FRA in Abu Dhabi. These echelons would be linked with RX (reparable exchange) and AIMI (aviation intensely managed items) control points. By September 15, however, the spares picture was considerably simpler. In fact, the only spares for TADS/PNVS in the theater at that time belonged to the units themselves, coming out of their ASLs and whatever "plus-up" they had obtained.

WHAT IF FIGHTING HAD ERUPTED IN OPERATION DESERT SHIELD?

We next analyze the potential consequences of intense combat operations involving the Apaches commencing September 15, as Iraqi armored forces are imagined to cross the Iraq/Kuwait border into Saudi Arabia.

In the face of massed Iraqi armored forces and little armored support on the ground, a heavy burden would fall on Apaches in the theater. While it is impossible to know exactly what the operational demands would be, they would likely be quite intense. For this analysis, we assume a steady-state tempo of three operating hours per day for each of the 18 aircraft in the four battalions.

⁴LTG William G. Pagonis and COL Michael Krause, "Theater Logistics in the Gulf War," *Army Logistician*, July-August 1992, pp. 2-8.

Methodology and Data

We model logistics support for TADS/PNVs in this scenario with the Dyna-METRIC model described in Chapter One. The input parameters for the analysis are drawn mainly from the Martin Marietta data support systems for TADS/PNVs. The parameters used for the Dyna-METRIC analysis are laid out in detail in Appendixes C and D.

RESULTS OF THE ANALYSIS

Sustainability of TADS/PNVs

Figure 4.1 shows the results of the Dyna-METRIC analysis of this hypothetical scenario. It shows how many Apaches would become not mission capable (due to holes in their TADS/PNVs) over the course of a 30-day operation commencing on September 15. Beginning with all Apaches' TADS/PNVs systems operational on D+1, we see an immediate drop-off in weapon system capability, with over 20 percent of the Apaches NFMCA for TADS/PNVs only five days into the operation,⁵ then climbing to a high of 56 percent by day 30.⁶ In short, there are clear logistical limits to trying to carry out such a demanding mission before the full support structure has been put in place.

What would be the major contributors to this outcome?

Logistical Constraints on Early Operations

There would be three main sources of support for Apache TADS/PNVs in an early operation such as that described here: spares on hand, resupply from CONUS, and theater-level repair. Management of theater-level repair resources is a critical issue, but one we will postpone considering until Chapter Five.⁷ We shall limit our attention to the first two elements, the two that played an important role in our previous "what if?" case based on OJC.

Spares Imbalances Between Units. A primary source of early support for these units is the slices of the ASLs they deploy with (or are able to replenish or "plus-up" through requisitioning before hostilities begin). But not all units are equally re-

⁵The Department of the Army standard for helicopter availability (including the Apache) is 75 percent mission capable (70 percent fully mission capable). Recall that we are modeling only one subsystem of the Apache (albeit a crucial one); the loss of 20 percent of the Apaches for just this subsystem implies that substantially more than 20 percent of Apaches as a whole will be NMC.

⁶All Dyna-METRIC results in this chapter and the next one are at the two-standard deviation level of confidence unless otherwise stated. Using a two-standard deviation level means that we estimate that 97.5 percent of the time the number of NFMCA Apaches would be below the stated level.

⁷For this analysis, we assumed only intermediate repair would be available. Although the FRA was operational at the start of this hypothetical scenario, it probably would not have played a large role, given problems in the theater distribution system. Retrograde times to the FRA in Operations Desert Storm/Shield averaged 13 days, repair times at the facility were in the range of two to four days, and OSTs to units were around six days. Thus, the FRA's repair capability would have been meaningful only toward the end of this early operations scenario. Chapter Five discusses ways of making both intermediate and depot-level repair in the theater more responsive to operational demands.

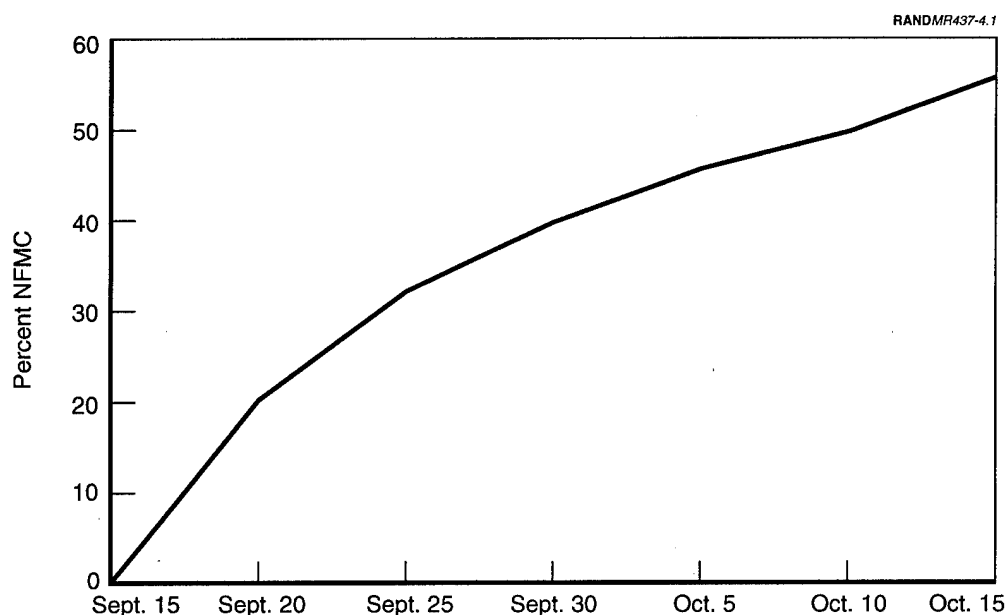


Figure 4.1—Effect of Early Combat on Apache Availability

sourced, and the resources each unit has may not be well matched to its operational demands.

Figure 4.2 gives graphic evidence of this, showing the actual distribution of all TADS/PNVs serviceable spares in the Southwest Asia theater as of October 1, 1990.⁸ There was wide variation in the spares possessed by each unit, ranging from the rich stocks of the 1/82 AHB to the mere five lines possessed by the 2/229.

There are no doubt many reasons for this. Different units maintain different ASLs, which are computed for each unit based primarily on peacetime demand history. The 1/82, richly resourced as the premier deploying unit, was also the first to deploy and the first to levy requisitions on the supply base; it obtained many TADS/PNVs spares from the local FRA before deploying. The 1/24, according to reports, may have had fewer spares on hand at this time because the division ASL had encountered difficulties arriving in the theater. (The ship it deployed on suffered mechanical failure en route.) The 2/229, by far the most poorly provisioned unit, is probably a special case. A part of the 101st AAD,⁹ it is based at Ft. Rucker, the Army Aviation Center and School. It is supported out of the logistics base there, which

⁸The data for Figure 4.2 were taken from the asset visibility system maintained by the Martin Marietta Corporation as part of its support operations of TADS/PNVs. Field technical representatives with each unit track the condition and location of assets by serial number and update the Orlando database regularly. We use the October 1 information, the data closest to the September 15 start date available to us, to represent spares allocation on September 15.

⁹It has since been moved to the corps aviation brigade.

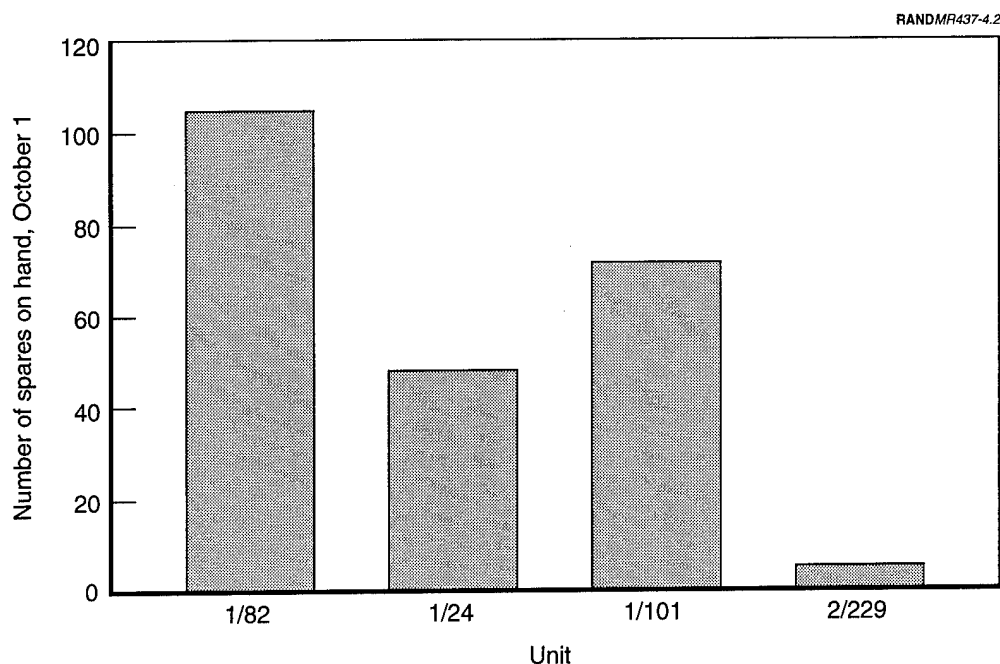


Figure 4.2—Distribution of TADS/PNVS Spares by Unit, Early in Desert Shield

is among the best in the Army for aviation, if not the best.¹⁰ Perhaps because of access to that support base, this particular AHB did not have a large stock of spares to deploy with. And unlike the 1/101, it is not located at the home station of the division, with all its deployable ASLs and other support resources.

If the missions of units were tailored to their logistic resources, these imbalances might not matter. But if, as we posit in this case, the tempos are not well matched to logistic resources, units will not be able to execute their mission. In this scenario, we assume the same tempo for all four battalions; Figure 4.3 shows the projected ability of each of the four units to maintain the needed levels of weapon system availability at this tempo. Unsurprisingly, the richly resourced 1/82 has few problems, in stark contrast to the 2/229.

Slow Resupply from CONUS. As the operation proceeds, the 1/82 as well would suffer significant loss of combat capability, as its own spares are eaten up and the local repair base is overwhelmed. Just as in OJC, slow, unresponsive resupply from CONUS would eventually put this operation in jeopardy.

In ODS, standard doctrine was used for prioritizing delivery of spare parts. The Uniform Military Movement and Issue Priority System (UMMIPS) designates 15 levels of priority (called requisition priority designators, or RPDs), gathered into

¹⁰The Ft. Rucker support structure is examined in the next section.

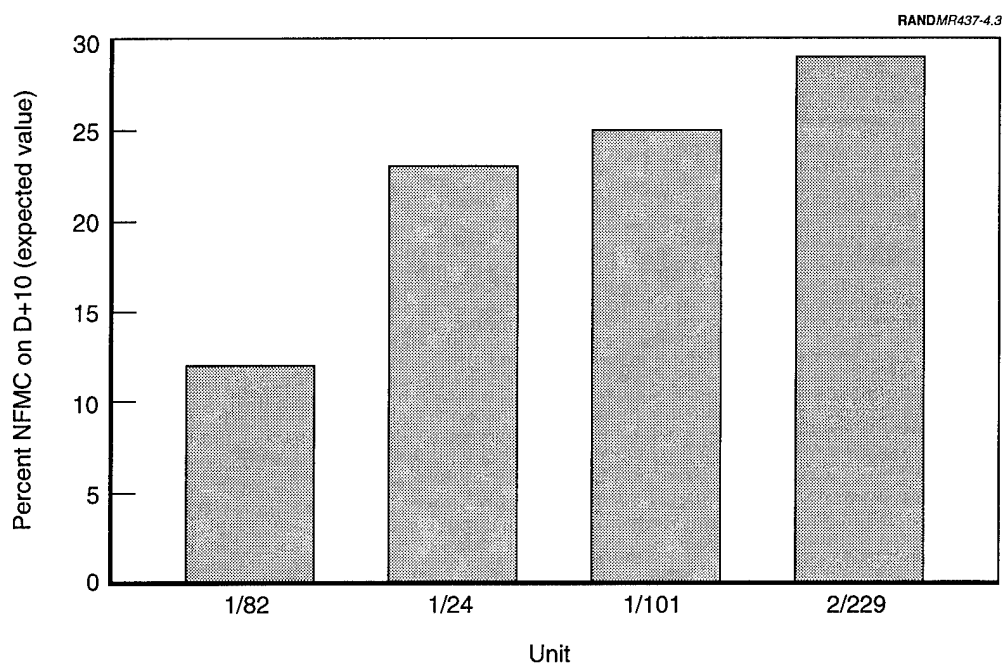


Figure 4.3—Apache Availability Across Units (Base Case, Expected Value)

three priority groups. Each requisition is designated with a force activity designator (FAD), which is assigned by units, and an urgency of need designator (UND), which is assigned by the requisitioner. The highest-priority group, Transportation Priority (TP) 1, includes the three highest RPDs and typically received special handling and high-speed transportation (usually air transport). TP 1 would have FADs I, II, and III (encompassing deployed or ready-to-deploy combat units) and UND A (meaning the parts without which the force/activity is unable to perform assigned operational missions). TP 1 requisitions have a standard delivery time of seven days in CONUS and 12–17 days overseas.¹¹

By most accounts, this standard system of resupply worked no better in Southwest Asia than it did in Central America. During Operations Desert Shield/Desert Storm, the supply system processed approximately 200,000 TP 1 requisitions. For those we can trace the full history of (less than 17,000), only about 12 percent met the OST objective; their average OST was 42 days. For Operation Desert Shield alone, only 11 percent of the requisitions (for which we can track the full history) were received within the UMMIPS objectives.¹²

¹¹As will be discussed in detail below, a new system, Desert Express, was added to circumvent the problems of the standard system. We treat this under "solutions" below.

¹²This figure was generated from Logistics Intelligence File (LIF) data, from the U.S. Army Logistics Control Activity, now part of the Logistics Support Activity. One may presume that those requisitions for which we do not have full documentation—including many that were lost or never delivered—would have had even longer OSTs. As this sample indicates, the LIF data are of limited practical use as a management

Table 4.1 breaks the order and shipping process into its pipeline segments. The delays were pervasive, as the table shows (with the exception of NICP processing); even leaving aside the logjams in theater (for which data are scarce), it is clear that simply getting materiel out of CONUS took too long.

As in OJC, there was priority inflation: lower-priority requisitions were marked as higher priority and, in consequence, the incentives increased to move more and more into the highest categories. There were approximately 200,000 TP 1 requisitions, versus 155,000 for TP 2 and 172,000 for TP 3. The end result was little discrimination of priorities or, more to the point, no advantage to having a higher priority. Table 4.2 shows that pipeline times barely differed for high- or low-priority ship-

Table 4.1
Pipeline Performance for TP 1 Requisitions in ODS/St
(October 1990–March 1991)

Pipeline Segment	Days in Pipeline	Percent Within Objective
In theater	6.6	35
NICP	1.6	95
Depot	4.0	66
Transit to CCP	4.6	52
At CCP	5.4	32
En route APOE	2.8	26
At APOE	3.0	59
In transit to POD	(10.3)	28
POD processing	(9.0)	4
Total OST	(42.3)	11

SOURCE: Logistics Intelligence File.

NOTES: CCP = consolidation and containerization point.

POD = port of debarkation.

() = small data samples.

Table 4.2
Days in Pipeline for Different Priority Groups

Pipeline Segment	TP 1	TP 2	TP 3
In-theater processing	6.6	5.8	5.6
NICP processing	1.6	1.8	1.7
Depot processing and hold time	4.0	4.2	5.1
In-transit to CCP	4.6	4.7	4.6
CCP processing and cargo accum.	5.4	5.1	4.8
In-transit to POE	2.8	2.9	2.8
POE processing and await lift	3.0	3.0	3.0
In-transit POE to POD	(10.3)	(6.9)	(10.9)
POD processing	(9.0)	(7.0)	(7.1)

SOURCE: Logistics Intelligence File.

NOTE: () = very small data set.

tool either to monitor historical performance or to help distribution managers identify and correct ongoing problems with the system.

ments.¹³ The highest-priority groups had special access to air shipment, but backlogs sometimes grew so great at APOEs that it was eventually determined to simply to send some items by surface. Delays were so great, and visibility so low, that many units in the theater submitted requisitions again and again, in hopes of jogging the system to get the needed parts out.

The end result was a clogged system that was sluggish, unresponsive, and lacking visibility of its resources. As will be discussed below, the executors of Operations Desert Shield/Storm took creative steps to rectify the situation in special ways, but our argument here is that the standard means—the way the Army plans on supporting its forces—would have put the forces and mission of an early starting operation at jeopardy.

SOLUTION DIRECTIONS

Solutions must address the problems affecting the three sources of support in this case: repair, management of local spares, and resupply from CONUS. As stated above, better management of local repair is a vital issue, but one we will postpone discussing until the next chapter. We confine our consideration here to the latter two concerns.

Managing Local Stocks Better

When units are managed in peacetime according to different criteria than during operational missions and when they deploy to the theater in steps, as happened in ODS, the units are not likely to all be at the same level of logistic sustainability at the commencement of operations. As depicted in this case, each unit's resources may not be well fitted to the operational demands placed on it.

One solution is to enhance local units' ability to exploit resources, such as spares, that are in the theater but not in their immediate possession. In particular, strategies for "cross-leveling" supplies of spares across units show great promise. Indeed, the Army is currently working on just such a set of new tools.

Total Asset Visibility and Objective Supply Capability. The recent developments in information technologies have opened up possibilities for new capabilities for asset management in the Army. Principal among new developments using these technologies are Total Asset Visibility (TAV) and Objective Supply Capability (OSC).

The TAV initiative currently being field-tested seeks to provide the Army with near-real-time visibility of the assets it owns, uses, or stores. It aims to track assets at all

¹³The higher the priority, the longer the requisition took to leave the theater, in part because of the review/approval process. TP 3 priorities spent 5.6 days in theater before being posted in the Defense Automated Addressing System (DAAS); for TP 2, the figure was 5.8; for TP 1, it increased to 6.6 days. For the highest-priority items, those going by Desert Express (discussed below), the time spent in theater for a requisition averaged 7.9 days.

levels—from wholesale depots to retail customers—as well as in-transit items.¹⁴ TAV will increase the Army's ability to see all assets across the theater and up to the national level, paving the way for seamless logistic support across the echelons. It intends to tie into emerging Army data systems that are providing the means for building asset visibility, such as new versions of the Standard Army Retail Supply System (SARSS), which provides a distributed and integrated supply system incorporating all units in a theater and providing asset visibility across divisions and corps.¹⁵

Another Army initiative that seeks to exploit asset visibility capabilities contained in TAV and SARSS is the Objective Supply Capability. OSC is an improved responsive "pull" system designed to give the supply system the ability to check for availability laterally within the theater and to provide units with accurate requisition status. OSC seeks to eliminate the long delays currently required to process requisitions by allowing requisitioners to access satellite-based communications systems integrated with gateway computers that have large-scale asset visibility. After a virtually instantaneous search, the system will inform the user whether the asset is available locally, whether it is at a neighboring unit, or whether the customer must go through the wholesale system. OSC can prioritize lateral resupply between units on the basis of "excesses" held among units. If appropriate command and control procedures can be established, then a unit critically short of particular items can requisition and obtain them from a neighboring unit.¹⁶

Such systems can be designed to help alleviate exactly the kinds of logistic problems that an early starting contingency might pose. Recall from Figure 4.2 the imbalances across deployed units that occurred in ODS, and from Figure 4.3 the possible consequences of those imbalances in terms of lost weapon system availability across units. What would have been the benefit of a working OSC system using a TAV-like asset tracking system?

Benefits of Better-Managed Local Stocks. Figure 4.4 indicates the possible benefits of such a system. It represents a model-based simulation of how OSC/TAV might improve overall weapon system capability by moving assets to where they are more needed.¹⁷ A system for cross-leveling by itself might increase overall weapon system availability 5 to 10 percent, that is, make another three to eight of the 72 deployed Apaches available for combat.

¹⁴See Timothy Yeager and Alan Estevez, "Total Asset Visibility," *Army Logistician*, May-June 1991, pp. 2-5.

¹⁵See Brian S. Phillips, "Logistics Automation Support for Desert Storm," *Military Review*, April 1991, p. 9.

¹⁶See Todd Wagenhorst, "Objective Supply Capability," *Army Logistician*, September-October 1991, pp. 2-4.

¹⁷Although Dyna-METRIC has a lateral resupply capability, it does not capture all the features of the proposed OSC system. The major difference is the lack of a "penetration level" in Dyna-METRIC. Penetration levels are defined in OSC as the safety stock level of a unit below which other units, even with higher priorities, are not allowed to requisition parts from the offering unit. This may tend to make Dyna-METRIC overestimate the benefits of OSC in our analysis (though not necessarily, since Dyna-METRIC may take away a unit's safety stock, to its detriment).

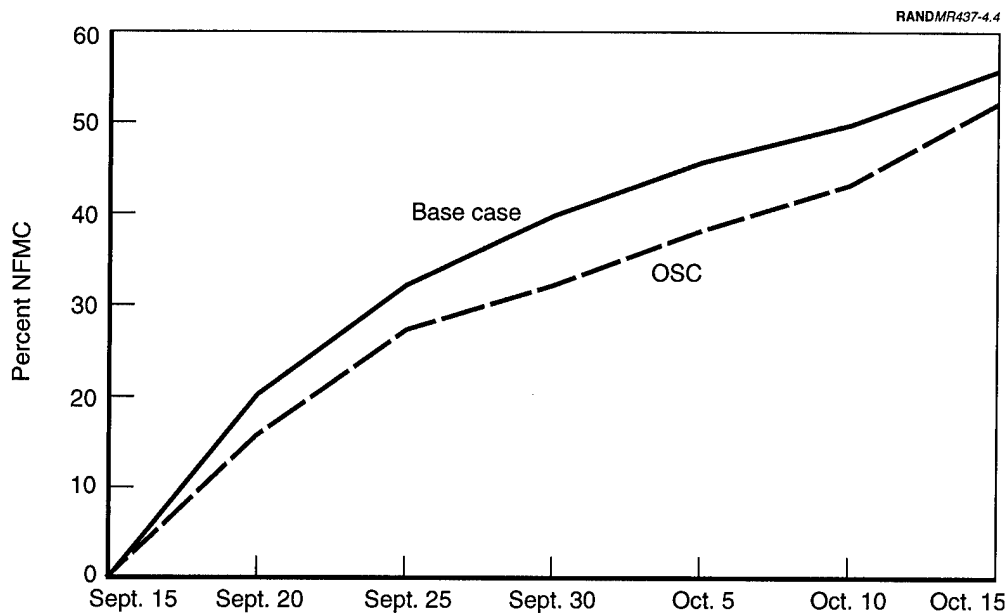


Figure 4.4—Effect of OSC on Apache Availability in Desert Shield Scenario

More striking than the effect on overall system availability is the benefit given to resource-short units. Figure 4.5 demonstrates the effect of an OSC-like system on weapon system availability across units.¹⁸ In contrast to the situation in the base case, using OSC would smooth out discrepancies across the units. Thus, the 1/82 would lose one weapon system (and be at 18 percent NFM) while all the other units increased their FMC rates to over 80 percent.

An OSC-type system, then, provides some overall benefit in system availability but, more important, preserves the overall commander's options in employing any of the units under his command. The benefit only goes so far, however. Even with OSC, high operational availability levels cannot be guaranteed with any confidence. NFM rates might still exceed 30 percent for the fleet (at the two-standard deviation level) over the course of the operation. Lateral resupply systems must be supplemented with other sources of reliable support, principally fast resupply from CONUS.

Fast Resupply from CONUS

Resupplying critical spares in an ODS-like contingency is considerably different from that in an OJC-like one. In the latter case, the critical factor, apart from the short duration of the operation, was principally the very small number of actors involved. This smallness allows more "customized" support, where supply officers or LARs can call their needs directly back to the CONUS.

¹⁸Figure 4.5 is given in terms of expected value.

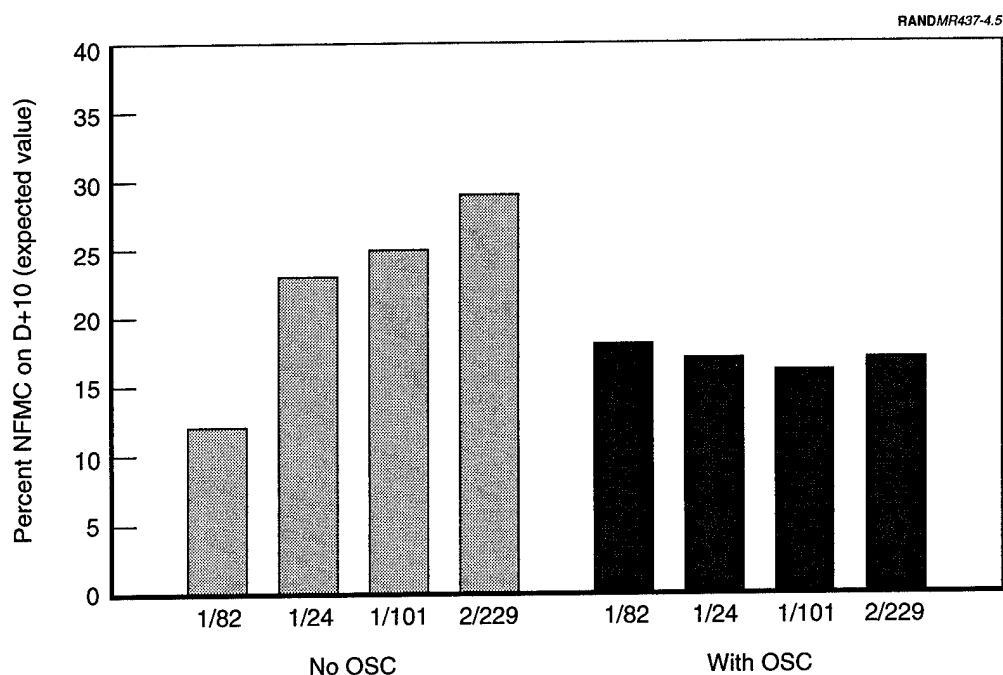


Figure 4.5—Effect of OSC on Units' Apache Availability on D+10

In an operation the size of ODS, this becomes less feasible. There were four Apache battalions in the theater, as well as other critical weapon systems (multiple launch rocket system [MLRS], Patriot, etc.); others, such as M1s and M2s, were on their way. Clearly, not every special demand could be called in without the system quickly being overwhelmed.

A second problem is that of dedicated airlift. The "Log Bird" alternative is less feasible; because there are a large number of home bases, there can be fewer of the Log Bird-type missions.

Larger operations of this sort require a more formalized system to meet the needs of a larger theater without losing responsiveness and timeliness.

Desert Express. One of the major logistical success stories of Operations Desert Shield/Storm was the enhanced resupply operation called Desert Express, a fast-response airlift system for extremely high-priority items given a special project code. It was intended to provide fast response time in CONUS, rapid transit to the theater, and priority distribution in theater to the consignee.

The Desert Express concept arose from the confusion and lags attending the resupply process in the early stages of the Southwest Asia deployment. During the September–October period, problems with lack of visibility and frustrated cargo led

to use of international carriers to cut delivery times and ensure arrival.¹⁹ After consultations among senior military leaders, Transportation Command (TRANSCOM) issued a concept of operations for Desert Express on October 12, and Desert Express service was implemented on October 30. Special project code 9AU was approved on November 7.

Initial successes led to an expansion of Desert Express services. A second segment from Europe to Saudi Arabia was begun to help support the European Command (EUCOM) forces deployed to the theater; a second regular CONUS mission was added both to accommodate increasing loads as well as to expand service to Dhahran and King Khalid Military City in addition to Riyadh.

The Desert Express process began with the assigning of a 9AU project code by units in the theater to certain requisitions. Eligible requisitions included medical items and spares and repair parts for 48 weapons and line item numbers (LINs) that were identified as "war stoppers." For Army requisitions, elements of Army-Central Command (ARCENT) Rear determined immediate priority for shipment, in conjunction with the MSCs and item managers; they issued priorities for each day's shipment. With such a listing, depots would use expedited transportation (such as Federal Express) to deliver requisitioned items overnight to the Desert Express port of embarkation, Charleston AFB, South Carolina. Packages were due to arrive no later than 10:30 a.m. and were immediately inducted into a special cargo-handling operation for Desert Express. They were then loaded directly onto a waiting C-141 for "wheels up" at 12:30 p.m. Upon arrival in the theater, the items were met for expedited intratheater delivery.

Approximately 5.5 million pounds of cargo were shipped using the Desert Express system through March 10, 1991 (75 percent from CONUS, 25 percent from Europe). Median OSTs were about 15 days, with typically five days required between establishing the requisition in the DAAS and departure from the APOE.²⁰ Army cargo took up 57 percent of the Desert Express load, and AVSCOM items accounted for 30 percent of the total tonnage shipped.

Desert Express, then, was a major step toward enhancing responsiveness of the re-supply system, but, as the foregoing made obvious, only with circumscribed success. Median OSTs (for some parts) were 15 days; in comparison, shipments via air line of communications (ALOC) ranged from 45 to 60 days. Still, 15-plus days is far from "overnight delivery."

¹⁹Aviation Systems Command (AVSCOM) had quickly turned to DHL, an international package delivery company, to help get high-priority aviation items into the theater in late September.

²⁰Based on the Master Inventory Record Post (MIRP) date in the Logistics Intelligence File (LIF) and excluding backorders. Only about one-third of the records in the LIF show MIRP dates. It is quite likely that many of the records without MIRP dates had longer OSTs. We have little information on what happened to the majority of parts upon their arrival in the theater. Anecdotal evidence suggests the system worked well when the customers knew the item was arriving and could meet it at the APOD. Otherwise, it appears that Desert Express items entered the standard theater distribution system, and their shipment to the ultimate customer could have been considerably delayed.

Figure 4.6 gives some indication of what accounted for these times. The greatest time savings are in the segments involving consolidation and containerization and at the APOE awaiting lift. Indeed, this part of Desert Express worked quite well. Upon receiving clearance to ship, depots moved parts rapidly to the APOE, Charleston AFB, where they typically arrived by 10:30 a.m. the next day. Avoiding logjams at the single consolidation and containerization point (CCP) at New Cumberland Army Depot, these parts were quickly put into pallets by personnel at the airport itself and then moved onto an aircraft, usually the same day.

On the other hand, the Desert Express system was considerably slower in clearing requisitions out of the theater for processing back to CONUS. The median time required for in-theater processing of Desert Express requisitions was eight days, versus five days for non-Desert Express items. Desert Express was a precious resource, and access to it was carefully monitored and controlled. But intense management attention translates into time and to a considerable degree the time advantages of Desert Express were reduced by that careful monitoring. Virtually half the OST for Desert Express items came from awaiting transmission of the requisition back to the NICP.

Clearly, it does little good to improve one part of a long chain of serial activities and expect more than marginal improvement. To make systems like Desert Express truly responsive, the whole system must be changed.

Needed Improvements to Desert Express-Type Systems. Innovations like TAV and OSC may make this possible. Recall that OSC is based on satellite transmission of requisitions; with modern technology (and assured access to often limited commu-

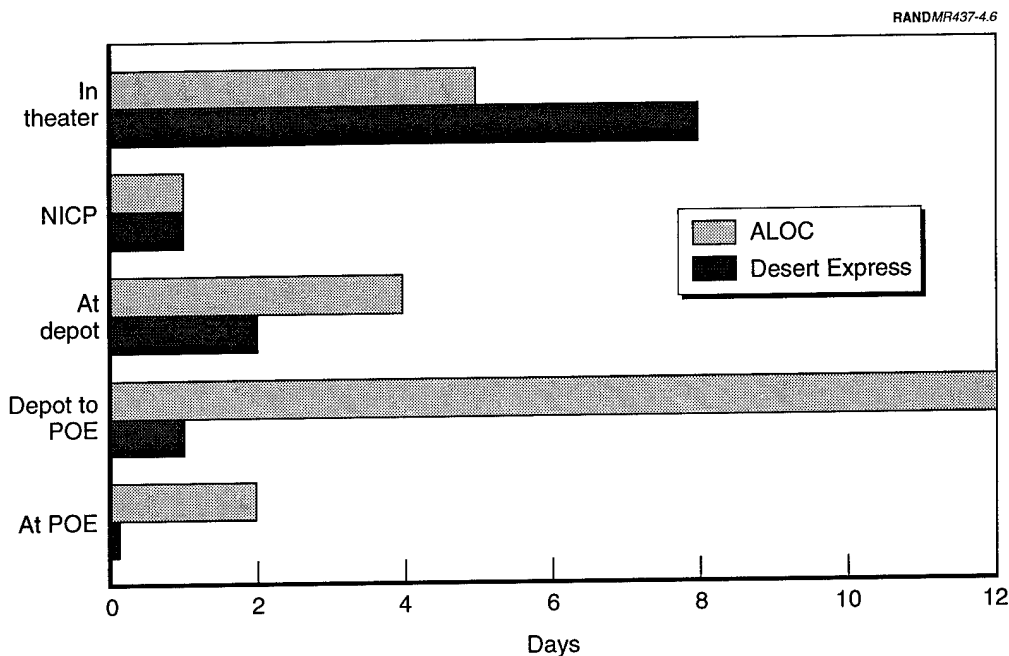


Figure 4.6—Pipeline Segment Times for Desert Express Compared to ALOC

nications resources), units may submit formal and accountable requisitions directly to a gateway controlling the OSC system, which then surveys local resources before moving the demand into the high-priority Desert Express-like delivery system. Theoretically, the process could be reduced to minutes; at the least, many days could be shaved from the nine-day average experienced in Southwest Asia.

Access to better requisitioning systems would solve part of the problem of a Desert Express-style system; another piece of the puzzle is the sometimes stringent review process that, as we saw before, kept the highest-priority requisitions lingering in the theater even longer than low-priority cases. With the incidence of priority inflation, this may make sense: One does not want all supply clerks deciding that their package needs express service, especially since the mode of transport is essentially "free issue" for them. On the other hand, in a relatively small operation of the sort we posit here (that is, much smaller than Operation Desert Storm), transportation—even express-style transportation—*should be* something of a "free resource" to the forces being supported.

Put another way, the managers of the distribution system should take the risk of "wasting" some transportation resources on noncritical (i.e., incorrectly prioritized) items to ensure that truly critical ones get the fastest service possible. If the cost of minimizing the use of transportation resources (say, one C-141 dedicated to express service) is longer review times for all highest-priority requisitions in the theater, then the distribution manager must strongly consider whether to add more transportation resources and reduce the scrutiny of requisitions in the theater.

Some constraints could still be applied. Only units that were directly involved in combat (or directly supporting those in combat) would get immediate access to express service, and only for weapon systems in their inventory. The number of items of a type might be limited for a particular delivery, preventing the units from using this resource to stock up. Other simple constraints might be used that could be overridden by human intervention.

But even if those constraints do not reduce the number of overprioritized assets being delivered, the distribution manager must accept that some wastage will occur and increase the transportation resources for express distribution. For a small operation of this sort, that is not likely to be a problem: sustainment cargo will typically be carried on C-141s, on narrow-body Civilian Reserve Air Fleet (CRAF) airplanes, or on chartered commercial aircraft and will not compete for space on C-5As carrying oversized and outsized cargo for deploying units.

In CONUS, delays at the NICP and depot level, though less critical, can also be reduced. Many of the problems in releasing materiel come from backorders or non-availability of spare parts at the depot. A fully comprehensive total asset visibility system would extend the reach of the item manager (IM) to what exists in the entire supply system (not just to what exists on depot shelves)—depots, nondeployed units in CONUS, deployed units, contractor-operated repair facilities, even possibly con-

tractor production facilities.²¹ The IM would then quickly be able to determine the best source for a needed part and, with proper authority, release it for immediate shipment to the APOE for next-day delivery.

It is not clear how effective and rapid such a system could be. In part it depends on the nature of the contingency; it also depends on solving problems not discussed here (such as the intratheater distribution function²²). Nonetheless, it does not seem infeasible to imagine an end-to-end fast distribution system that can move the most critical parts on a regular basis in ten or fewer days.

Benefits of a Fast-Resupply System. What would be the logistics benefit of such a system? Figure 4.7 shows how it helps, based on the case in question. It shows the results of Dyna-METRIC analysis of the ODS case, with the effects of instituting an improved Desert Express-type fast resupply system. The top line presents the base case, assuming standard support of four Apache battalions with combat commencing September 15. The next line below that repeats the effect of using a TAV/OSC system for lateral resupply. The next lines show the effect of a Desert Express-style system, with 20-, 10-, and 5-day OSTs.²³

In an operation of this sort, fast resupply can make a substantial difference in combat capability. A 20-day OST (approximately what Desert Express achieved) would lower NFMC rates to about 30 percent at a maximum; 10- and 5-day OSTs would reduce that to approximately 25 and 20 percent, respectively, and the NFMC rates would in fact level off, being sustainable for the 30-day operation and even beyond it.

²¹The asset status system for TADS/PNVS operated by Martin Marietta maintains high-accuracy information on parts location at all of these places.

²²This is discussed in more detail in Chapter Five.

²³The 20-day OST is meant to roughly resemble Desert Express's performance in Operation Desert Shield; given that we have data from only a third of the requisitions (showing a median OST of 15 days), the 20-day estimate may be somewhat optimistic, as discussed previously.

In the model, OST covers only the time after a need from CONUS is determined, not from removal of the item. In addition to the 5, 10, or 20 days is time for searching local units and evacuating the carcass back to intermediate repair to determine feasibility and time necessary to make a repair. Only afterward would the part be sent via fast resupply from CONUS.

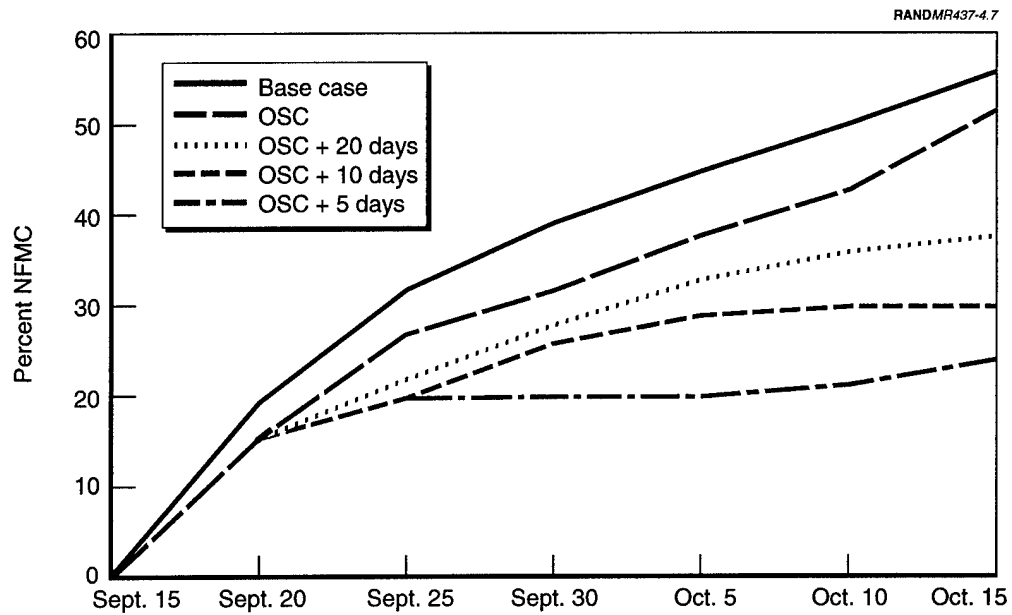


Figure 4.7—Impact of OSC and Fast Resupply on Apache Availability in the Desert Shield Scenario

**SUPPORT ISSUES IN A MAJOR CONTINGENCY:
OPERATION DESERT STORM**

SUPPORTING MAJOR CONTINGENCIES

Operation Desert Storm (ODSt) was one of the larger and certainly most successful military operations carried out by the United States since World War II. It was an operation that tested and validated many of the features of U.S. armed forces' training, doctrine, acquisition, and philosophy. Many concepts passed their test of fire with flying colors, such as that of AirLand Battle and the utility of "fight by night." Strikingly, the United States' technological edge, in all the services, proved its worth to all but the most hardened critics.

ODSt was a logistics success as well. The movement of forces and supplies to the theater was unprecedented in terms of size and speed; that achievement was matched by the famous "left hook," for which transporters moved two entire corps in secret to the west of the Iraqi forces. The commander of CENTCOM, GEN Schwarzkopf, was not exaggerating when he said, "The task faced by the logisticians can only be described as daunting, and their success can only be described as spectacular."¹

ODSt was also the first sustained test of the Apache. Some 274 Apaches were deployed to Southwest Asia in 15 units; they were credited with destroying almost 1200 targets, including 278 tanks and 235 armored vehicles, during 83 missions in the conflict.² And, as is well known, Apaches from the 101st Air Assault Division (AAD) fired the first shots of the war, successfully taking out critical Iraqi air defense radars.

Logistically, the Apaches far exceeded expectations. During the conflict, the Apache fleet maintained a mission capable rate exceeding 93 percent, well above the stated Army goal of 75 percent.³ In fact, the Apache was noted, in the words of the former

¹LTG William G. Pagonis and COL Michael D. Krause, "Theater Logistics in the Gulf War," *Army Logistician*, July-August, 1992, p. 2.

²General Accounting Office, *Operation Desert Storm: Apache Helicopter Was Considered Effective in Combat, but Reliability Problems Persist*, GAO/NSIAD-92-146, April 1992.

³Clifford Beal and John Boatman, "Deadly by Design: The Anti-Tank Helicopter's Evolutionary Progress," *International Defense Review*, 6/1992, p. 523; Department of Defense, *Conduct of the Persian Gulf War, Appendix T: Performance of Selected Weapon Systems*, Final Report to Congress, p. T-18.

commander of the Army Aviation Center, as “leading the fleet in terms of availability.”⁴

The General Accounting Office, theretofore a harsh critic of the sustainability of the Apache, also noted that, despite some logistics and reliability problems, the Apache’s overall combat effectiveness “had not been compromised.”⁵ The same report noted several problems in the field for the Apache—among them, malfunctions of the 30mm gun system, degradation of TADS/PNVS performance, and so on—but no problem was severe enough to prevent the Apaches from accomplishing their assigned missions.

Purpose of “What If?” Analysis

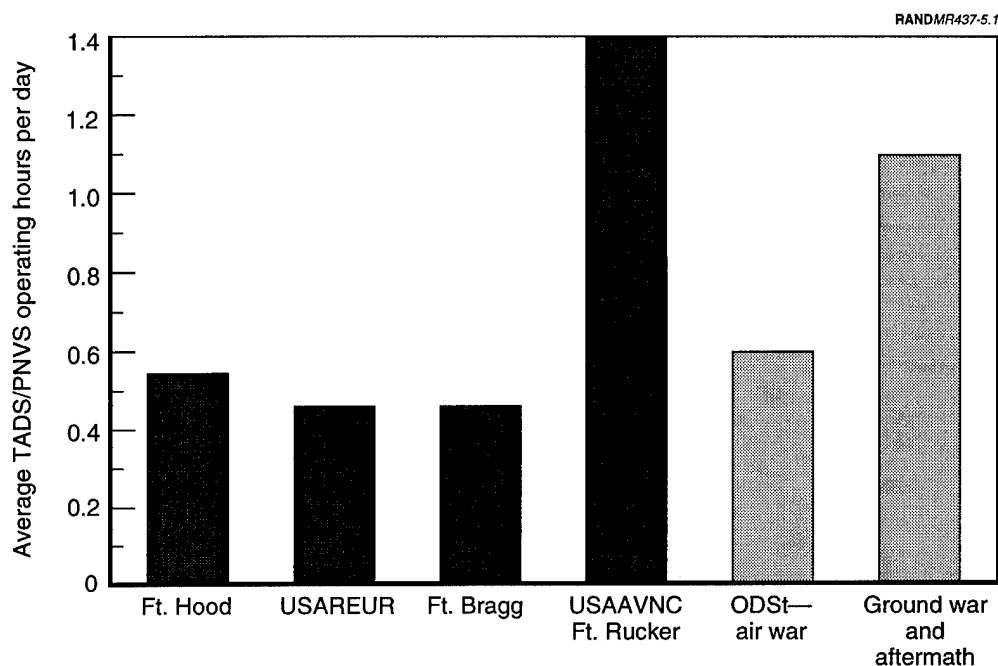
ODSt joins its predecessors, Operation Just Cause (OJC) and Operation Desert Shield (ODS), as a stunning success for the U.S. military and especially the Army. Exceeding virtually all expectations, the Army overcame difficult barriers in executing a challenging mission. It may be that ODSt, like OJC and ODS, will be the most onerous kind of mission the Army will have to face in the future, and, if so, what served the Army well in these missions may continue to do so in the future.

But to plan on that basis may expose the Army to unwarranted risks. Just as in OJC and in ODS, where the length of the former and deterrence of the foe in the latter were critical, so too in ODSt there were characteristics of the operation that eased the logistics problem. We may not be able to count on these advantages in the future.

Three factors were especially critical for easing the logistics problems in ODSt. First was the level of demands arising from relatively low operational tempos. As fierce as the combat was in ODSt, the demands for logistics support were less than might be expected in all-out combat. Eleven of the 15 Apache units executed 83 combat missions, including 652 helicopter sorties. Data from the Martin Marietta Operating Hours system shows a per-aircraft daily operating tempo of 0.6 to 1.1 hours per aircraft per day for the Apache fleet. Figure 5.1 shows how that compares with peacetime operating tempos. Although the operating rate was rather higher in the last two than in the first four weeks of the war, even these rates were not substantially greater than normal peacetime experience; indeed, they are substantially less than that expected on a daily basis at the Army’s Aviation Training Center (USAAVNC) at Ft. Rucker. Clearly, the Apaches’ flying tempo did not have to be higher in ODSt; after all, it was sufficient to help win the war. And in the future, possibly no more will be expected of them. But it is at least prudent to expect that deployed weapon systems will have more demanded of them, and to plan logistics support on that basis. We will ask, then, what if the Apaches had been on call to operate at higher tempos than was the case in ODSt?

⁴David F. Bond, “Apache Helicopter Proves Reliability to Rebut Reputation for Deficiencies,” *Aviation Week and Space Technology*, March 4, 1991, p. 25.

⁵GAO, *Operation Desert Storm: Apache Helicopter Was Considered Effective in Combat, but Reliability Problems Persist*, p. 28.



SOURCE: Martin Marietta Operating Hours System.

Figure 5.1—Comparative Operating Tempos: Operation Desert Storm and Peacetime

A second factor was the rich resource base. The Army deployed a greater than doctrinal number of EETFs to the theater; an FRA was deployed with extra personnel, and plans were in place to deploy more FRA test equipment from the Germany-based FRA. Some \$48 million worth of TADS/PNVS spares were sent—more than sufficient to cover the actual removals of Operation Desert Storm. A future smaller Army may not be able to call on such large stockpiles of resources. The deployed forces may by necessity have to do more with less.

The third critical factor was time to prepare the logistics base. ODSt began at the United States' initiative and followed almost six months of deployment. It also followed almost six months of refining logistics support that led to many adaptations in the field as need demanded; one, Desert Express, has already been discussed. Other adaptations proved quite successful, like the Camel Flights intratheater distribution system, which will be discussed presently.

In short, the Army was able to support the Apache in ODSt in ways that were not strictly "doctrinal." The question arises, what would have happened had the Army not had the opportunity to invent new solutions as it went along, but instead if it had "gone by the book"? That is, what if the Army had fought (and supported) in war as its doctrine calls for it do, and as it trains in peace? How different would Desert Storm have been had there been no Desert Express or Camel Flights, or other mid-stream adaptations?

The analysis in this chapter will look at this set of “what ifs.” It will consider the consequences of supporting a large force like that in ODS_t at different operating tempos. It will begin by considering the effect of supporting the forces with a doctrinal structure (i.e., “by the book”). The point is not to criticize what was done in Southwest Asia in any way, but rather to isolate the value of the adaptations made in the theater, to call for building them into the Army’s concept of support, and to point out the need for yet further adaptations to make support more resilient in the face of unpredictable contingencies.

Organization of the Chapter

ODS_t was an unusually large operation that raised many problems for logistics analysis. In the next section, we will address the support concept used, including its adaptations, and evaluate its performance. Next, we will consider the series of “what ifs” based on exposing a base-case doctrinal support structure to differing logistics demands. We then consider what problems would emerge from such a scenario and why. We then lay out the argument for improving the support concept for high-technology weapon systems like the Apache. Some of these changes, like Desert Express and the Camel Flights, were in fact made during ODS/ODS_t. Others, like the consolidated repair facility and an integrated weapon system sustainment management system, are new ideas we propose the Army adopt. We believe that all these changes form a package that put together would form a robust and cost-effective structure for supporting future contingency operations.

TADS/PNVs SUPPORT IN OPERATION DESERT STORM: CONCEPT AND EXECUTION

Support Structure

EETFs. To support the Apache operations in Operations Desert Shield/Desert Storm, eight EETFs and one FRA were deployed into the theater. The EETFs arrived on a staggered schedule. Five arrived between September 1 and October 8, and three additional EETFs arrived between December 6 and 18. During January and February, these EETFs were repositioned to better support fighting operations from locations closer to the front. One EETF moved to Log Base B on January 6; by January 28, two EETFs had moved from King Fahd International Airport to Log Base C. In February, individual EETFs moved to Log Base E and King Khalid Military City (KKMC), followed by movement in March of the unit from Log Base E into Iraq and Kuwait. See Figure 5.2.

FRA/TAMP. FRA support was provided by deploying the Fayetteville, North Carolina, FRA to Southwest Asia. In peacetime, that FRA devotes its support to an Apache attack helicopter battalion (AHB) at Ft. Bragg, the 1/101 AHB at Ft. Campbell, and the 1/130 AHB of the North Carolina National Guard. With Operations Desert Shield/Storm, however, it was called on to support the 274 deployed Apaches in combat conditions. Figure 5.3 shows the timeline of that deployment. As part of the uncertainty surrounding early planning of the operation, it was unclear if the FRA

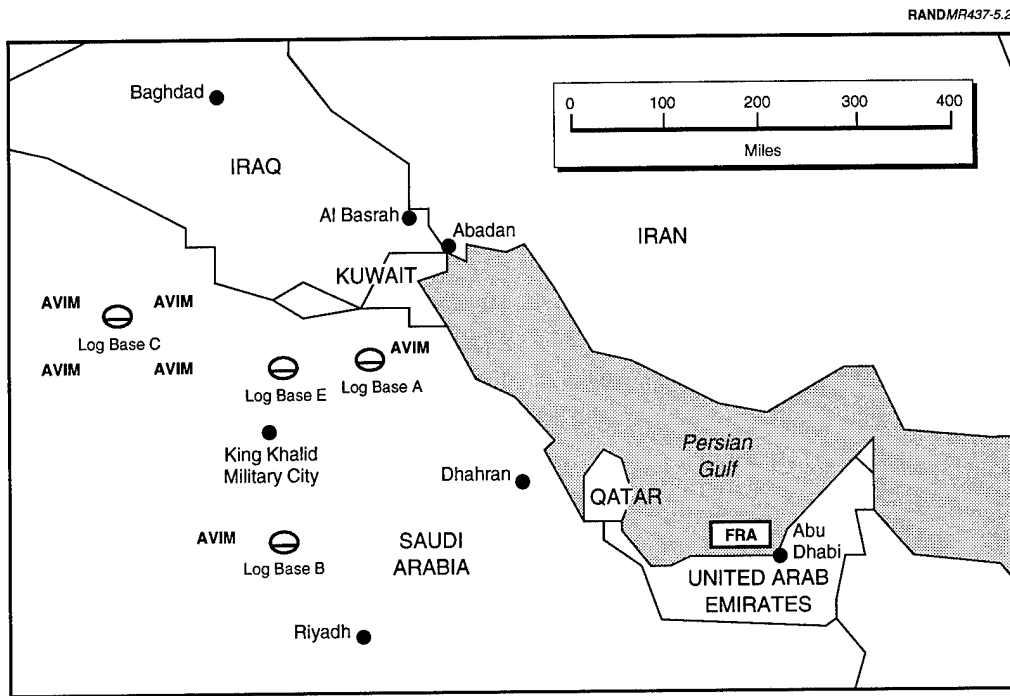


Figure 5.2—Laydown of Apache Support Structure, February 3, 1991

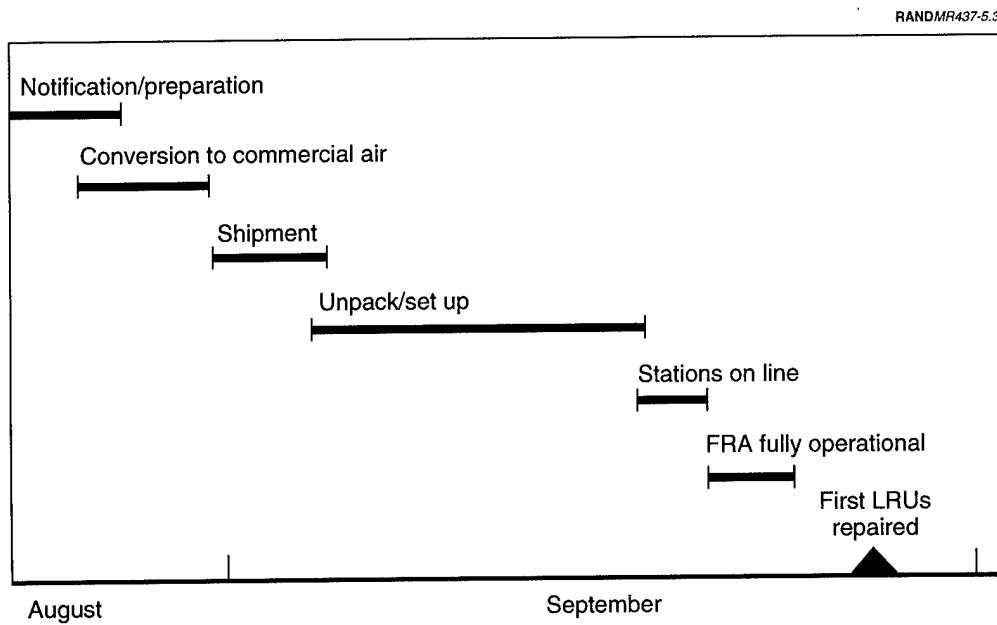


Figure 5.3—Timeline of FRA Deployment to Southwest Asia

would travel via military or commercial aircraft; after some delay awaiting the government's decision, a commercial plane was chartered. Additional delays were incurred in establishing usable power sources at FRA's new location in an airline warehouse in Abu Dhabi, some 500 miles from the front line.

Originally, only the test/repair equipment from the North Carolina facility was deployed. In March, a hot mockup/aircraft simulator (the initial screening mechanism used at the FRA) was added from the Germany-based FRA.

Original manning was also based on the North Carolina operation and included ten technician-specialists, a quality assurance specialist, and a supply/administration manager. Early in the operation, six additional personnel were deployed from Germany to allow two-shift operations.

While two-shift operations were necessary for a period of about three to four weeks during the heaviest workload, the typical daily operation was one shift of 10 to 12 hours.

The FRA was part of the larger Aviation Systems Command (AVSCOM)⁶ concept for supporting deployed aircraft called the Theater Aviation Maintenance Program (TAMP). The TAMP was an innovative approach to theater-level aviation maintenance developed by AVSCOM to meet the needs of the large operation. The TAMP was built in echelons. TAMP-Base was located in Abu Dhabi. The capabilities of this base centered around FRA support for the Apache TADS/PNVS, the Integrated Helmet and Display Sight System (IHADSS), the Heading and Attitude Reference System (HARS), some Apache mechanical systems, and for the OH-58D, the Mast Mounted Sight. Inventory operations included control of 1000 lines (121,000 items) of battlefield spares, 142 lines of AIMI, and 2100 lines of repair parts to support the depot-level repair operations. At its peak, TAMP-Base involved 76 contractor personnel, 15 Department of the Army civilian (DAC) employees, and 19 military personnel.

TAMP-Forward was located at Dammam, Saudi Arabia. The vast majority of non-FRA support was provided at this location, including aircraft processing, limited depot-level airframe repairs, technical support, and modifications. At its peak, it included 532 contractor, 10 DAC, and 21 military personnel.

TAMP-KKMC was established shortly before hostilities to provide support closer to the front lines. Its capability included reparable exchange (RX), technical support, maintenance augmentation, modification work, classification, and retrograde (rearward movement of spare parts); it was also the crash/battle-damaged airframe theater collection point. At its peak, it included 69 contractor, five DAC, and five military personnel.⁷

⁶AVSCOM has since been consolidated with the Troop Support Command and renamed the Aviation Troop Command, or ATCOM.

⁷AVSCOM *After Action Report*, Aviation Systems Command, no date.

Support Structure Performance

Division of EETF/FRA Workload in War and Peace. As Table 5.1 shows, about 1200 TADS/PNVS LRUs were removed over the entire course of operation, extending from August 1990 to May 1991. The table also shows that the majority of those items were fixed at the FRA in Abu Dhabi; AVIM units in the theater turned around one-fifth of all removed LRUs. Table 5.2 breaks down in-theater repair by echelon and time period. AVIM repair was less than one-quarter of in-theater repair in Operation Desert Shield and the postwar period⁸ and reached 37 percent during Desert Storm, with the FRA making up the remaining workload.⁹

The eight EETFs were located in seven AVIM units (one, the 7/159, had two EETFs). Table 5.3 shows the breakout of repair and NRTS actions (not repairable this station,

Table 5.1

TADS/PNVS LRU Removals and Source of Repair (August 1990–May 1991)

Source of Repair	Number	Percent
AVIM	254	21
FRA	638	53
CONUS depot	130	11
Unknown ^a	179	15
Total	1201	100

SOURCE: Martin Marietta Fault File.

^aRemoved but final source of repair not known.

Table 5.2

In-Theater Repair of TADS/PNVS by Period

Period	Repaired at AVIM		Repaired at FRA	
	Number	Percent	Number	Percent
Desert Shield	100	24	320	76
Desert Storm	119	37	205	63
Postwar	29	23	99	77
Period unknown	6	30	14	70

SOURCE: Martin Marietta Fault File.

⁸"Postwar" here covers the period from March 10 to May 1.

⁹These data are from the Martin Marietta Fault File data system operated in Southwest Asia. Another data collection effort during the war yielded similar results. Technical representatives from General Electric, which supports the EETF, also collected production data from the EETFs. Their results accord with those from the Martin Marietta system. The GE system counted 230 EETF actions from the beginning of the operation until the closeout of data collection on April 30, 1991; the Martin Marietta system counted 233 EETF actions in the same time period (the number shown in Table 5.1 is greater because it extends beyond the GE cutoff date).

Table 5.3
Contribution of AVIMs to Repair by Time Period

AVIM	Beginning-Jan. 2		Jan. 3-Mar. 1		Mar. 2-Closeout	
	Repair	NRTS	Repair	NRTS	Repair	NRTS
TADS/PNVS repairs at:						
I/159 (Ft. Bragg)	52	45	7	7	0	1
K/159 (Ft. Hood)			18	2	3	0
7/159 (USAREUR)			18	8	22	13
8/159 (USAREUR)			27	10	8	3
H/159 (Ft. Campbell)	24	18	6	6		
K/159 (Hunter)	12	8	37	7	6	1
F/1 (Ft. Riley)	13	10			11	1
Total TADS/PNVS	101	81	79	40	50	19
Total non-TADS/PNVS	106	39	79	11	9	5
TADS/PNVS fixed at FRA	141		280		189	
TADS/PNVS fixed at depot	1		18		43	

SOURCES: GE technical representative reports (AVIM), Martin Marietta Fault File (FRA/depot).

that is, evacuated to a higher echelon for repair) by time period at each of these units. The table also gives some idea of the contribution of TADS/PNVS to EETF load (the EETF tested 78 LRUs, 18 of them TADS/PNVS). About 54 percent of all LRUs processed at the EETF were TADS/PNVS. Table 5.3 also shows FRA and depot repairs in the same time period.¹⁰

Finally, Table 5.4 shows the division of workload during ODS/ODSt down to the LRU level. Note that while many of the LRUs are not supported at the EETF (for lack of fielded test program sets (TPS) or software needed to run these components on the test equipment), large percentages of components that are testable at the EETF were in fact fixed at the FRA; in fact, about 75 percent of the TADS/PNVS components removed were EETF-testable.

ODS/ODSt marked the first time EETFs (or the FRA) had been deployed for combat operations. The exigencies of combat operations (e.g., frequent movement, lack of visibility of carcasses) might explain why AVIM repairs form such a small percentage of the total. However, Table 5.5 compares the production by AVIMs in Operations Desert Shield/Storm with many of these same repair units in peacetime by showing the relevant breakdown in AVIM/FRA workload for Forces Command (FORSCOM) and U.S. Army Europe (USAREUR) units. For Ft. Bragg, USAREUR, and Ft. Hood, the AVIM contributes workload in the range of 14 to 47 percent; the 29 percent of the in-theater repair performed at the AVIM during ODS/ODSt falls squarely in that range. Thus, here was a case where the support structure performed in war as it trained in peace.

¹⁰Clearly, NRTS figures from the EETFs and repair numbers at the FRA and depot do not coincide. The reasons for this are unclear, but apparently (as discussed below) many of the items repaired at the FRA were never inducted into the EETF.

Table 5.4
Distribution of Local Repair by LRU
(Desert Shield and Desert Storm)

LRU	Number	Percent Repaired at	
		AVIM	FRA
AND	3	33	67
BSM ^a	22	4	96
CPA	21	52	48
DSSH ^a	7	0	100
DSSA	31	26	74
ECS	4	25	75
GCCA	16	38	62
IVD	40	45	55
LEU	16	38	62
LHG	5	80	20
LTR	22	14	86
LTU ^b	62	2	98
NSSH ^a	5	0	100
NSA	66	44	56
ORC ^a	22	4	96
PECA ^a	12	0	100
PEU	34	47	53
ADG	30	27	73
PSSH ^a	31	6	94
PTUR	86	33	67
RHG	10	80	20
TTI ^a	39	5	95
TECA ^a	33	3	97
TEU	70	67	33
TPS	23	35	65
TVS	34	26	74

SOURCE: Martin Marietta Fault File.

^aNo TPS capability at the EETF.

^bIncludes 50 defective LTUs removed for testing and retrofit.

Table 5.5
AVIM/FRA Production in Peacetime and War

	Percent Repaired at		
	AVIM	FRA	Total LRUs
Ft. Bragg ^a	14	86	229
USAREUR ^a	31	69	517
Ft. Hood ^a	47	53	2610
Operations Desert Shield/Storm	29	71	744

SOURCE: Martin Marietta Fault File.

^a1988–1990.

Aspects of EETF Performance in Operations Desert Shield/Storm. Between January 15 and February 18 (based on available data from GE technical representatives), the EETFs inducted 111 LRUs (TADS/PNVS and non-TADS/PNVS). Of these, 58 percent

were tested, repaired, and returned to supply. Of the remaining 42 percent NRTSed to a higher echelon, the breakdown for cause was

- 18 percent, not authorized for repair
- 11 percent, lacked test equipment or tools
- 12 percent, awaiting parts over two weeks
- 1 percent, lacked technical data.

But, as mentioned above, many LRUs bypassed the EETF regardless of whether they might have been repaired or NRTSed from there. Part of the reason might lie in the FMC status of the test equipment.

The reported availability of the EETFs in Operations Desert Shield/Storm was quite good. In the reports for the entire operation (September 4, 1990 to April 30, 1991), the EETFs logged 14,136 hours and had only 287 hours of maintenance time, for a readiness rate of 98 percent. Without taking away from this achievement, it is important to realize what it does and does not include. Typically, these logged hours referred to the operational status of the core computer without which, admittedly, the entire system could not operate. This figure, however, does not tell us if the system was *fully* mission capable—whether, for example, the electro-optical bench (EOB) that is critical for testing many TADS/PNVS LRUs was functional. Here, the reporting system may not have conveyed some underlying problems.

The EETF belonging to K/159 burned a signature card in a major adapter in the EOB in mid-December. It borrowed one from the EETF at I/159 but it burned too; the EOB then remained problematic until it was reported up on March 1, 1991. Other problems accrued among the EETFs such that on February 8, not long before the ground war, four of the eight EOBs were out of commission. In the 23 weekly or bi-weekly reports delivered by GE technical representatives, there were 71 problems; on average, three of the five to eight EETFs were partially mission capable when reported over the period. It is clear that a reported 98 percent readiness rate does not tell the whole story.

There is some question about how well retrograde back to the EETFs and FRA was organized. Field representatives' reports disagreed about whether parts should be sent to the EETF or moved directly to the FRA. There were delays, also the subject of field report comments, in getting parts to fix the LRUs, which may have contributed to units bypassing the EETFs in retrograding workload.

Field adaptations were made or considered that had implications for EETF management. In a number of instances, EETFs were collocated. For example, two of the three log bases initially had two EETF operations, as did Dhahran and King Fahd airfields. For both troubleshooting and repair operations, parts could be swapped as needed (as happened with the two EETFs of the 7/159). A second idea discussed in the field was the use of a single officer to control the workloads of all EETFs at a single location. Had this been implemented, it might have affected the number of LRUs

that were bypassing a broken EETF on their way to the FRA and bypassing other functional EETFs nearby.

WHAT IF OPERATIONAL TEMPOS HAD BEEN HIGHER IN OPERATION DESERT STORM?

Apache availability rates were outstandingly high. Although the Army goal for mission capable helicopters is 75 percent, availability rates for the Apache exceeded 90 percent throughout the duration of combat.

How robust was the structure that helped achieve those high availabilities? Had the war unfolded differently, would similar successes have been forthcoming?

A successful logistics structure must be able to deliver performance across a range of demands. The system should be able to degrade gracefully as the level of support demands increases. Previous "what if?" cases examined longer operations and earlier starts. Here we have replayed Desert Storm and varied the operating tempos.

Scenario Assumptions

In our replay of Desert Storm, we made a series of changes involving operating tempos. As Figure 5.1 showed, for the Apache fleet over the six weeks of the conflict, per-aircraft daily flying demands averaged roughly three-quarters of an hour per day, or about 22 hours a month. In Chapter Four, we assumed an operating tempo of three hours a day; a Central European scenario would require a 30-day operating tempo for one AHB of 4.3 hours per aircraft per day, and if we assume two of three battalions are engaged at any one time, an optempo of some three hours per day results.

Future contingency operations are likely to demand operating tempos somewhere between these two points on the continuum; the uncertainty about where the demands would fall is of course part of the unpredictability of these kinds of operations. It is thus of interest to look at a set of "what if?" cases that in fact examine that spectrum and assess logistics robustness as the tempo is ratcheted upward.

In the analysis that follows, we present four cases: an actual Desert Storm operating tempo (0.75 operating hours/aircraft/day), a doubling of that (1.5 operating hours/aircraft/day), a tripling (2.25), and a quadrupling (3.0).

We also assume that the support structure is standard, or "doctrinal"—that is, we purposely do not use some of the adaptations actually employed in supporting TADS/PNVS in ODSt. For example, we do not include the innovation of the Camel Flights intratheater distribution system, which will be discussed below.

The purpose of this analysis is not to replay ODSt; rather, it is to evaluate the ability of a *standard support concept* for a large, demanding operation. Thus, we emphasize a support structure as dictated for TADS/PNVS in the initial planning for Southwest Asian operations and practiced in peacetime. In short, this means reliance on dispersed EETFs at the division and corps level, and a wholesale-level FRA supporting the forward-based forces. It further means use of standard theater transportation

and standard resupply from CONUS (typically air line of communication [ALOC]). Also, as will be discussed below, we assume no specialized or sophisticated asset and weapon system management systems, such as TAV and OSC.¹¹

Results of the Analysis

Figure 5.4 shows the results of the Dyna-METRIC analysis. It represents the number of Apaches NFMC for TADS/PNVs at the two-standard deviation level of confidence. The key in the upper right explains the cases used, which differ by operating tempo. The bottommost curve is the simulation that most closely reflects operating tempos in ODS itself. It shows that expected Apache NFMC rates from TADS/PNVs with the standard support concept would be remarkably low, varying around 5 percent for the duration of the conflict. This accords fairly closely with the overall availability of TADS/PNVs in Operation Desert Storm.¹²

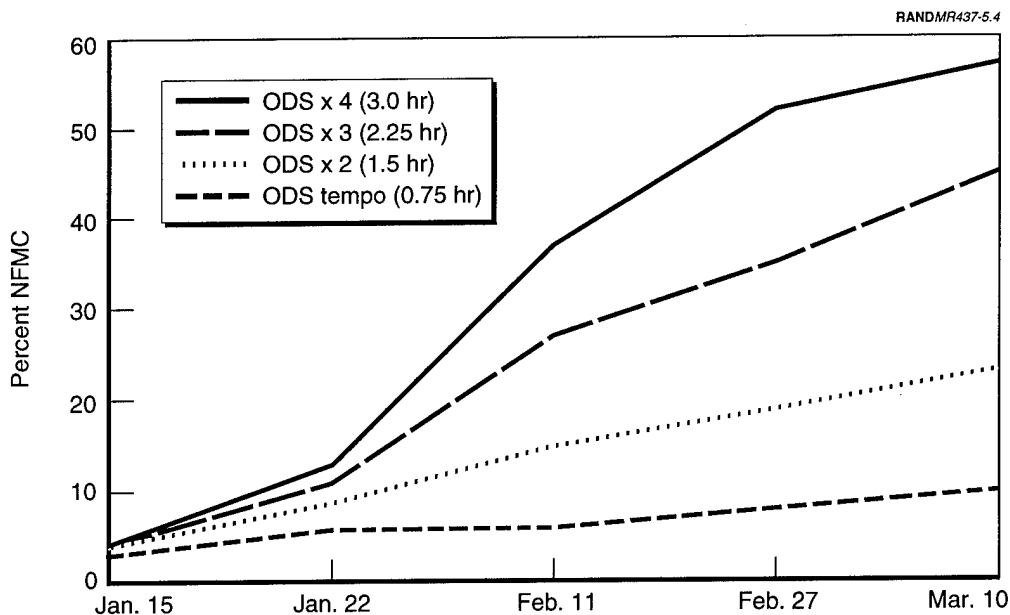


Figure 5.4—TADS/PNVs Sustainability with Varying Optempos, Standard Support Structure

¹¹In fact, as will be discussed, there was a special and very sophisticated information system even more capable than TAV for TADS/PNVs, operated by Martin Marietta as part of its overall support operations.

¹²The Martin Marietta Fielded System Status data provided evidence on TADS/PNVs subsystem availability. For three snapshots dates (January 15, February 27, and March 10), an average of about 3 percent of TADS/PNVs subsystems were NFMC.

The three curves above the lowest one show the effect of increases in ODSt operating tempo.¹³ A doubling of the rate in ODSt, to an average of 1.5 hours per Apache per day, would increase the number of NFMFC weapon systems, on February 11 of this scenario, from an average of 3 to 5 percent to between 15 and 20 percent at the worst. Still, 15 percent Apaches NFMFC (from only TADS/PNVS) is well above Army requirements for the helicopter.

Past this point, however, the ability of the standard TADS/PNVS support concept to deliver high availability rapidly breaks down. Had the operation been fought at tempos exceeding 2 hours per day per Apache, there would have been significant losses of combat capability of these systems. At 2.25 hours per Apache per day, NFMFC rates would increase quickly, approaching 50 percent NFMFC by the end of the fighting; at 3 hours per system per day, the loss in capability would continue apace, with almost 60 percent of Apaches NFMFC in the later stages of the fighting.

Potential Weaknesses in the Standard Support Structure

The results argue that the present concept for supporting high-technology subsystems like TADS/PNVS lacks robustness. What are the sources of that fragility? Why would there be such a dramatic drop-off in performance at levels of operation that may well be demanded of these sophisticated weapon systems in future conflicts?

Many of the reasons are the same encountered in the previous cases; some are new:

- Shortfalls in critical spares
- Inefficiency of intermediate repair
- Lack of weapon system sustainment management tools at critical repair facilities like the FRA
- Slow, unresponsive movement of critical items through the intratheater distribution system
- Vulnerability to lack of critical resupply from CONUS.

Shortfalls in Critical Spares. Support begins with stockpiles of spares located with deployed forces. Large operations like ODSt are not expected to have deployed spares sufficient to cover all the needs of the forces (which is why maintenance units and procedures for resupply are also involved). Nonetheless, shortages of spares would be an early and critical problem in supporting more intense operations of the kind considered here.

¹³Operating tempos were increased as follows. Actual operating tempos for TADS/PNVS in Southwest Asia were obtained from another Martin Marietta data system operating in the theater, the Martin Marietta Runtime File. These operating hours were rolled up into their associated units, and a battalion-level operating scenario was laid out as an input for the Dyna-METRIC analysis. Typically, this would be in the form of "1/82 aircraft operate 1.2 hours per day per aircraft from Day 35 of the war until Day 40, after which they operate 0.7 hours per day per aircraft until Day 50," and so on. To test support structure sensitivity to increases in tempo, we simply multiplied operating tempos, so that for the case where tempo is doubled, the 1/82 scenario would be 2.4 hours per day from Day 35 to Day 40, then 1.4 hours per day between Days 41 and 50.

Table 5.6 lays out how shortages of spares might be manifested. It takes as an example an intense scenario, but not the most intense: the 2.25 operating hours/aircraft/day case, or three times the actual ODSt tempo. The table shows the net difference between spares on hand at the start of the operation as of January 15 and the expected number of demands, or removals, of those components across the six weeks of operations.¹⁴ The case from the actual ODSt is given for reference, showing the net difference between spares on hand as of January 15 and the total number of removals for each LRU between January 17 and March 10.

One of the reasons the actual ODSt was supportable, as the table shows, was the rich abundance of spare parts on hand. In fact, virtually all of the 26 LRUs constituting

Table 5.6
Ability of Spares to Meet Demands in
Operation Desert Storm

LRU	Spares on hand Jan. 15 less removals Jan. 17-Mar. 10	
	Actual Desert Storm	Desert Storm Tempo $\times 3$
AND	23	23
ADG	20	-14
BSM	17	-7
CPA	4	-10
DSSA	18	-12
DSSH	27	27
ECS	15	15
GCCA	46	20
IVD	20	-14
LEU	21	-7
LHG	23	23
LTR	25	7
LTU	-2	-38
NSA	2	-72
NSSH	14	14
ORT	24	10
PECA	26	26
PEU	13	-27
PSSH	50	50
PTUR	-22	-136
RHG	28	28
TECA	35	7
TEU	-11	-95
TPS	-1	-37
TTI	11	-23
TVS	-1	-49

SOURCE: Martin Marietta Fielded System Status file for spares and Martin Marietta Fault File for removals.

¹⁴We simply multiplied the actual number of removals in ODSt by three. This resembles an "expected value" solution; in a real contingency, the actual number of removals would likely differ in many ways.

the TADS/PNVs subsystem had sufficient spares on hand before hostilities commenced to cover all theater needs, even without repair or resupply from CONUS. It is no surprise, however, that in a more intense operation, that would not be the case. The table reveals potential shortfalls for more than half of the LRUs. However, even in this more intense operation, almost half the LRUs are completely supportable out of stocks on hand. Most of the potential problems are associated with just a few critical LRUs, principally the night sensor assembly (NSA), the PNVs turret (PTUR), and the TADS electronic unit (TEU). These three LRUs, unfortunately, are also among the most expensive components of the TADS/PNVs system, making a strategy of "stock buyout" extremely costly.

Inefficiency of Intermediate Repair. Intermediate repair is deployed because spares stockpiles would never be considered adequate to support an intense and extended operation of the sort considered here. A substantial intermediate support capability was deployed to the theater for ODSt. In fact, more than doctrinal levels of intermediate repair were sent—whereas the standard support concept for Apaches calls for one EETF to support three Apache battalions (54 aircraft), eight EETFs were in the theater to support the 274 deployed Apaches, or one per 37 aircraft.

Yet there is strong reason to believe that even this abundance of intermediate support would not have sufficed in the more intense kind of operation we consider here. As Table 5.4 showed, the EETF has the capability (in terms of available test program sets) to test almost 80 percent of TADS/PNVs removals. According to our simulation of intense operations, based on performance data from ODSt itself, intermediate repair units relying on EETFs for testing and diagnosis would have been able to convert no more than 25 percent of the carcasses they received to serviceable status.¹⁵ This inability to exploit the EETF's full capacity would put enormous added pressure on higher echelons of repair—the FRA.

Lack of Weapon System Sustainment Management Tools at Critical Facilities Like the FRA. The analysis in this scenario strongly suggests that the FRA would be overwhelmed with work. In the six-week period of high-intensity operation (2.25 hours/system/day), we might expect over 1000 TADS/PNVs removals, with less than 25 percent of them being returned to service at the intermediate level, leaving the remainder to be fixed at the FRA or retrograded out of the theater back to CONUS. The given capacity of the FRA in the theater for the duration of the operation was roughly 300 LRUs,¹⁶ leaving a backlog of about 400 LRUs to either wait for repair at the FRA until some point after the operation or for retrograde back to CONUS.

The FRA would be able to complete fewer than half the repairs forced upon it (mostly by inefficiencies at the intermediate level), with serious consequences for weapon

¹⁵That is, the EETFs would have been able to successfully test no greater a percentage of broken LRUs than was actually feasible in Operations Desert Shield/Storm. The constraint was not available hours on the test stands; other factors affected test stand performance—skill of the personnel, total system capability, availability of repair parts, efficiency of the retrograde system back to the maintenance units, and so forth.

¹⁶The constraint on FRA repair is time on the hot mockup aircraft simulator. Average time per LRU on the simulator is about two hours. Assuming four weeks of two-shift operations and two weeks of 10 to 12 hours a day operation, we estimate FRA capacity at 300 LRUs repaired.

system sustainability. As will be shown below, these kinds of backlogs create problems for workload prioritization. Simply put, not all repairs have equal value. Some items once fixed can quickly bring a weapon system back to FMC status. Other items might fill holes in weapon systems but (as in the OJC examples) cannot by themselves bring up a weapon system that needs more than one LRU. Other LRUs when returned to serviceable status would do no more than fill a hole in a unit's ASL or in theater war reserves.

In fact, current Army systems cannot help maintenance personnel distinguish among these cases so they can focus on the most important repairs. As a result, and absent other means of getting that information, repair facilities like the FRA would be forced to handle their large backlog on a first-come, first-served basis.

Slow, Unresponsive Movement of Critical Items Through the Intratheater Distribution System. Despite changes in Army doctrine about intratheater distribution,¹⁷ the intratheater transportation doctrine has not caught up to changes in the weapon systems the Army now uses or much of the maintenance structure supporting these weapon systems.

The FRA has already been accepted as integral to support of the TADS/PNVS, and was deployed to Southwest Asia as part of the overall plan of Apache support. In addition, other FRA capability was created during Operations Desert Shield/Storm to help support other systems of the Apache, as well as the OH-58 and the UH-60. This additional capability was set up in the United Arab Emirates, some 600 miles behind the front lines. Although this capability was critical to aviation sustainability, it was not deployed as part of an entire package concept that included the transportation means necessary to move items to and from the FRA setup in a timely manner. As will be discussed below, and was the case with so much else, effective adaptations to deal with this problem were made over the course of Operations Desert Shield/Storm. However, had there been no chance to make those adaptations, the utility of these distant support resources might have been significantly reduced.

Before the initiation of the Camel Flight program, to be discussed below, transportation to and from the FRA used standard in-theater channels. Items from the FRA first were transported to Dhahran, where they entered standard theater distribution channels to the forward units and had to compete with all other items being moved forward. Transportation times from the FRA forward to the unit averaged roughly six days.

¹⁷For example, the standard Army logistics field manual describes air distribution as "mak[ing] possible rapid resupply of critical items over extended distances, close to or directly to forward employed units." FM 100-10, *Combat Service Support*, February 1988, p. 9-4. Likewise, FM 55-10, *Movement Control in a Theater of Operations* (Section III, Chapter 10) also ascribes to intratheater air the function of resupply of critical Class IX items over extended distances and retrograde of reparable. However, it mentions use of Army fixed-wing aircraft only in their role of command and control while at the same time expressing reservations about the use of Air Force intratheater lift (noting, for example, that lead times for preplanned requests will be longer than if Army assets are used). No mention is made of possible use of Army assets like National Guard C-23B Sherpas for dedicated movement of high-priority items in a sizable theater. One of the conclusions of our work is that the means of intratheater airlift have to be designated—whether Army or Air Force—and written into doctrine and routinely practiced in peacetime.

Vulnerability to Lack of Critical Resupply from CONUS. In the previous cases, fast resupply from CONUS, such as the OJC Log Birds and the ODS Desert Express, played crucial roles in sustaining the deployed forces. In the specific case we are describing here, with depot-level repair in the form of the FRA deployed forward, that CONUS resupply might play less of a pivotal role. CONUS resupply would still be vitally important, however; it would, for example, be relied on to quickly deliver suddenly needed parts where repair is not handled in the FRA or other in-theater facility. Perhaps more important, Desert Express-like systems could be used to deliver repair parts to forward-based repair as the need arose. These shop replaceable units (SRUs) are the components needed to make LRU repairs. If anything, their levels of demand are more variable than those of LRUs, making predictive stocking and deployment even less of a science. Yet if they are not immediately available when needed, they can delay repair of critically needed LRUs.¹⁸

SOLUTION DIRECTIONS: AN INTEGRATED THEATER SUPPORT CONCEPT FOR LARGE-SCALE OPERATIONS

We next lay out the concept and rationale for a different type of support structure for large-scale contingency operations than that contained in current Army policy. To some extent, this concept adopts the successful adaptations made in Operations Desert Shield/Storm and is, in that sense, not offering anything new. Other concepts are in fact new, and still others are being considered by the Army but are not yet adopted. The purpose of this analysis, in addition to proposing new ideas the Army has not yet considered, is to develop the idea of an *integrated* theater support structure, where the changes offered are part of a total package concept, so that all elements support each other.

There are four principal elements of this integrated support structure:

- Consolidation of intermediate repair in a theater support facility, including integration of intermediate repair facilities with FRAs
- Dedicated intratheater transportation for distribution forward and retrograde of high-technology parts
- Fast CONUS resupply of critical parts, especially repair parts for the integrated theater support facility
- Weapon system sustainment management systems to allocate constrained resources better.

The next subsections will lay out the rationale and structure of this concept.

¹⁸In this analysis, we did not model repair down to the SRU level, mainly because there was little information on SRU stockage in the theater. However, some anecdotal evidence to be given later demonstrates the potential importance of fast resupply of SRUs.

Consolidated Repair Facility

The Army has made major investments in automated test equipment like the EETF, systems that can have capital costs of \$10 million and recurring operating and support costs close to \$1 million a year; the planned new consolidated test equipment, the Integrated Family of Test Equipment (IFTE), may have similar price tags.

Such resources need to be better exploited if the Army is to pursue cost-effective support strategies. At present, they are not very effective either in peacetime or in war, as Table 5.5 showed above.

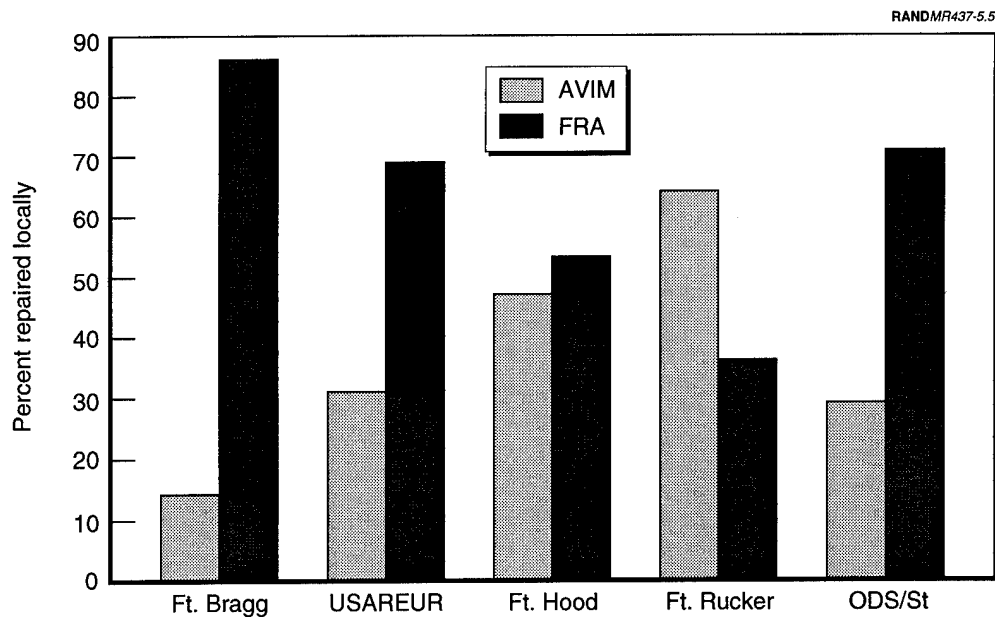
There are many reasons for this less than optimal performance. Isolated test stands are subject to significant downtimes of crucial stations because of lack of repair parts for the stands themselves; substantial NRTSing apparently happens when AVIMs are unable to obtain needed repair parts, or SRUs, for broken LRUs. There is reason to believe that green-suit personnel in organic EETFs simply are not receiving the intensity of experience to make them effective repairers. With their other duties, these personnel may only be producing upward of two direct man-hours of repair a day in peacetime; also, because of the low intensity of peacetime operations, they are not seeing the kind of workload that prepares them to handle all the problems of high-technology repair. As Table 5.5 showed, Apache units have become accustomed to being supported by the FRA rather than the EETF; in some fashion, that system was simply transferred over to the wartime setting. Yet as the preceding analysis showed, such reliance on FRA-only solutions wastes precious resources and puts wartime availability goals at risk.

How Can Logistic Resources Like the EETF Be Better Exploited?

Different EETF Performance at Fort Rucker. The highest operating tempos for Apaches occur at the U.S. Army Aviation Training Center and School at Ft. Rucker, Alabama. Student pilots are run through an intense course to turn them into trained pilots ready for assignment to Apache combat units. The 51 Apaches at Ft. Rucker are put through a punishing schedule, with flying rates on a week-in, week-out basis approaching three to four times those at other active Army bases. (See Figure 5.1.) Rather than meet a readiness goal, the support structure at Ft. Rucker must meet a flying-hour sustainment goal: each day, a certain number of missions must be flown in various mission configurations (night flying, gunnery, and so on). The result is a level of demands not seen for any similar sized support structure in the Apache fleet.

A key to achieving these mission goals at Ft. Rucker is better exploitation of its EETF capability. Figure 5.5 shows evidence of this larger contribution by comparing EETF workload at Ft. Rucker with other Army cases. Almost two-thirds of all TADS/PNVs repairs are accomplished at Ft. Rucker's EETF facility and avionics shop; this is more than double the rate seen in ODS/ODSt and more than four times the peacetime rate at Ft. Bragg.

This exploitation of local resources is most important for those components that tend to drive availability—the NSA, PTUR, and TEU. In ODS/ODSt, these three ac-



SOURCE: Martin Marietta Fault File.

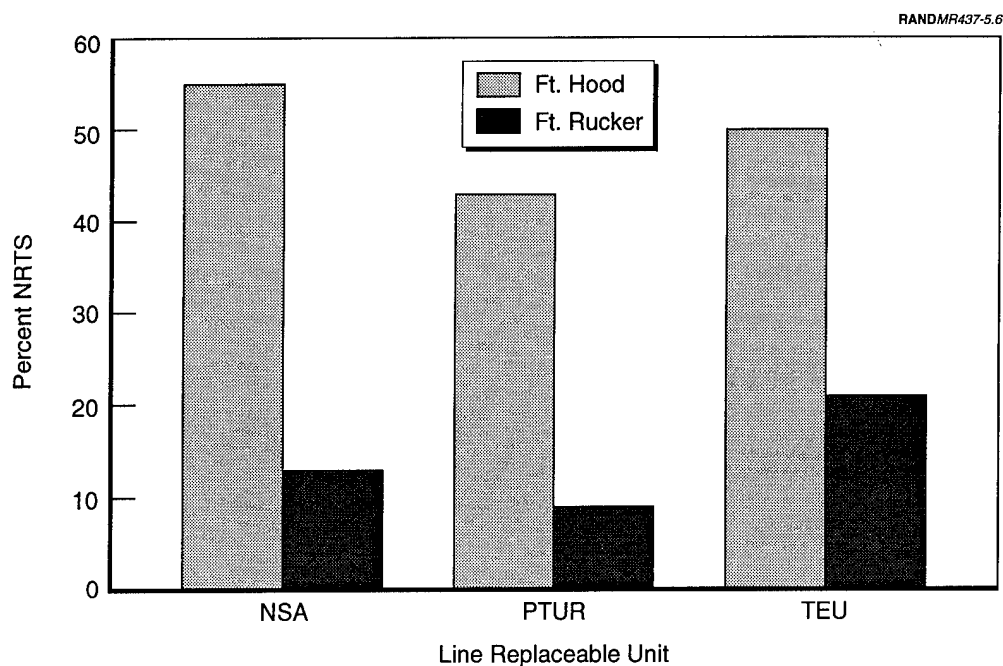
Figure 5.5—Distribution of Repair Workload Between AVIM and FRA by Location

counted for 30 percent of TADS/PNVS removals. In the Ft. Rucker operation, special care is taken to make these repairs in the local shop rather than sending them to the wholesale-level repair facility, the FRA. Figure 5.6 shows the results of those efforts: the great majority of NSA, PTUR, and TEU repairs are done on the base itself, in contrast to the situation at Ft. Hood, even though Ft. Rucker and Ft. Hood have comparable overall AVIM NRTS rates.

Sources of Different Output. The Ft. Rucker structure is based on a different concept of EETF operation than that seen elsewhere. Most visibly, this is not an organic, green-suit facility. It is contractor-run, with civilian technicians operating the EETF and performing repairs.¹⁹ These personnel have no other responsibilities and put in eight hours of direct and indirect repair time each day. Further, the EETF is not van-mounted, as most other EETFs are. Instead, it has been moved into a larger, climate-controlled building and is tied into the electrical power grid rather than relying on its own generator. This facility has been bolstered by another partial EETF, containing the core computer and test package sets but missing its EOB.

This structure yields many advantages. The controlled climate and fixed location boost the overall true availability of the EETF. The presence of a partial additional EETF does much the same by providing sources of repair parts to keep at least one of

¹⁹However, it is not entirely unique. The EETF at Ft. Hood that supports the Apache Training Brigade is also contractor-run.



SOURCE: Martin Marietta Fault File.

Figure 5.6—Comparative NRTS Rates of High-Driver LRUs at Ft. Rucker and Ft. Hood

the test sets operational at all times. The manning structure provides many advantages as well. Personnel become competent at using the EETF and exploit that competence—that is, they are not promoted out of repair jobs once they gain expertise. They work eight hours a day at the same job and see repeated problems, becoming experienced with them and all their possible variations. The very intensity of the Ft. Rucker workload helps familiarize workers in a very short time with diagnostic problems of TADS/PNVS and the EETF.

This expertise has allowed the repair facility to streamline its operation. Since time is often of the essence, diagnostic procedures are often abbreviated by use of “gold cards” (shop-standard SRUs) and by the experienced judgment of the repair technicians. The result is much faster throughput of LRUs on the EETF, as Table 5.7 shows. Especially for critical LRUs (such as NSA and PTUR), much less time spent is on the test equipment at Ft. Rucker.²⁰

The operation of the EETF at Ft. Rucker differs from that anywhere else in the Army and is clearly not “according to doctrine.” Nonetheless, it shows how expensive resources can be exploited to support weapon systems far better than the same equip-

²⁰These shortcuts do not result in lower repair quality. Using the Martin Marietta Fault File dataset, we addressed the question of whether repaired LRUs from the Ft. Rucker facility performed more poorly than those being repaired at other intermediate maintenance facilities. Our analysis showed no significant difference in mean time between removals.

Table 5.7
Comparative On-EETF Test Times at
Ft. Rucker and Ft. Hood

LRU	Time on EETF (in hours) at	
	Ft. Rucker	Ft. Hood
CPA	1.2	0.7
DShrd	1.2	1.2
DSSA	1.7	4.3
GCCA	1.0	2.0
IVD	2.4	8.4
LEU	3.6	3.6
LHG	1.4	1.4
NSShrd	0.5	0.5
NSA	1.9	6.0
PEU	1.7	1.4
ADG	1.0	3.4
PTUR	1.7	8.2
RHG	1.4	1.4
TEU	4.8	4.6
TPS	1.9	2.6
TVS	1.0	2.4

SOURCES: Ft. Rucker: Special RAND Collection, March–September 1989. Ft. Hood: RAMLOG Data Collection, 1987.

ment elsewhere. Chapter Six discusses the implications of a Ft. Rucker–style use of EETFs for supporting TADS/PNVS in wartime.

Concept of a Consolidated Repair Facility. The experience of support in ODS_t and the counterexamples of alternative concepts such as that in operation at Ft. Rucker should lead the Army to consider new doctrines for repair structures. Especially for high technology, writers of doctrine should take to heart the message of TRADOC PAM 525-5, calling for “unweighting selected echelons so that critical maneuver commanders are unburdened logistically and thus better able to focus on the joint and combined arms fight.”²¹

The Army’s high-technology systems do not benefit as much as other systems might from a fix-forward philosophy. While remove-and-replace must be done as far forward as possible and while supply points must remain within fast and easy access of combat forces, there is no clear reason why the repair of high-technology components has to be as close to the fight as possible. Instead, the Army should consider a move to something resembling a robust two-echelon structure for supporting high technology.

We call this modified two-echelon structure a “consolidated repair facility,” or CRF. In concept it is quite simple: remove-and-replace operations occur forward; removed components are evacuated to an accessible centralized facility in which oper-

²¹TRADOC PAM 525-5, *AirLand Operations: A Concept for the Evaluation of AirLand Battle for the Strategic Army of the 1990s and Beyond*, 1 August 1991, p. 24.

ations like the FRA and EETF (and in the future, IFTE) are collocated. That collocation can imply a close distance, walking or short driving distance, or the collocation may be more in terms of management—a single manager who allocates workload among somewhat dispersed repair facilities, sends repair parts for components and test stands back and forth among the facilities, and the like.

The automated test equipment, like EETF and IFTE, may be dismounted from the vans and floor-mounted, depending on the type of contingency. That would, however, make the equipment far less mobile than forward-located repair facilities. Being well out of the combat area, it may be manned differently. Conceivably, the CRF, like the present FRA, could be manned by white-suit technicians, either contractors or Department of the Army (DA) civilians. Or there might be a mix of civilians and green-suit technicians. Alternatively, one might imagine combining both: They could be reservists who fill the CRF in a civilian capacity in peacetime and then are mobilized to man the CRF as soldiers in wartime.

Removing high-technology repair to echelons above corps might be seen as a radical step—one that combat commanders believing in unity of command might resist. We believe, however, that the advantages of such a system would outweigh any such concerns:

- Higher productivity of a higher-skilled workforce
- Better allocation of workload across repair resources to avoid overloading some stands while others are underburdened
- Greater overall test stand availability, through reduced demand for movement and ability to cannibalize stands to support other stands
- Consolidation of workload in one location (or set of locations) to combine the benefits of batch processing repairs and prioritization.

A greater concern for the feasibility of the system is that by removing repair from the combat units, sustainability might be reduced through extended pipelines and the responsiveness of the support system degraded. Clearly, it is critical to keep the pipelines short and to key the support system to the changing needs of the battlefield. In the next subsections, we describe how this can be accomplished through better transportation, both intratheater and intertheater, and through better management systems.

We leave open the question of where the CRF should be, except that it should be removed from the fighting or where frequent relocation is required. One possibility is that it not deploy at all. The Army is attempting to address the problems of distribution as a whole, and not just of the highest-priority items that would use a Desert Express-type system. If the Army's Total Distribution System effort proves fruitful in making the distribution system as a whole more responsive, it may not prove necessary to deploy facilities like the CRF. Instead, the Army can consider high-technology

repair as a candidate for "split operations," in which more support is provided from the CONUS base, even in a large contingency of the type we are considering here.²²

Whether the CRF is located in the theater or in CONUS, the problem of supporting operations from a long distance (such as the 600 miles between the FRA and the front in ODS) needs to be resolved. We discuss that issue next.

Dedicated Intratheater Lift

One of the more interesting adaptations made during the course of Operations Desert Shield/Storm was the Camel Flights aviation parts distribution system.

The Camel Flights were an AVSCOM-organized, in-theater transportation network connecting the Theater Aviation Maintenance Program base location in Abu Dhabi with forward locations in Saudi Arabia and Iraq. The system operated with five Shorts Brothers C-23B Sherpa fixed-wing aircraft belonging to the Connecticut National Guard. This unit was mobilized during ODS, deployed to Egypt for training, and then moved to Southwest Asia. In a somewhat ad hoc manner, it was assigned to the TAMP to expedite forward movement of serviceables and retrograde movement of carcasses from the units to the FRA and other AVSCOM repair resources in the theater.

The Camel Flights played a vital role in enhancing the value of the TAMP and the FRA. With them, delivery time from Abu Dhabi to the forward units was on the order of two days, whereas the time to deliver items through standard in-theater channels was at least six days.

Although high-technology equipment is costly, its demands on the transportation system are in fact negligible, at least in terms of weight and cube. The Army, for example, had thousands of short tons of ammunition shipped to Southwest Asia; by contrast, the transportation demands of high-technology parts is measured in thousands of *pounds*. The total weight of all TADS/PNVS LRUs removed during the nine months of Operations Desert Shield/Desert Storm and the postwar period was approximately 133,000 lbs, or 66 short tons. In the intense Desert Storm scenario we examined here, with operating tempos of 2.25 hours per day, the daily transportation requirement for removed LRUs would be somewhat over one ton. This is about one-third of the maximum payload of a single C-23B Sherpa, itself a very small transport.

High technology requires only the smallest amount of transportation resources, but those resources need to be very responsive. Fast transportation is an exceedingly cheap alternative to buying the expensive spares that long pipelines require and is infinitely cheaper than forgoing the combat capability high technology provides.

²²See Chapter 12, "Logistics," FM 100-5, *Operations*.

Fast CONUS Resupply of Critical Parts

Just as in the two types of contingency discussed earlier, fast resupply from CONUS is vital to successful support of a large-scale contingency operation. The innovation of Desert Express, used in both Desert Shield and Desert Storm, was discussed in Chapter Four. The same type of formalized but quick-reacting operation would be required in the larger theater we are considering here.

How a Desert Express-like system would be employed might depend on the circumstances. In the larger theater case, there is a substantial and highly capable in-theater repair structure; much of the burden of supplying serviceable LRUs can be met from within the theater, either from deployed spares or, more typically, from repair of carcasses at the CRF. With repair and distribution turnaround times of just a few days, in-theater repair would satisfy the needs of the fighting units more efficiently than a fast CONUS resupply operation averaging ten days OST.

However, fast CONUS resupply would still play a valuable role in this larger contingency. First, some repair, especially depot level, cannot be moved to the theater because of the amount of test equipment in the inventory, the size and delicacy of the equipment, and so on. For these non-theater-reparable items, a Desert Express-type capability is vital. Second, in-theater repair is only as good as the repair parts available to it. Repair of LRUs depends on having the right SRUs; furthermore, the test equipment (especially the EETFs) may break down and need its own LRUs or SRUs. It is difficult to judge the demands for these items and thus deploy the correct number. Since in-theater repair of many types of SRUs is difficult, a Desert Express-like system can be valuable for supplying these items in a timely manner.

The experience of the FRA in Desert Storm supports of this. On one of the Desert Express flights, on January 13, 1991, some 111 SRUs, ordered by the FRA on January 4, were sent to the FRA in Abu Dhabi, arriving the next day. These SRUs, which permitted the repair of over one hundred LRUs, totaled 764 lb and 918 cubic feet, or just a few pounds and cubic feet per LRU fixed and aircraft made (potentially) FMC.

Desert Express reduced OSTs from ALOC's 45–60 days to around 15–22 days; we suggested ways in which that might be further reduced to ten days. OSTs might even approach five or so days. If so, a completely different philosophy of support might be possible. The Army could consider true "support from afar" and deploy no intermediate or depot-level repair; the consolidated FRA we describe here might operate out of CONUS itself, no matter where the forces are. This would reduce or eliminate the need for deploying FRA and AVIM equipment, and more combat capability could be sent in their place. Alternatively, a mixed strategy could be pursued, with the more easily deployable EETFs sent, and all demands not satisfiable from intermediate-level support supplied from CONUS. Significant problems in fixing the logjams that afflict the resupply system would have to be fixed to make a truly fast-response

system like this work, but a breakthrough in this area would do much to make the Army truly a highly mobile and potent force-projection force.²³

Future contingencies would benefit by incorporating Desert Express/Camel Flight-type networks operating on standard schedules with daily stops at each location, no matter how small the load for a particular day. By keeping the operation small and separate from the vast mass of other materiel being moved, documentation and visibility issues become easier to handle. And by radically cutting down the total OST through all elements of the process, total spares need can be substantially reduced, with consequent budget savings and potential impact on weapon system sustainability.

However, faster throughput of repair and transportation resources to move assets through and to the theater are only tools; they give no indication of how they should be used. One last vital element of the system is needed—a management information system to act as the “brains” of the supporting network.

Weapon System Sustainment Management Systems

For the past several years, RAND's Arroyo Center has been helping the Army develop new concepts of weapon system sustainment management. Weapon system sustainment management entails changes in structures, roles, organizations, and concepts; it calls for new effectiveness criteria and measures by which systems and individual performance are judged. It also demands new types of information and management systems geared to employing resources in ways to achieve weapon system availability goals. To allow logisticians to exploit their resources, it calls for “seamless” systems that provide visibility of all assets as well as current weapon system status.²⁴

A vital part of these new weapon system sustainment management systems is a decision support tool for better exploiting constrained repair and supply resources. One such tool developed by RAND has been tested by the Army under the name Readiness-Based Maintenance (RBM). RBM, which employs an algorithm known as DRIVE, exploits these resources by establishing prioritization rules for repair and distribution. Thus, not all broken LRUs have equal claim on constrained repair and transportation resources; rather than, say, repairing on a first-come, first-served basis, certain LRUs will be allowed to “jump the queue.” The same goes for distribution. The oldest requisition should not necessarily be the first filled (indeed, it may be the last); rather, the unit most in need should be served first. The concept behind these prioritizing systems is to manage workload so that no resource is wasted. By

²³See, for example, the interview with then-DCSLOG LTG Jimmy Ross, “Army Logistics Chief's Swan Song: New Ways of Doing Business,” *Defense Week*, November 18, 1991, pp. 8–9, and “New Agency Looks to Revamp Logistics After Gulf War,” *Defense Week*, December 2, 1991, p. 8.

²⁴See John Dumond, Rick Eden, John Folkesson, Lionel Galway, and Arnold Levine, *Weapon System Management: An Approach to Improving Business Practices in DoD Logistics*, RAND, MR-336-OSD, 1994; and John Dumond, Rick Eden, and John Folkesson, *Weapon System Sustainment Management: Documented Briefing*, RAND, DB-104-A, 1993.

doing so, weapon system availability will be increased, even with no increase in the resources (repair, spares, transportation) needed to achieve those levels.²⁵

Appendix A demonstrates generally how such systems can benefit weapon system sustainability. It reveals in particular how asset visibility (into the weapon system itself), assured rapid transportation (for both forward and retrograde shipping), and these prioritizing systems can be integrated to greatly increase weapon system availability with few or no additional resources.

BENEFITS OF AN INTEGRATED THEATER SUPPORT STRUCTURE

Parameters of the Analysis

In the following analysis, we replay the ODS_t scenario at operating tempos ranging from the actual 0.75 hours per Apache per day up to 3.0 operating hours per day. This time we substitute the new concept of support outlined above. The central elements of that support concept, as reflected in the Dyna-METRIC analysis, include the following:

- All intermediate diagnosis and repair equipment moved rearward and consolidated under single management, with performance characteristics (test equipment availability, test times, NRTS rates) the same as experienced at Fort Rucker and with the number of EETFs reduced from eight to three.
- An RBM-like prioritizing system employed at the EETFs and the FRA.²⁶
- A dedicated intratheater distribution system, based on the Camel Flight operation employed in Southwest Asia; OST from the consolidated rearward repair center to forward-located units set at two days.
- Prioritized retrograde of urgently needed carcasses located forward in the theater with retrograde time of two days, and 13 days for noncritical carcasses.
- An implied access to resupply from CONUS of critically needed SRUs (not explicitly modeled here).

We hypothesized that an integrated theater support structure could provide higher availability at lower cost. In the following analysis, the structure modeled included

²⁵On RBM, see Patricia M. Boren, K. Isaacson, J. Payne, M. L. Robbins, and R. Tripp, *An Evaluation of the VISION Execution System Demonstration Prototypes*, RAND, R-3967-A, 1991; on DRIVE, see Louis W. Miller and John B. Abell, *DRIVE (Distribution and Repair in Variable Environments)*, RAND, R-4158-AF, 1992.

²⁶We have not tried to illustrate all the capabilities of RBM and Weapon System Sustainment Management (WSSM)-type systems in this analysis. RBM can also proactively schedule repairs and distribution before they are required by units by anticipating what units' future needs are likely to be. We have also only described one type of weapon system sustainment management system. RAND is helping the Army develop and field other types of capabilities, such as the VISION assessment system, which will help logisticians evaluate logistical operational plans and identify the resources they need to support commanders. On the first point, see Patricia Boren et al., R-3967, and on the latter point, see C. L. Tsai, R. Tripp, and M. B. Berman, *The VISION Assessment System: Class IX Sustainment Planning*, RAND, R-3968-A, 1992; and C. L. Tsai, P. Boren, and R. Tripp, *An Initial Evaluation of the VISION Assessment System*, RAND, R-4182-A, 1992.

63 percent less intermediate repair capability (three EETF-equivalents versus eight in the base case) and substantially less stock (reduced 46 percent from the base case).

Results of the Analysis

Figure 5.7 shows the results of the Dyna-METRIC analysis. It represents the number of NFMCApaches (due to TADS/PNVS only) over a fictional Desert Storm supported by the new concept, with operating tempos varying from 0.75 to 3.0 hours per day.

The comparison of the base case (see Figure 5.4) is striking. Where before at the highest tempos Apache NFMCA rates might climb as high as 60 percent by the end of the operation, here NFMCA rates are sustained at no more than 25 percent at the most demanding optempo, and for all lesser cases, the number of Apaches lost to TADS/PNVS would not exceed 10 percent.

Figure 5.8 indicates how parts of the support structure might contribute to this outcome. It divides out the contribution of each element if each was to be added sequentially to the support structure. We illustrate this for one case, with operating tempos set at an average of 2.25 hours per Apache per day.

The top curve represents the base case, assuming support is according to doctrine (with none of the adaptations made during the actual ODS). As shown before, an operational demand of 2.25 hours per system per day would likely result in NFMCA rates approaching 50 percent toward the end of the operation.

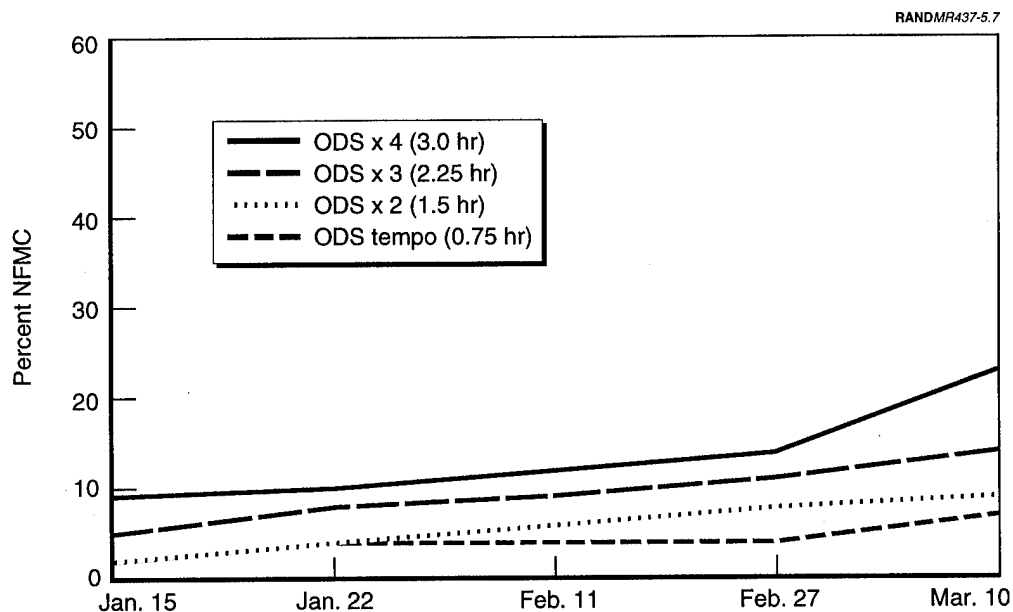


Figure 5.7—Sustainability of TADS/PNVS in Desert Storm Scenario with Varying Optempos: Improved Support Concept

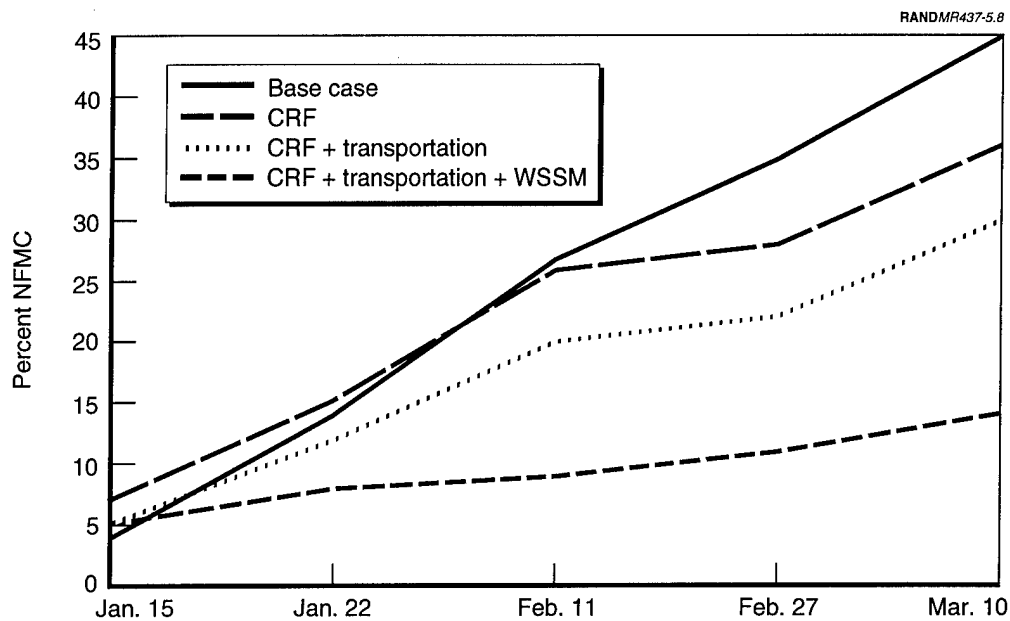


Figure 5.8—Differential Impact of Improving Parts of the Support Structure in a Higher-Intensity Desert Storm (2.25 hr/day)

The next curve below shows the effect of changing the organization and management of intermediate repair. It reflects the benefits of rearward movement of intermediate repair, applying Ft. Rucker performance standards, while increasing retrograde time back to those repair facilities. It also reflects reducing the number of EETFs deployed from eight to three. This change would reduce the number of NFMC Apaches to approximately 30 percent by the end of the fighting.

The next curve represents the effect of adding a dedicated in-theater distribution system based on the C-23 Sherpa experience in ODS. The net effect of this innovation would be to reduce OSTs from the FRA and the consolidated intermediate repair from six days to two days on average. As the figure shows, this would further reduce the number of NFMC systems, to approximately 25–30 percent by the end of the operation.

This last point suggests the importance of an integrated view of high-technology support. Viewed simply as a means of reducing OST forward, an in-theater distribution system might not appear to have much value. However, when used in coordination with other features of this support system, dramatic benefits may be gained.

The last curve on the figure reflects this. It shows the benefit of adding a prioritized repair and distribution system to the CRF, based on an RBM-like system. Here, truly dramatic gains are achieved, with NFMC rates dropping toward the 10 percent level throughout the course of the operation.

This gain can be attributed to several reasons. In part, it occurs because the maintainers can choose among available carcasses to make the repair that does the most

good. In addition, it reflects the weapon system sustainment manager's ability to reach out to the entire theater to get the resources he needs to maximize weapon system capability.

One such resource is the carcasses at the units. With the ability to specify promptly which carcasses are needed and the further ability of the in-theater transportation system to pick them up virtually immediately and return them to the repair facility, the standard retrograde time of 13 days is reduced to two days. Therefore, the joining of asset visibility systems, repair and distribution prioritization systems, and quick-response transportation systems provides a marked increase in the ability of the forces to fight. Moreover, enormous gains in combat capability can be achieved at a cost no greater—and almost certainly substantially lower—than the present system.

Cost Implications of the Integrated Theater Support System

Because of the inefficiencies of the current support concept, seeking higher weapon system availability does not necessarily imply higher costs; indeed, both higher performance and lower costs can be obtained.

Table 5.8 provides evidence for possible cost savings. It shows a zero-based costing of two alternative TADS/PNVs support structures, including spares, intermediate repair, FRA, in-theater transportation, and information systems. Costs are based on a 20-year life cycle, including procurement and operation and support (O&S).²⁷ On this basis, the integrated support concept would be considerably cheaper than the actual support structure deployed to Southwest Asia to support the Apache's TADS/PNVs subsystem. Taking total system cost into account, the savings might be as great as 40 percent.²⁸

²⁷This might be seen as misleading, since the acquisition of EETFs is included in the analysis and in fact all EETFs have already been acquired. EETF acquisition costs are approximately \$10 million per setup and yearly O&S costs are approximately \$1 million. Thus, even if procurement were not considered, the integrated support concept, with three versus eight EETFs, would still be cheaper. We also took into account in this analysis the fact that EETFs diagnose more than TADS/PNVs. (As stated earlier, approximately 50 percent of EETF workload is non-EETF.) In the Dyna-METRIC analysis, the availability of the EETF for TADS/PNVs diagnosis was reduced to half of total EETF time. Since this analysis focuses only on TADS/PNVs, we do not here consider the effect of rearward location of EETFs on support of non-TADS/PNVs high-tech components.

It should be noted that the FRA is possibly considerably overpriced. Much of FRA work—perhaps as much as half—is for modifications and SRU repair; thus, much of the 18-person workforce we cost out in Table 5.8 might not be required to repair the LRUs modeled in this analysis. This might drop the cost of the FRA, for the purposes of this analysis, as much as \$16 million.

²⁸The greatest unknown in this cost analysis is the cost of information management systems like OSC, TAV, and RBM. These will not be insignificant, as they will require hardware and software and the support for them, personnel to acquire data and run the systems, and the necessary training to make the system work. It is difficult to apply a cost here because such systems would apply to many weapon systems across many more units than we consider. Ideally, we would wish to show the cost of these systems amortized to cover just the TADS/PNVs subsystem for just the 274 Apaches. Such information is not available, so we are forced to make our best guess. The figure of \$10 million is a conservative estimate, roughly the discounted 20-year life-cycle cost of the Martin Marietta set of data systems it uses to track TADS/PNVs asset status, repair activity, and subsystem usage. This system is actually more demanding than what we propose for the Army, and the cost shown here is likely to be higher (and higher as well in that it covers all Apaches, not just the slice of the force we model in this analysis).

Table 5.8
Cost Savings of the Integrated Theater Support Concept
(\$ millions)

Support Structure	Base Case	Integrated Support
Stock	48	26
Intermediate repair	8@22.4	3@22.4
In-theater transportation	0	21
Forward repair activity	37	37
Management information system	0	10-20
Total	264	161-171

SOURCES: Robbins et al., R-3768-A (FRA and in-theater transportation); U.S. Army Aviation Center, "EETF Relative Life-Cycle Costs," September 12, 1989 (intermediate repair); Army Master Data File 1993 (stock costs).

NOTE: Intermediate repair, FRA, and in-theater transportation costs are for a 20-year life cycle. Dollars are \$FY1988. For recurring costs, a discount factor of 7.75 percent is used.

SUMMARY: HIGH-TECHNOLOGY SUPPORT ISSUES IN THREE TYPES OF OPERATIONS

This report has illustrated, using evidence from three recent operations, how Army logistics must change to support the demands of the force-projection mission, and especially how the Army's new high-tech weapon systems require more responsive and cost-effective means of support. This chapter briefly summarizes the results of Chapters Three, Four, and Five, while the next chapter draws conclusions and makes recommendations.

SMALLER FORCE, SHORTER OPERATIONS

Figure 6.1 shows in simplified form the basic finding of the OJC analysis. In future small-scale, fast-moving contingencies, deployed high-tech weapon systems will not

RANDMR437-6.1

Operation	Plausible Risk	Reasons Why Cannot Support	System Change Recommended
Just Cause	What if intense fighting lasted longer?	<ul style="list-style-type: none"> • Can't predict needs • Resupply too slow 	Fast U.S. resupply
Desert Shield			
Desert Storm			

Figure 6.1—Supporting Small Operations

be able to rely only on in-theater repair resources for maintaining high system availability. Thus, the Army must develop highly responsive links with the CONUS supporting base and must deliver critically needed components in the shortest time possible. However, the Army must recognize that not all operations should be supported by the same type of resupply mechanism.

The resupply system has to satisfy many functions: deliver items in time to satisfy need, deliver large stocks of materiel without overloading the system and causing delays, and maintain accountability for the supplies. Yet the importance of each of these functions varies by the type of operation. Smaller operations, especially those relying heavily on high-tech weapon systems with precision-guided munitions, will be less mass-oriented. Fast-moving operations will put a premium on responsiveness over accountability, or at least timely accountability (assuming the books can be straightened out later). Therefore, the Army must modify the resupply system—or *tailor* it—to fit the needs of particular operations.

We argue that small, short operations like OJC could profit from a resupply operation tailored to move critical supplies through more informal channels, such as email/phone/fax delivery of requisitions to special operations centers, and direct delivery of items from any convenient source, including the production line or the home base.

Such a system will work only if the operation is small. Past a certain scale, this informal system would become overloaded and more formal systems for support become necessary.

MID-SCALE OPERATIONS

Two characteristics typify a mid-scale operation: large enough scale to make more “personalized” support solutions unwieldy, and probable lags between the deployment of combat forces and the support network they depend on. As was the case in small-scale operations, fast and responsive resupply is a must, but the system needs to be formalized. In addition, if full logistic resources cannot be deployed in time, all available in-theater resources must be exploited to the maximum through use of new and sophisticated management information systems. Figure 6.2 summarizes these results and relates them to those for small operations.

LARGE-SCALE OPERATIONS

Figure 6.3 summarizes the results of the Desert Storm–based analysis and links them to the previous cases. We see that a large, demanding mission like ODSt presents many more complexities (and therefore more areas demanding improvement) than the earlier simpler operations. Many of the solution directions are similar—the need for fast transportation and asset visibility systems. Others arise from the high level of demands of this kind of operation: integration and full exploitation of all repair resources.

RANDMR437-6.2

Operation	Plausible Risk	Reasons Why Cannot Support	System Change Recommended
Just Cause	What if intense fighting lasted longer?	<ul style="list-style-type: none"> • Can't predict needs • Resupply too slow 	Fast U.S. resupply
Desert Shield	What if fighting had erupted in mid-September?	<ul style="list-style-type: none"> • Limited repair • Resupply too slow • Spares imbalances 	Asset visibility and lateral distribution
Desert Storm			

Figure 6.2—Supporting Mid-Scale Operations

RANDMR437-6.3

Operation	Plausible Risk	Reasons Why Cannot Support	System Change Recommended
Just Cause	What if intense fighting lasted longer?	<ul style="list-style-type: none"> • Can't predict needs • Resupply too slow 	Fast U.S. resupply
Desert Shield	What if fighting had erupted in mid-September?	<ul style="list-style-type: none"> • Limited repair • Resupply too slow • Spares imbalances 	Asset visibility and lateral distribution
Desert Storm	What if operating tempo was higher?	<ul style="list-style-type: none"> • Resupply too slow • Insufficient spares • No prioritization of repair • Unproductive intermediate repair • FRA overwhelmed 	Integrated theater support

Figure 6.3—Supporting Large-Scale Operations

The main conclusion is that support for high technology in large-scale, high-tempo operations must be *highly responsive* and *integrated*. A common characteristic of support for high technology in all operations is the need for the system to respond as quickly as possible to needs as they emerge: both the quickly moving nature of the operations and the limited number of high-technology resource make this responsiveness necessary. In large operations, integration becomes particularly important. Supply, transportation, and maintenance must be considered as alternative strategies in one overall support package. Fixing one functional stovepipe of a support system will bring little overall improvement. Faster turnaround of repair will be most beneficial if OSTs are brought down; in addition, the concept of the FRA (or the more ambitious CRF introduced here) can best be exploited if retrograde is improved. An integrated, responsive support system blurs the distinction between a broken LRU coming out of a weapon system and a serviceable component sitting on the shelf: only a few days may separate one from the other. This means that transportation and repair (and the management of those resources) can substitute for the stocks of high-technology spares that are becoming less and less affordable to the Army.

The analysis of Operation Desert Storm also supported recommendations for unweighting the forward echelons by removing maintenance resources and merging them into a theater-level repair facility. It also suggested that if sufficient advances are made in improving the DoD distribution system, the possibility of split operations be extended to maintenance, and that little or no intermediate/depot-level high-tech repair be deployed at all.

IMPLICATIONS FOR A GENERAL LOGISTICS STRATEGY

The analyses of three recent operations point to support solutions configured to specific needs. Each operation will always be unique. The needs of an Operation Provide Comfort or an Operation Restore Hope will in turn differ in some degree from what we have discussed here.

The Army needs to be able to develop dedicated types of support packages (including resources, procedures, and training) for each kind of operation that lies along the force-projection spectrum. The details of each support package will depend on the characteristics of the specific mission.

Underlying these plans, however, must be a common philosophy of how the Army intends to support its forces, especially its high-value high-tech weaponry. These analyses have touched on some common themes. In Chapter Seven, we discuss these themes in the context of a philosophy of support we call "precision-guided logistics."

In this final chapter, we argue that a common philosophy underlies the solution directions for supporting various types of operations. We believe this philosophy stands in contrast to much of the previous practice of Army logistics, enough so to demand a new name. Consciously alluding to the revolutionary effect that precision-guided munitions (PGMs) have had on warfare, we call this philosophy of support "precision-guided logistics," or PGL.

PGMs marry technology and information to new doctrine and types of command and control; the end result is far greater lethality at vastly less expenditure of resources. PGL is intended to do much the same thing. Its essence derives from four fundamental principles.

FUNDAMENTAL PRINCIPLES OF PRECISION-GUIDED LOGISTICS

Substitute Information and Speed for Mass

Logistics resources are becoming too expensive to be carried to the battlefield in mass—in terms of the dollar costs of increasingly expensive spare parts, in terms of the time to deploy to theater, and in terms of the burden they put on theater infrastructure for moving and accounting for them. Perhaps even more to the point, much of that mass is not even needed or used.

As Army Chief of Staff GEN Gordon Sullivan has argued, America's military must move from an *industrial-age* to an *information-age* basis: "Speed and precision are becoming the dominant requirements of the battlefield."¹

If logisticians can generate, maintain, and exploit the necessary information to make sure reduced resources are used as efficiently as possible, mass can be greatly reduced at no loss in combat effectiveness and sustainability. We have given several examples in which, by better use of information, the responsiveness and robustness of logistics support can be increased, at reduced cost.

¹GEN Gordon Sullivan and COL James Dubik, "War in the Information Age," *Military Review*, April 1994, p. 57.

Emphasize Fungible Resources

One way mass can be reduced is by relying on more-robust mechanisms. A spare part, for example, can only replace the same broken part. A repair station can fix many types of broken parts, and a dedicated express distribution system can move any number of parts quickly and can access stores of parts from many sources, inside or outside the theater.

Given the uncertainty of combat and the unpredictability of demands, greater emphasis must be put on acquiring the resources that can help cover that uncertainty, such as more-responsive repair and transportation, and less on static resources, such as stockpiles of spare parts.

Recognize Time as an Enemy

Rapid response in a wartime environment is a fundamental necessity for support structures. Delivering masses of supplies after the battle or operation is over, or to a location that the unit has long vacated, is worse than useless. In a reduced-resource environment, all items are critical, but their value is subject to how time is used. A \$200,000 LRU that has just failed has no value—but it may be only two days away from being made serviceable again and just as useful as a spare in an ASL, *if* retrograde, repair, and forward distribution are responsive enough. While the business practice of “just in time” may not be fully applicable to a wartime environment, its critical underpinning of speed of movement is fundamental to logistics support.

Configure Support to the Operation, and Reduce the Tail

A major conclusion of this report has been that in logistics for force-projection operations, one size cannot fit all. Different missions will require different forms of support—packages of differing sizes as well as rules and practices that will vary by type of mission. The Army needs to be creative in designing support packages for the various types of operation along the spectrum of possibility, writing them into doctrine, and practicing them in peacetime. We have suggested how packages might be configured for different operations.

No matter the type of operation, the need for reducing the tail will always persist. Burdens on limited strategic lift and the difficulty of building a theater infrastructure, often from scratch, will limit what can be sent over. Deployed elements will have to be as productive as possible, such as the consolidated repair facility we explored in Chapter Five, even if commanders have to deemphasize lesser needs, such as the ability of repair to follow combat units as they move (instead, the distribution network can follow them as they move). Increasingly, support will need to be provided by the resource base left behind in CONUS; the useful concept of “split operations” should be expanded to include not only information management but repair and a larger role for strategic resupply as well.

PRECISION-GUIDED LOGISTICS AND ARMY DOCTRINE

The core characteristics underlying Army logistics doctrine remain those enunciated in FM 100-5: *anticipation, integration, continuity, responsiveness, and improvisation*.² While we believe that the Army's adoption of a new philosophy of logistics, here called precision-guided logistics, will entail many changes in current practice as well as in the specifics of logistical doctrine, we also believe that the concept is based squarely on the Army's fundamental doctrinal principles.

Anticipation

According to FM 100-5, from a logistical perspective *anticipation* "means identifying, accumulating, and maintaining the assets and information necessary to support operations at the right times and right places . . . [and] developing logistics capabilities that are versatile and mobile enough to accommodate likely operational or tactical events."

A new vision of Army logistics demands anticipation in place of open-ended surge. Logistical planners must consider what support packages should be created for what types of missions and what slices of support need to accompany smaller deployments; capabilities that will be needed in wartime (such as specialized requisitioning of critical, expensive items and fast resupply of critical items) need to be designed and practiced in peacetime. A gap exists between current and highly elaborate planning down to fine detail for scenarios that will not unfold as planned and the unplanned activity that takes place at the start of operations: the ferocious surging of capacity, sometimes with little consideration of the actual needs of the operation, and the massive pushing of materiel to the forces (and their open-ended requisitioning of "just in case" materiel) that as often as not plays no greater role than to clog up distribution channels. Recent experience has shown Army logisticians to be wonderfully adaptive in solving problems as they occur during deployments, but better anticipation could reduce the need for such ad hoc changes to logistical procedures.

Integration

FM 100-5 refers to "fully integrated concepts of logistics and operations." PGL means that and more. Logistics must be integrated with the operational plans of combat commanders or the logisticians will not be able to do their job of supporting the fight. The logistician must be able to anticipate combat needs based on expectations of future operations, whether during peacetime planning or during the heat of fighting itself.

With PGL, the concept of integration goes beyond this. PGL calls for the integration of all parts of the logistic structure that support the same goal. It seeks to tear down the functional stovepipes that lead, at best, to local efficiencies but may do little to

²Headquarters, Department of the Army, FM 100-5, *Operations*, June 1993, Section 12. The quotes in this section from FM 100-5 come from pp. 12-3 through 12-5.

accomplish the overall goal. PGL seeks integration through better information management and overall direction and control of logistics processes. It seeks to assess the performance of the logistics structure at any point in its accomplishment of a goal and balance resources to aid that goal's achievement. So, for example, it looks upon a carcass residing at a unit in terms of its contribution to the warfighting effort: Should it be retrograded quickly? How quickly should it be repaired? What contribution will it make to weapon system availability? How quickly can it be turned into a serviceable that can be delivered to a unit in greatest need of that part? That is, no element of the system, down to that carcass, sits in isolation from any other part of the logistics system. It is, indeed, a "system" in which all parts relate to a common whole and each part, if used properly, can contribute to the overall system's goal.

Continuity

According to FM 100-5, "continuity of support is the lifeblood of combat operations at all levels Continuity means adapting to changing missions and priorities quickly and adjusting to temporary or permanent losses"

In the view of PGL, continuity requires that the system be robust. Units that lack needed supplies must be able to get them the quickest way, such as from neighboring units. Overloaded repair facilities must be able to maximally exploit their limited resources through such means as prioritization of repair (and distribution); access to precious transportation resources (like a Desert Express) must be carefully restricted to only the truly needed so that they do not become overwhelmed, yet at the same time the system must continue to respond quickly.

Responsiveness

Referring to logistic *responsiveness*, FM 100-5 declares that "the logistics system must react rapidly in crises Logistics commanders and staffs must adapt units to requirements, often on short notice. Tailoring organizations will be the rule."

Responsiveness is the true heart of PGL. Its fundamental concept is delivering the right thing to the right place at the right time. Knowing it will always be limited to the materials at hand, the Army must use them wisely—first knowing what the true needs of the field are and then making sure they arrive when needed. Responsiveness above all implies information: the knowledge of what the needs are now and what they are likely to be, what resources are available, and how they should best be exploited. Responsiveness implies integration: the ability to tie all parts of the logistics system together to funnel materiel to those in need.

Improvisation

FM 100-5 discusses logistical *improvisation* in terms of "the talent to make, invent, arrange or fabricate what is needed out of hand."

In the PGL world, this implies the need for flexibility. No planning will ever be perfect; no practice in peacetime will ever prepare logisticians for the challenges of a specific operation. Support will have to be configured for the operation and reconfigured as demands change. But again, this implies the use of information and responsiveness and integration. Logisticians must know what the problems of the theater are to improvise new solutions; they must have a complete view of the situation, including all available logistics assets, to make those adaptations useful; they must be ready to adapt any part of the structure from the forward-based support unit to the depot back in CONUS with an understanding of how this will benefit the deployed forces. A flexible system must be lean; too much mass will lead to inertia.

LOGISTICS FOR THE NEW WORLD

Three elements have combined to spark a need for a new concept of logistics: costly high-tech weapons, each one a precious resource for the combat commander; the demise of a standard threat and its replacement with a world of unpredictable operations; and a greater focus on the combat value received for each dollar spent. The solution to this challenge of designing new methods of providing support is to develop an integrated yet flexible concept of logistics.

Much of what the Army has been doing is squarely on track, despite natural growing pains. The development of Total Asset Visibility, Objective Supply Capability, and In-Transit Visibility; the growing emphasis on premium transportation, both in peace and during operations; and the expediting of repair for critical high-tech items, as represented by the FRA, are all steps in the right direction.

What the Army still needs is the means of integrating these innovations, and others, into a single concept or structure of logistics that can guide the provision of support into the next century. This report has attempted, through case study analyses and extraction of the principles underlying those analyses, to contribute to the debate over what should guide Army logistics doctrine, policy, and practice.

ILLUSTRATION OF REPAIR PRIORITIZING SYSTEMS

In Appendix A, we illustrate how a readiness-based maintenance (RBM) system provides its benefits; how it is intimately tied into other ongoing Army initiatives such as TAV; and how it could be expanded to make it even more capable—for example, by prioritizing retrograde movement of carcasses.

The key to RBM is matching limited resource capacity against needs that threaten to overwhelm those resources. The system first must know what those needs are. A system like TAV provides that information. If modified properly for high-technology subsystems, the system should be able to examine the weapon system and show what is there and what is missing, a valuable asset in wartime. Figure A.1 shows a snapshot of a TADS/PNVs subsystem status report for a particular Apache during

RANDMR437-A.2

TADS/PNVs FIELDed SYSTEM STATUS DISPLAY SPECIFIC SYSTEM						
TADS SYSTEM 4027 PNVs SYSTEM 264 PV NO. 189 TAIL NO. 85-25368						
DATE 02/27/91 Location 1/227 AHB HOOD DEP						
A/C STATUS XL SYSTEM STATUS XT NOTES TEU REQ						
Part	Serial	Status	Part	Serial	Status	
TTI	76180	273	ORC	74259	10023	
ECS	76018-019	97	CPA	75988-019	249	
BSM	75454-019	213	LHG	75975	356	
TECA	76208-029	4033	RHG	75976	104	
DSSA	76144-019	4107	AND	76309	233	
DSSH	76090	178	IVD	74292-029	263	
LTU	79020	138	TEU			
LTR	77510	224	LEU	79400-019	472	
TVS	7639	234	TPS	75523-039	4272	
GCCP	76378	100178	PTUR	80250-029	200	
GCCY	76378	100504	PSSH	80400	137	
GCCR	76378	100470	ADG	80423	209	
NSA	76056-029	74	PEU	80410-039	219	
NSSH	76080-019	193	PECA	80399	226	
Location Limit			Press any key to continue		ESC to Quit	

Figure A.1—Example of Asset Visibility During Operation Desert Storm from the Martin Marietta Fielded System Status Report

ODSt. It shows the absence or presence of LRUs in the weapon system and identifies them by serial number and configuration.

For illustration, we will assume a more streamlined view of asset needs in the fighting force. Table A.1 shows a snapshot of unit needs on February 27 in a more intense ODSt.¹ In a somewhat simplified version of what would really be shown, it presents the number of TADS/PNVS systems not fully mission capable (NPMC) at each unit, and shows how those holes are allocated among aircraft. Note that some aircraft have one hole in their TADS/PNVS system while others have as many as five. We assume that units practice controlled substitution and thus will consolidate holes on NPMC aircraft to maximize the number of systems at the unit that can be made FMC.²

Consolidating maintenance resources and reducing in-theater OST would provide dramatic gains: On February 27, some 50 out of 224 Apaches, about 22 percent, would be NPMC, which is substantially better than the performance of the standard system as shown in Figure 5.8, but is still far worse than the NPMC rates below 10 percent achieved in the actual ODSt.

How could an execution management system like RBM help make support more responsive?

RBM achieves higher weapon system availability with no additional resources simply by better management of what exists. To understand how this works, consider the following example.

Table A.1 shows the systems down for particular LRUs, ordering them by ease of solution; that is, it lists them in each unit by number of holes in the TADS/PNVS system. Altogether, there are 50 TADS/PNVS systems that are NPMC because of 81 missing LRUs. A weapon system sustainment manager could make straightforward decisions simply by using this table. If he or she had a single spare TPS to allocate, one of four Apache TADS/PNVS could be made FMC in the 2/227 AHB or the 2/229. (Ten other Apaches are also missing TPSs, but since they are missing other LRUs as well, giving them the TPS would not make them FMC.) The manager might most profitably send the TPS to the 2/229, as the 2/227 already has 16 of 18 TADS/PNVS systems FMC, while the 2/229 only has ten of 18.³

¹The following analysis is based on an average optempo of 2.25 hours/day/Apache where repair has been consolidated under a single manager in a CRF and assured fast transportation is available. The results of the Dyna-METRIC analysis of this particular case (that is, without prioritization) can be seen in Figure 5.8. The pipeline contents were derived from the pipeline computation feature of Dyna-METRIC, Version 6.3.

²For example, the 1/1 AHB, in this illustration, has two Apaches NPMC for TADS/PNVS: one is missing a TEU, and a second is missing a TEU, LTU, and TPS. This unit has had two more TEU removals than can be provided from unit spares or from resupply. To make other Apaches FMC, an LTU and a TPS have been cannibalized from one of them. The 3/1 has three Apaches NPMC for TADS/PNVS, all missing a TEU. To make other Apaches FMC, the unit has cannibalized two TVS, an LTU, a PEU, and a TPS from these aircraft, consolidating the holes on two aircraft.

³In this simplified example, we do not take into account the problems of configuration control. That is, LRUs that have had modifications or were produced at different times may not be compatible on all TADS/PNVS systems. The Martin Marietta Fielded System Status database, as illustrated in Figure A.1, provides that information, and can help the manager determine if the spare TPS on hand would be useful for the NPMC Apache in the 2/227 or 2/229.

Table A.1
Illustration of Aircraft Missing TADS/PNVs LRUs (February 27, Hypothetical Desert Storm)

Unit	No. NFM	NFM TADS/PNVs Systems, Rank-Ordered by Number of Holes								
		1st	2nd	3rd	4th	5th	6th	7th	8th	9th
1/1	2	TEU	TEU, LTU, TPS							
2/1	3	PTUR,TEU	PTUR,TEU	PTUR, TEU						
2/6	9	PTUR	PTUR	PTUR	PTUR	PTUR	PTUR	PTUR	PTUR	PTUR,ORC
3/1	3	TEU	TEU, TVS	TEU, TVS, LTU, PEU, TPS						
2/227	2	TPS	TPS,TEU							
4/229	2	PTUR	PTUR,TPS,TEU							
1/3	4	NSA	NSA	NSA	NSA,BSM, PTUR					
1/82	0									
1/24	1	TEU								
1/101	5	PTUR	PTUR	PTUR	PTUR	PTUR				
2/229	8	TPS	TPS	TPS	TPS,PTUR	TPS,PTUR	TPS,PTUR	TPS,PTUR, TEU	TPS,PTUR	TPS,PTUR TEU
1/227	5	PTUR	PTUR	PTUR	PTUR	PTUR,LTU,RHG				
5/6	2	NSSH	NSSH,NSA, PEU,PTUR,TPS							
3/227	4	PTUR	PTUR	PTUR	PTUR,NSA,LTU					

Table A.2 takes the next step in prioritizing the workload. Starting from 50 systems down for 81 LRUs, it shows that 32 can be made FMC with only 32 LRUs. Nine more TADS/PNVs systems can be made fully mission capable by repairing and distributing 18 LRUs, and seven more systems require three LRUs each. Thus, 71 LRUs will make 48 of the 50 NFMC TADS/PNVs systems FMC; the remaining ten holes if filled will bring up only two systems.

This then brings us closer to an effective prioritization of repair and distribution. The first LRUs to be fixed and distributed to fill holes at units include the 21 PTURs, four TPSs, three TEUs, and so on.

Table A.3 shows the status of resources that can be applied to those needs. It presents a TAV-like snapshot for all uninstalled carcasses in the theater on February 27 of the contingency. Note that for all TADS/PNVs LRUs, some 28 have been fixed at the CRF and are in forward movement to supply points and units, 245 carcasses are at some stage of retrograde back to the CRF, a process that takes (as in ODSt itself) some 13 days on average; and finally, there are 62 carcasses presently at the FRA, either in the queue or in work.

Out of 335 uninstalled LRUs in the theater, either carcass or serviceable, only 71 match the immediate needs of the combat units and deserve the logistician's attention. What is the status of those needed 71?⁴

Table A.4 draws information from the previous table for these critical LRUs. Nineteen of the needed LRUs are in forward pipelines to units (note that one LRU—a TVS—is in excess of current holes). Presumably, either a prioritizing distribution

Table A.2
Rank Order of LRU Demands to Increase Number of FMC Systems

1 LRU Is Needed	2 LRUs Are Needed	3 LRUs Are Needed
21 PTURs	7 PTURs	5 PTURs
4 TPSs	5 TEUs	4 TEUs
3 TEUs	4 TPSs	4 TPSs
3 NSAs	1 ORC	3 LTUs
1 NSSH	1 TVS	2 NSAs
		1 DSSA
		1 BSM
		1 RHG
32 LRUs to make 32 systems FMC	18 LRUs to make 9 systems FMC	21 LRUs to make 7 systems FMC

⁴For this analysis, we ignore the ten LRUs needed to bring the remaining two TADS/PNVs systems up to FMC status. In reality, it might be better to ignore them as well. In the time it would take to repair and distribute those ten LRUs, it is quite possible that other Apaches would become NFMC for TADS/PNVs for which those ten LRUs could be used to bring substantially more than two systems back up. Only if capacity caught up with demands caused by holes in weapon systems would it be worthwhile to spend much effort filling holes in weapon systems on which so much cannibalization has occurred. At that point (if optempos have decreased for a period), it may be possible to direct repair toward filling holes in shelves in the ASL; in that case, the analysis would be different from that presented here, and would focus more on anticipated future operations and likely demands resulting from those operations.

Table A.3
Location of Uninstalled TADS/PNVS LRUs
(February 27, hypothetical Desert Storm)

LRU	Serviceables En Route	Carcasses in Retrograde to FRA	Carcasses at FRA
ADG	1	7	2
AND	0	0	0
BSM	0	10	2
CPA	0	1	0
DSSA	0	10	2
DS shroud	0	0	0
ECS	0	3	1
GCCA	1	9	2
IVD	2	14	2
LEU	3	8	5
LHG	0	0	0
LTR	0	0	0
LTU	0	12	2
NSA	3	23	3
NS shroud	0	2	1
ORC	1	8	5
PECA	0	2	0
PEU	0	14	7
PNVS shroud	0	0	0
PTUR	8	41	12
RHG	0	8	0
TECA	2	10	3
TEU	3	28	5
TPS	2	15	4
TTI	0	8	4
TVS	2	12	0
Total	28	245	62

Table A.4
Prioritization of Workload and Retrograde to CRF

LRUs Required	Serviceables in Theater	Carcasses at the CRF	Carcasses in Retro to CRF	Expedited Retro Required
33 PTURs	8	12	41	13
12 TPSs	2	4	15	6
12 TEUs	3	5	28	4
3 LTUs	0	2	12	1
1 RHG	0	0	8	1
5 NSAs	3	3	23	0
1 NSSH	0	1	2	0
1 ORC	1	5	8	0
1 TVS	2	0	12	0
1 DSSA	0	2	10	0
1 BSM	1	2	10	0

tool, like RBM, or a prioritizing lateral resupply tool, like OSC, could then direct those LRUs to the units where they were most needed (e.g., one PTUR to a unit where one PTUR would bring up an NFM system).

Twenty-seven of the needed LRUs could be found at the CRF, as carcasses waiting for repair. Obviously, these carcasses are the CRF's highest priority; they should be put at the front of the queue of 62 total carcasses awaiting repair at the FRA (see Table A.3).

Note, however, that not all 71 demands can be satisfied either from existing spares or carcasses available at the CRF. With an output of between 15 and 20 LRUs a day, the CRF can repair these 27 in slightly under two days; with OSTs of two days, in just a few days a large number of TADS/PNVS systems will be fully operational again. Then the CRF will have run out of priority work. It can proceed to repair other items waiting in the queue, but these LRUs are not needed to bring up downed systems; they can only fill local stocks and ASLs. This is a far less effective use of scarce repair time at the CRF.

Worse yet, not having the needed carcasses on hand greatly diminishes the number of systems that can be made FMC. This can be clearly seen in the case of the PTUR. Thirty-three PTURs are required among the total of 71 LRUs; there are 20 readily available (eight serviceables and 12 carcasses at the CRF). Those missing 13 alone mean that 13 TADS/PNVS systems will not be made fully operational.

Now the situation is that only 37 of 50 system can be made FMC, and the CRF will run out of high-priority work in about two days. How can this situation be improved?

An attractive solution is expedited retrograde. To bring the 48 systems up, a certain number of carcasses could be retrograded to the CRF: 13 PTURs, four TEUs, six TPSSs, and one LTU and RHG each, for a total of 25 carcasses altogether. These 25 carcasses constitute 10 percent of the 245 carcasses spread out among units and other intermediate points. Expediting retrograde of these carcasses would help ensure that 12 more systems could be made fully operational.

Expediting retrograde has long been part of soldier training. Maintenance personnel know the importance of expedited retrograde and are constantly encouraged to practice it.⁵ Nonetheless, retrograde remains a serious problem, both in peacetime and wartime. In peacetime, the average retrograde time from the unit to the FRA is 20 days (with a median retrograde time of seven days). At Ft. Bragg, the average retrograde time is 42 days, with a median of 31 days. (At Ft. Rucker, which depends more on the FRA to maintain its high flying tempos, the median retrograde time to the FRA is four days.) By comparison, improvements were made in ODSt, where retrograde time to the FRA averaged 13 days.⁶

⁵For example, see "The Turn-In Caper," *P.S. Magazine*, No. 440, July 1989, pp. 27-34. The advent of stock funding of depot-level reparable has probably increased the speed of retrograde in peacetime (though not always, as units may explore alternatives to depot-supplied spare parts). It is not so clear that the same pressure will apply in wartime when financial accounting rules are different.

⁶Peacetime retrograde numbers from the Martin Marietta Fault File data system, 1985-May 1990; the ODSt figure is from the same data system in Southwest Asia during the war. Interestingly, the retrograde times were virtually the same in Desert Shield and Desert Storm.

Yet 13 days is not necessarily good enough, especially in a case like the one above when it means that vital and limited repair resources have no priority work, possibly for many days. Can't the retrograde time be shorter, say on the order of two days?

In fact, it can be. And the key is to realize, as implied above, that not *everything* requires expedited retrograde. In the above case, only 25 items—10 percent—of the available carcasses needed to be sent back to the CRF in two days or fewer. The evidence from ODSt suggests that is well within the bounds of possibility.

Figure A.2 shows the distribution of retrograde times for LRUs sent back to the FRA in Abu Dhabi during ODSt. Note that while indeed the overall average is 13 days, many LRUs made the trip back in considerably less time. In fact, some 15 percent of the carcasses were retrograded in five days or fewer.

Once again, the issue is prioritizing scarce resources. Typically, certain carcasses will arrive back earlier than others; what is important is that the *right* ones are retrograded early. The problems of slow retrograde are not fully understood; it is not clear what the constraints are (i.e., why not simply send all carcasses back when they break?). It could be that there is limited space on returning transportation; it could be a scarcity of packing containers; it could be that forward maintainers are too pressed for time to move every carcass back as they receive it. It could be that peacetime experience has conditioned the maintainers to feel that retrograde and repair are too slow to affect the supply of parts in a pressing situation.

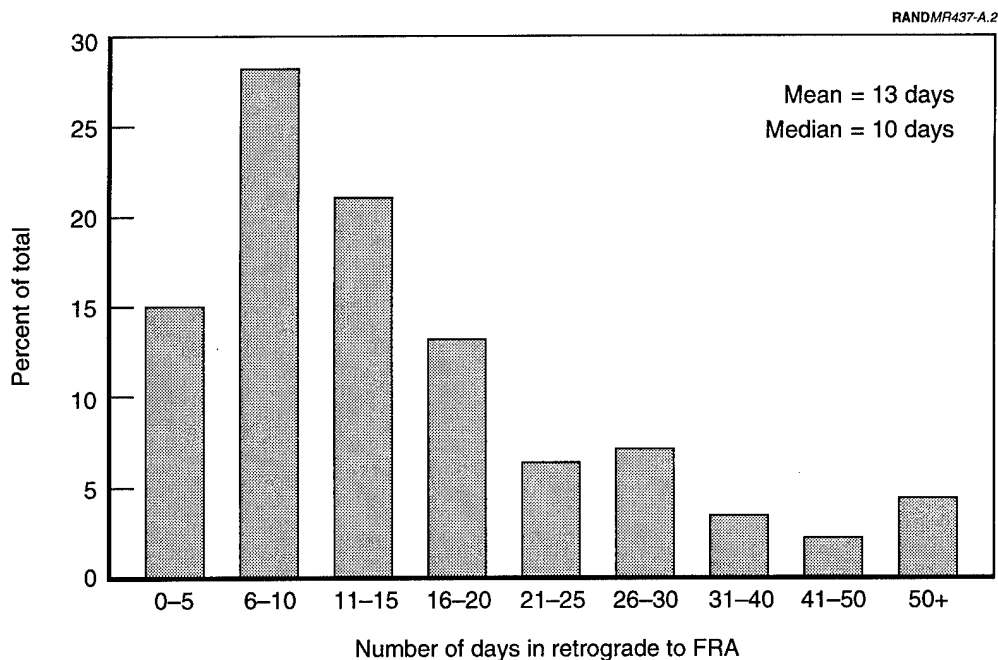


Figure A.2—Distribution of Retrograde Times to the FRA in Operation Desert Storm

A prioritizing system would ease those constraints. It would simply use the capacity of the system as is (e.g., 15 percent of LRUs retrograding in five or fewer days) but direct which LRUs those would be. A version of TAV with RBM-like capabilities could be used. The CRF manager would contact the possessor of a carcass and request that he expedite its retrograde. Indeed, this will probably occur down to the serial number, an important factor when questions of interchangeables and substitutables arise.

This capability has not been posited for execution systems (like RBM) or visibility systems (like TAV) before. Yet it is a crucial part of these management systems. It will become necessary for the weapon system manager to direct the expediting of retrograde. There is good reason to think that this system will work well. The people being requested to expedite will be relieved of attempting to expedite everything without seeing an effect; they will be able to see a direct effect of the new system (their FMC rates will increase); and they will pay more attention to a request to expedite retrograde of "PNVS Turret Serial Number 232" as opposed to "retrograde all your carcasses as quickly as possible."⁷

⁷LTC Pat Oler, the manager of TAMP-Base during Operation Desert Storm, mentioned in an interview being able to use the Martin Marietta asset visibility system on an informal basis to arrange for the retrograde of critical repairable LRUs during the contingency.

THE MARTIN MARIETTA TADS/PNVS DATA SYSTEMS AND IMPLICATIONS FOR FUTURE ARMY DATA SYSTEMS

Appendix B describes the main data systems used to make the Operations Desert Shield/Desert Storm analyses and then discusses their relevance for the development of improved Army data systems.

MARTIN MARIETTA DATA SYSTEMS

Most of the data used in Chapters Four and Five came from data systems maintained by the Martin Marietta Aerospace Corporation, the manufacturer and depot-level maintainer of the TADS/PNVS system.

The database for this study was assembled by collating relevant information from three separate Martin Marietta data collections over two periods of time. The data collections used were the Fault File, the Runtime File, and the Fielded Systems Status File. The time periods over which the data were collected were 1/1/86–5/31/90 (peacetime database) and 8/2/90–5/17/91 (Desert Shield/Storm database). The databases contain similar information for each time period.

Fault File

The Martin Marietta Fault File (MMFF) is a history of all maintenance actions on TADS/PNVS systems in the field. It does not include parts removed for retrofit only, although repairs required during retrofit are included. Information used in creating the MMFF was collected from the DRF (depot repair form), the 2410, the 2407, the FFI (Field Failure Information), the ERF (EETF Repair Form), the vendor analysis reports, the depot status reports, and the daily reports from the field. Repair histories are linked so that the progress of an LRU can be tracked from removal from the aircraft through intermediate maintenance, to the FRA, and to the Martin Marietta depot facility at Orlando, FL. (Movement of LRUs or SRUs to vendor repair facilities is not tracked.) Because LRUs are identifiable by serial number, life histories of particular LRUs are available. Each LRU removal is associated with the aircraft and TADS/PNVS system in which it was housed; therefore, repairs even back at the depot can be associated with a particular weapon system.

Runtime File

The Martin Marietta Runtime File (MMRF) contains weekly cumulative flying hour totals for TADS/PNVS systems by aircraft, location, and system number, recorded from the onboard meter. Operating times for both the TADS and the PNVS subsystems are available (each has its own onboard meter). It should be noted that TADS or PNVS operating times are not necessarily equal to helicopter flying time. Typically, they are somewhat longer, as they include power-up time on the ground.

Fielded Systems Status File

The Martin Marietta Fielded Systems Status File (MMFSS) contains status and location information on all TADS/PNVS systems and LRUs in the field for a specific day. This file maintains information on locations of uninstalled spare LRUs, broken LRUs undergoing repair, and LRUs currently installed on an Apache. Each LRU is tracked by serial number and part number (permitting identification of its modification status).

The MMFSS was maintained during Southwest Asia operations as well. Data from those operations were archived in the Martin Marietta facility. For this study, we obtained four snapshots of FSS data, for the dates 10/1/90, 11/29/90, 1/15/91, 2/27/91, and 3/10/91.

All three data systems have been maintained for the life of the Apache program, with coverage extended into the Southwest Asia operations as well. Because these data systems are integral parts of the Martin Marietta support activity, their transfer to Southwest Asia was arranged and facilitated by AVSCOM.

The success of these data systems, some of whose capabilities are demonstrated in this report, has important implications for future Army data systems. Besides providing descriptions of the operational tempo and resulting support demands with exceptional accuracy, this collection of detailed and readily available information in a wartime environment demonstrates some of the possibilities for information gathering in the future. A critically relevant question, of course, is why the Army would need this kind of information. This issue is addressed below.

COMPARISON OF MARTIN MARIETTA AND ARMY DATA SYSTEMS

The Army's data systems cover the full range of organizations and functions that deal with the TADS/PNVS equipment in operational use, in supply, in maintenance, and in transportation over the echelons from pilot and crew chief, through AVUM, AVIM, Directorate of Logistics (DOL), and depot repair, including supply and support organizations such as AVSCOM engineering and contractor support. Over this diverse environment, there are several characteristics that Army data systems share. They are focused on the particular echelon, function, or report generation that is their principal use, and usually focus on the mean. In supply, for example, much of the data effort centers on the mean wholesale demand rate for an item. There is nothing wrong with the focused use of data for different functional organizations, but

structuring the database in this way precludes its use for other support management purposes.

Different echelons use different data elements to generate estimates of parameters that are important for their function. If the data are structured to generate average estimates, the data cannot be used to generate other estimates or to look at other phenomena by linking the data elements. Army data systems tend to be "opaque." A high level of detail may be achieved, only to be lost when the data are processed to serve a gross need (like calculating a population mean) or a narrow specific need (like showing time remaining before overhaul). Those limited products become the only residue of the data-gathering process.

Fortunately, after data are captured, the preservation of the needed linkage is not difficult or costly if the system is built with this objective. The Martin Marietta files described above allow such linkage and can thus be used for such purposes as configuration management, asset location management, supply management, engineering change proposal (ECP) development and assessment in engineering management, and maintenance management.

What is usually involved in using data for different purposes is grouping subsets of the data and examining the detailed linkages to see the effect of changes in configuration, operating environment, removal patterns, etc. For example, operating time for a particular set of aircraft can be linked to a particular modification to see if the incidence of problems in operation is as expected.

NEED TO DEVELOP NEW ARMY SYSTEMS

Recognizing the challenges inherent in the introduction of high-technology subsystems into main force equipment, the Army has begun developing new systems to deal with management problems. Total Asset Visibility (TAV), Readiness-Based Management (RBM), the Vision Assessment System (VAS), and Weapon System Sustainment Management (WSSM) are all initiatives that bring new capabilities for management use of data. Linkage into other Army management remains an important challenge, because, as certain past systems have demonstrated, a minimally used data system is a waste of resources. The use of the data for management is important, the existence of the data in a vacuum is not.

These data issues are particularly important in the current environment of constrained resources because there has been a tendency to look at the cost of data while ignoring the very real costs of not having data. It is difficult to manage something without measurements. When something is measured only in aggregate, it is difficult or impossible to assign cause and effect in the process.

The visibility of assets in TAV and the linkage of cause and effect or projected effect in RBM and WSSM are at the heart of the new management capabilities that these initiatives bring.

IMPLICATIONS FOR FUTURE HIGH-TECHNOLOGY WEAPONS

As the Army's population of high-technology weapons grows over time, there are opportunities to use technology in data capture and reporting in ways that can ease the difficulties that high technology brings to support functions. In automated equipment, much of the information for diagnostic reporting of anomalous operation or malfunction is already present in the equipment in digital form. Only rudimentary efforts have been made in current equipment to use this information to generate a self-logging capability to capture this information with minimal demands for data recording by either the operator or maintenance personnel.

In like fashion, the growing use of automatic test equipment can allow the generation of a detailed maintenance history without the time, expense, and errors of a manual system. Such data are needed to deal with problems such as "bad actor" individual repair parts and no-evidence-of-failure removals from operational equipment. This capability is also important because it reduces the difficulty of applying maturational development to the acquisition of complex weapon systems.¹ This acquisition approach has great potential to reduce the support cost and operational problems experienced in the fielding of complex weapon systems.

Thus, despite bringing complex new support problems, high technology can generate the data needed to deal with these problems without increasing the operator or maintenance workload.

¹John Dumond, Rick Eden, Douglas McIver, and Hyman Shulman, *Maturing Weapon Systems for Improved Availability at Lower Costs*, RAND, MR-338-A, 1994.

**DYNA-METRIC INPUTS FOR OPERATION
DESERT STORM SIMULATION**

Appendix C documents the data sources and assumptions used to execute the Dyna-METRIC analysis in Chapter Five. It is organized according to the general format of Dyna-METRIC parameters.¹ It divides the explanation of parameters into the Base Case, which reflects, as far as possible, the nature of the doctrinal support structure, and the Integrated Theater Support Case, which incorporates adaptations to the doctrinal structure employed in Southwest Asia and other improvements to the support structure for high technology, as discussed in the body of the text.

This and Appendix D are presented both to document the parameters used in the Desert Shield/Desert Storm analyses and to function as a "data dictionary" for potential future users of these Dyna-METRIC input sets. All the cases documented here are available for interested users of Dyna-METRIC who wish to replicate the analyses or perhaps pursue other sensitivity analyses. The following assumes reader knowledge of Dyna-METRIC terminology and structure.

ADMIN AND REPORT TIMES

Base admin time set to zero: base admin time rolled up into retrograde time.

CIRF admin time set to 1 day: queue time at the AVIMs approximately 0.5 day during ODS/S, according to the Martin Marietta Fault File (MMFF).

Depot admin time set to 3 days: queue time at the FRA was three days during ODS/St, according to the MMFF.

Analysis times requested were Days 93, 100, 120, 136, and 147. We posit Day 1 for the scenario as October 16. We assume that on Day 1 all systems are FMC and all pipelines are empty. We then run the model for 93 days until wartime to fill up the pipelines. The report days shown in the analysis convert to:

Day 93 — January 15
Day 100 — January 22
Day 120 — February 11
Day 136 — February 27
Day 147 — March 10.

¹For the format of Dyna-METRIC, see Karen E. Isaacson and Patricia Boren, *Dyna-METRIC Version 6*, RAND, R-4214-AF, 1993.

These dates were chosen to match the Martin Marietta Fielded System Status (MMFSS) snapshots acquired for the study (January 15, February 27, and March 10) as well as to get a more complete picture of sustainability trends over the course of the operation.

UNITS AND SUPPORT RELATIONSHIPS

Base Case

Our analysis used the following support relationships between AVIMs and Apache units:²

AVIM	Units
7th/159	1/1 (1st Infantry Mech, Ft. Riley, Kansas) 2/1 (1st Armored, Ansbach, Germany) 2/6 (11th Aviation Brigade, Illesheim, Germany) 3/1 (1st Armored, Ansbach, Germany) 2/227 (3rd Armored, Hanau, Germany) 4/229 (11th Aviation Brigade, Illesheim, Germany)
I Co./159th	1/3 (1st Cavalry, Ft. Hood, Texas) 1/82 (82nd Airborne, Ft. Bragg, North Carolina)
K Co./159th	1/227 (1st Cavalry, Ft. Hood, Texas)
H Co./159th	1/101 (101st Air Assault, Ft. Campbell, Kentucky) 2/229 (101st Air Assault, Ft. Rucker, Alabama)
K Co./158th	1/227 (1st Cavalry, Ft. Hood, Texas)
8/158th	5/6 (12th Aviation Brigade, Wiesbaden, Germany) 3/227 (12th Aviation Brigade, Hanau, Germany). ³

The unit identifications and support relationships were derived in the following manner. First, helicopters were assigned to units. The list of tail numbers was generated from the Martin Marietta Runtime File (MMRF). That list was matched against the Gold Book (*Army Aircraft Inventory Status and Flying Time*, Department of the Army, USAMC Materiel Readiness Support Activity), January 1991, for assignment to units. Only aircraft with appreciable flying hours in ODS/St were included. (This led us to exclude 50 of the 274 Apaches deployed to Southwest Asia that did little flying, according to the MMRF.)

Combat units were assigned to support units through "triangulation." A first cut of support relationships was made using the Work Order Logistics File (WOLF) for ODS/St for aviation unit identification codes (UICs), compiled by the Materiel Readiness Support Activity (MRSA) and supplied to RAND. By using customer and supporting UICs (with the nomenclature of those UICs gained from a variety of sources), we were able to tentatively identify which AHBs went to which levels of re-

²One maintenance unit, F/1, played a very small role in supporting TADS/PNVS, according to our data, and is not shown in our model.

³A fifteenth unit, the 5th Battalion, 229th Aviation Regiment, from Ft. Hood, was also deployed to Southwest Asia but used only as theater war reserve. GAO, GAO/NSIAD-92-146, p. 12.

pair, as listed above. Next, as a more definitive check, we turned to the MMFSS. We had five snapshots at different times (see above). We were able to follow a "flow" of parts—both good and bad—by identifying uninstalled spares and then tracking them over time. For example, a serviceable spare might have been located at K/158 on October 15, at 1/227 on November 29, and back at K/158 again on January 15. This strongly suggested that unit 1/227 obtained spares from K/158 and sent its carcasses there.

A frequency count was done on these patterns of requisitions and retrogrades for each unit. While there was never a one-to-one correspondence between AHBs and supporting AVIMs, there were predominant tendencies. (There could not be a one-to-one correspondence because over time a spare could migrate to an unrelated unit.) On this basis, we made final determination of support relationships.

Integrated Theater Support Case

In the Integrated Theater Support Case, all intermediate repair is collocated in the rear. It becomes, as it were, general support, not owned or supporting any particular unit. In the Dyna-METRIC model, we establish one location for intermediate repair.

Dyna-METRIC Unit Codes

As Dyna-METRIC limits the spaces for unit identifications, we adopted the unit codes employed in the Martin Marietta data systems for identifying combat and support units. The following identifier codes were used:

Dyna-METRIC code	Unit
Attack Helicopter Battalions:	
2011	1/1
2013	1/3
2021	2/1
2026	2/6
2031	3/1
2056	5/6
2101	1/101
2124	1/24
2127	1/227
2182	1/82
2227	2/227
2229	2/229
2327	3/227
2429	4/229
AVIMs:	
2058	8/158th
258K	K Co./158th
2597	7/159th
259H	H Co./159th
259I	I Co./159th
259K	K Co./159th

In the Integrated Theater Support Case, the set of collocated intermediate repair facilities is identified in the Dyna-METRIC data set as "2INT."

Base to CIRF Retrograde Time

Base Case. According to the MMFF, retrograde time was less than one day. We apply a factor of 12 hours (0.5 day).

Integrated Theater Support Case. All intermediate repair is located rearward and consolidated; it may be collocated with the FRA. We posit a system using dedicated air transport and prioritizing systems for repair, distribution, and retrograde. We assume that such a system will allow retrograde for critical items of no more than two days.

However, Dyna-METRIC does not allow discrimination in retrograde times by priority of the item. It allows only a single number for the pipeline time between two nodes in the support system. We represent that prioritizing by a simplifying assumption of two days retrograde for all items. Admittedly, this may overstate the capabilities of this support system, but not by a large amount in our opinion. In essence, this change means that carcasses are moved from large stacks at the units to large stacks of broken boxes at the consolidated repair facility. Given prioritized repair, these carcasses will not necessarily be repaired any sooner. It does mean, however, that once a need is determined for a carcass, it is effectively already on hand, having been retrograded in two days to the CRF after removal from the weapon system. As a sensitivity test, we set *all* retrograde times back to the consolidated repair facility at four days; there was no loss in weapon system availability. While it is not possible to determine exactly how much the need to set retrograde times globally in Dyna-METRIC exaggerates the performance of the integrated theater support system, we suspect it is probably a small effect.

Retrograde Time to the Depot (DFRA)

Base Case. According to MMFF, the average retrograde time to the FRA (date received minus date failed) was 13 days during both ODS and ODSt.

Integrated Theater Support Case. We assume the FRA is generally collocated with the consolidated intermediate repair. All items, whether or not they are repairable at the intermediate level, pass through that echelon first (that is, have a two-day retrograde time if they are critical). We posit a further retrograde time of 0.5 day from the collocated intermediate repair to the FRA.

Transportation Time from the Depot

Base Case. We assume an OST from the FRA (identified as DFRA in the Dyna-METRIC database) of six days. There is no direct evidence supporting this number. However, some limited information from the Logistics Intelligence File (LIF) shows approximately six days transportation from receipt of items at the APOD until receipt

at the supply support activity. As items from the DFRA shipped by standard means would transit through the APOD, we also adopt an OST of six days.

Integrated Support Case. This case assumes the C-23A-based rapid delivery system operating in the theater for critical high-technology parts. An After Action Report obtained from the theater relating the Aviation Logistics Division's involvement in ODS/St stated "C-23 Sherpa support to VII Corps. Critical repair parts have been provided in an extremely timely manner. Usually within 24 to 48 hours if the part is in theater."

FLYING PROGRAMS FOR UNITS

Number of Weapon Systems

It was not always clear to us if Apaches deployed and fought as units. There is some evidence that in-theater aircraft were assigned to units they previously had no relation with. For our analysis, we assigned Apaches to units based on their appearance in the MMRF. These would typically total 16 to 19 per unit. On this basis, we assume each AHB had the doctrinal 18 helicopters. Three units had obviously fewer aircraft:

1/1—14
2/1—6
2/227—6.

These "partial" units were included in the Dyna-METRIC set with the smaller numbers of aircraft. Altogether, the analysis included 224 aircraft that could be assigned to units. This left 50 aircraft that neither exhibited substantial operation during ODS/St nor could be identified with deployed units. We therefore ignored these aircraft in the model, treating them as Class VII theater war reserve.

Flying Hours per Day

Flying hours were available from the weekly Martin Marietta Runtime File (MMRF), which gives a running tab of operating hours for the TADS and the PNVs subsystems by aircraft by week. Given the helicopters assigned to units, we were able to determine the total flying hours per unit per week. From this information, it was straightforward to create a Dyna-METRIC flying scenario. Hours in this scenario are expressed in terms of TADS operating hours per aircraft per day. (All removal rates, including those for PNVs LRUs, are expressed in terms of TADS operating hours.)

The scenarios for two units were generated differently. The 1/24 and 4/229 had virtually no aircraft reporting operating hours in the MMRF. We do not know the reason for this. To generate a scenario for these two units, we created a surrogate flying program based on their removals. Overall removal rates for TADS/PNVs LRUs differed by time period: 0.03174/operating hour for Desert Shield; 0.04251/operating hour for Desert Storm. We assumed that removals for these two units reflect these removal rates (e.g., ten removals in Desert Shield would represent 315 hours operated). While weekly operating hour totals were not available for these units, weekly

removal totals could be produced. On this basis, we created weekly operating hour totals for these units and, therefore, Dyna-METRIC flying programs.

Attrition

There was no significant attrition of Apaches in ODS/St. This parameter was set at zero.

Flying Hours per Sortie

So that sorties could be used in Dyna-METRIC, we established an equivalence of sorties and flying hours. To show more intense flying in "what if?" scenario spinoffs, we increased the number of flying hours per sortie.

Maximum Flying Hours (Sorties) per Weapon System

This was set to eight, by assumption. Based on evidence from the RAND study at Ft. Rucker, individual aircraft can be flown eight hours a day (or somewhat more) for several days in a row.

SUSTAINED DEMAND START TIME

In this modeling, we needed two removal rates, with the later one the higher, so as to model the lower removal rates of ODS ("peacetime) and the higher ones of ODSt (the actual war). To do this we "tricked" the model by making the ODSt removal rates the sustained demand rates appearing on the VTM record. The sustained demand start time was set at Day 95, or January 17.

DETAILED LRU AND SRU INFORMATION

LRUs modeled are the complete set of TADS/PNVS LRUs. Note that GCCA is actually an aggregate: it covers three circuit card assemblies; apparently, stockage (see below) counts each circuit card separately, thus accounting for the rather large number of GCCA spares.

No SRUs were modeled. In part, this was for simplicity's sake, but more important, we have no information on stockage of SRUs in the theater and very little on their consumption. SRUs, as well as consumable piece parts, are vital for high-technology support, and we do not mean to regard them as trivial by not including them in the analysis. The data were not sufficient to include them in the analysis, but issues of SRU/piece part stockage and resupply need to be resolved for the kind of support described in this report to be effective.

Level of Testing

This was determined by knowledge of what TPSs exist at the EETF for TADS/PNVS LRUs.

Demand Rates

As stated before, two demand rates were used: for ODS and ODSt. Removal rates were calculated as the total removals divided by the total TADS operating hours for the two periods: August 15 through January 16 for ODS; January 17 through March 10 for ODSt.

We use the "onshore" demand rates in the model; the offshore column is included for reference only. Those rates shown in the offshore column are also included in the sustained demand rate portion of the VTM block.

CONUS Resupply

We assume most items would be sent by Desert Express, with a mean OST of 20 days. In this particular analysis (and given that we do not explicitly model SRUs and piece parts), resupply from CONUS plays a less vital role. There are other alternatives, as suggested in the text, such as providing all support from CONUS and deploying no repair capability to the theater. Such a support concept would demand resupply times of ten, five or even fewer days.

Base, CIRF, and Depot-Related LRU, SRU, and SubSRU Data

Base Case. Repair times at the EETF are taken from the EETF RAM/LOG, the same as used in our previous report.⁴

AVIM NRTS rates are from the MMFF and are for removals in ODSt only. NRTS rates early in ODS were quite high: many of the AVIMs had not deployed yet. NRTS rates are defined in this study as the obverse of items fixed; that is, the AVIM NRTS rate would be: $[1 - (\text{proportion fixed by the AVIM})]$. This caused one difficulty in our analysis. Many items arriving at the AVIM were not fixed (at least during the time period covered by our data) but were never NRTSed to a higher echelon; that is, by and large, they were simply kept as carcasses at the AVIM. For ODSt removals, 15 percent of all removals arrived at the AVIM but were never fixed or NRTSed. One can speculate as to what happened: they were kept for cannibalization, or on hand to be fixed when the unit redeployed and could get spare parts. Whatever the case, they create a difficulty for the model. Dyna-METRIC does not recognize "keeping things around"; you either fix it, NRTS it as unrepairable, or overflow it because of queue length. Also, the option of cannibalizing it for SRUs does not apply here, as we did not model SRUs. The solution was to cut the Gordian knot and consider it as a NRTS.

⁴M. L. Robbins, M. B. Berman, D. W. McIver, W. E. Mooz, and J. Schank, *Developing Robust Support Structures for High-Technology Subsystems: The AH-64 Apache Helicopter*, RAND, R-3768-A, 1991.

(The AVIM did not fix it; if it was kept as a source of SRUs, that suggests problems with the AVIM structure (possibly that it is hard to get needed SRUs). Thus, these LRUs would be sent to the FRA.)

One problem remained. FRA NRTS rates were calculated the same way: $[1 - (\text{proportion of arrivals the FRA fixed})]$. But these LRUs never arrived at the FRA. Would the FRA have fixed them or NRTSed them? We assume that they would have been fixed in the same proportion as those that did arrive. FRA NRTS rates are factored into the model as "condemnations" that are then replaced by reorders from the supplier. This is the equivalent of CONUS depot repair, where CONUS depot is not constrained (as it is not in our model).

FRA repair times are based on analysis of FRA depot report forms (DRFs) from all FRAs.

Integrated Theater Support Case. In this alternative, we assumed an intermediate support unit with the capabilities of the intermediate support system in operation at the U.S. Army Aviation Training Center at Fort Rucker, AL. Accordingly, we use EETF diagnosis times and NRTS rates as found at Ft. Rucker. Some of these parameters are as listed in Table 5.7. These factors were generated from a RAND study of the Ft. Rucker support system, with data collected March–September 1989.

Time on the hot mockup and NRTS rates from the FRA are the same in the Integrated Theater Support Case as in the Base Case.

SPECIFIC LRU INFORMATION

Test Equipment

We assigned a generic test stand "TFRA" at both EETFs and FRAs, although the actual equipment is different. The constraint modeled at the FRA is the hot mockup; that at the EETF is the test bench itself.

VTMR

VTMRs were derived from demand data in the Unscheduled Maintenance Sample Data Collection (UMSDC) and are the same ones used in a previous RAND study of the Apache (see R-3768-A, 1991).

Sustained Demand Rates

These are the same as the offshore rates and are the removal rates experienced in ODS.

Application Fractions

All application fractions are 1. This causes a glitch in that it may provide too many GCCA spares. On the other hand, the GCCA removal rate appears to include each removal of a circuit card, so there may not be a problem.

LRU Stockage

Base Case. LRU stockage for each location is a roll-up of the uninstalled spares on snapshot days from the MMFSS (see above). Each location has both serviceables and carcasses; to simplify, all carcasses were made into serviceables, and then the scenario was "backed up" and run to generate pipelines. For example, the spares snapshot of January 15 was used to generate stockage levels. All carcasses on January 15 were made into serviceables. Then, with those stockage levels set, the scenario was "backed up" and started running as of October 16. The situation on Day 93 (January 15) then generally reflected the number of carcasses actually existing on the real January 15.

Integrated Theater Support Case. In this case, the only change in stockage is that all spares located at intermediate locations are consolidated rearward at the repair facility identified in the Dyna-METRIC analysis as "2INT."

Test Stands

EETFs. EETFs were available an average of 12 hours per day over the entire scenario, according to data tabulated by GE tech reps in the theater and provided by the product manager for TADS/PNVs.

The input parameter for EETF availability must be modified to account for the non-TADS/PNVs workload that EETFs also handle. To accomplish this, we determined how much of the workload was non-TADS/PNVs and then decremented the EETF availability figure in the model. Thus, all EETF hours in the model were assumed to be for TADS/PNVs diagnosis only.

According to GE tech rep reports, from 9/4/90 through 4/18/91 the EETF inducted 619 LRUs. Of these, 370, or 60 percent, were TADS/PNVs. This suggests that the TADS/PNVs share of the EETF should be 60 percent. But this must be weighed by time on test equipment. Taking test equipment time from R-3768-A, Appendix C, we see that on a case-by-case basis (one induction for each LRU at the EETF), the total TPS "run time" for all EETF-testable LRUs is 110 hours; the total TPS run time for TADS/PNVs LRUs is approximately 55 hours, or 50 percent. That is, TADS/PNVs and non-TADS/PNVs demands on the EETF, on an equal-removal basis, are even. Thus, there is no need to further weight the 60 percent figure.

FRA. According to representatives from Martin Marietta, the hot mockup/aircraft simulator was the main constraint in FRA repair, and we adopt it as the constraining test stand in our analysis. For the duration of ODS/St, there was one hot mockup in the theater. (A second was deployed from Germany in March.) Typical FRA opera-

tions were 10–12 hours a day. However, during combat, the facility ran a two-shift, seven-day operation.

Thus, for this analysis, we assume a sustained operating tempo of 12 hours a day, with 16-hours-a-day operation commencing on Day 133 of our scenario.

Dyna-METRIC Input Parameters for Test Stand Availability

In Dyna-METRIC, it is not crucial that the “right” number of test stands be input, but rather that the right testing capability be reflected in those parameters. So, while there were eight EETFs and one FRA hot mockup, the number of stands used in our model input data bears little resemblance to those figures.

Instead, we seek to capture in the model the capability of those systems, defined in Dyna-METRIC terms as number of test-stand hours available per day.

Base Case. In this case, each EETF is available 12 hours a day, with 60 percent of its time devoted to diagnosing faults in TADS/PNVS components. Thus, each EETF has 0.3 test-stand-days per day for TADS/PNVS; with eight EETFs in the theater, the Dyna-METRIC inputs should total 2.4 EETF test-stand-days per day of the scenario. The FRA, as stated above, is available 12 hours a day in the sustained mode, and 16 hours a day during the period of greatest intensity (after Day 133 in the scenario). Since the FRA only repairs TADS/PNVS, the available test-stand-days are respectively 0.5 and 0.67.

Test stands are assigned to locations (CIRFs or depots), but in this use of the model we could designate only one type of test equipment, even though the EETF and the FRA hot mockup are fundamentally different pieces of equipment. While this uniformity of test equipment designation makes no substantive difference to the analysis (as the key parameters defining the differences between the EETF and the FRA are test times and NRTS rates), it does complicate determining the number of stands to put at each location. In the base case, to yield 0.5 and 0.67 test-stand-days at the FRA and 2.4 test-stand-days allocated across the AVIMs, we used the following input parameters for number of test stands and availability per day at each location:

TFRA test-stand availability per day set at 0.167.

For the DFRA, assume three stands until Day 95, and four until Day 133, and then eight for the rest of the scenario.

For the AVIMs, assume the following number of test stands per location:

2597	—	4
259I	—	2
259K	—	2
259H	—	2
2058	—	2
258K	—	2

Thus, for example, there are 14 test stands assigned to the AVIMs, but with per-day availability of 0.167, the overall availability is 2.34 test-stand-days (14×0.167).

Integrated Theater Support Case. In this analysis, the input parameters are somewhat simpler. We assume the same capability at the FRA (0.5 to 0.67 test-stand-days per-day of the scenario). Intermediate diagnostic capability in the EETFs is consolidated at one location, and the overall number of EETFs is reduced from eight to three. We assume the same per-day availability of the EETFs in this case, at 12 hours per day, although it is possible that in the support concept we are describing, consolidation will likely increase overall test equipment availability considerably. The same 60 percent workload figure applies to the TADS/PNVS portion of the work. Thus, we have one intermediate support facility with three stands at 12 hours a day, 60 percent of which is for TADS/PNVS, or 0.9 test-stand-days per day of the scenario. To represent this in the model, we assigned an overall test-stand availability figure of 0.1, with five stands at the DFRA until Day 95 and seven stands until Day 133 (yielding availabilities of 0.5 or 0.7). At the consolidated intermediate facility, we assign nine stands to achieve a daily capability of 0.9 test-stand-days (9×0.1).

Prioritization Rules

Dyna-METRIC Version 6.3 allows two modes of scheduling carcass repair and distributing serviceables to forward locations: first-come, first-served and prioritization based on the effect of a repair/distribution action on overall weapon system availability. Simply put, in the first case, the carcass waiting the longest will be repaired first, and the oldest outstanding requisition will be filled first; in the latter, the model will repair first the carcass that has the highest probability of making a non-mission-capable weapon system fully mission capable; distribution rules follow the same logic.

Base Case. We assume first-come, first-served rules for both repair and distribution at the FRA and priority repair and distribution at the intermediate repair echelon. Since there is no theaterwide information system, logisticians at the theater level would be unable to keep up with the quickly changing demands of the units, and so would face obstacles in prioritizing their workload. By contrast, we assume that no elaborate information system is required for the smaller-scale operations at the corps and division levels; instead, telephonic or other forms of communications would give repair and supply personnel the information they need on a daily basis to allow them to best schedule their workload. (A similar logic was used in the ODS simulation; see Appendix D.)

Integrated Theater Support Case. This analysis employed Dyna-METRIC's prioritization capability for both repair and distribution for the theater-level support facility modeled in this case.

Queue Overflow

Base Case. We assume a queue overflow parameter of four days, in accordance with Army doctrine. That is, after a backlog of 96 hours is reached, newly arriving carcasses are evacuated (NRTSed) back to the FRA.

Integrated Theater Support Case. There is no Army doctrine for a queue overflow limit in this situation. Given the integrated management of all FRA and intermediate resources, we assume a much shorter queue overflow limit of one day's worth of backlog for the intermediate repair resources before they can be sent to the FRA.

**DYNA-METRIC INPUTS FOR OPERATION
DESERT SHIELD SIMULATION**

The Dyna-METRIC simulation in Chapter Four used a Dyna-METRIC set modified from the larger one needed for the analyses in Chapter Five. Appendix D lays out the major differences and walks the reader through the setup of the analysis of the ODS case. The three cases included in this analysis are *Base Case*, *Cross-Leveling*, and *Cross-Leveling/Fast Resupply*.

ADMIN AND REPORT TIMES

Admin times are the same as in the ODSt case, whereas report times are handled differently. In the ODSt case, a "peacetime" (ODS) period with lower operating tempos is modeled before the commencement of fighting (on Day 95 of the scenario). In this analysis, the fighting is assumed to begin on Day 1 of the model-based scenario (which we set as September 15). The scenario continues through Day 30 (October 15). Dyna-METRIC report days included in the analysis are D+5, D+10, D+20, and D+30.

UNITS AND SUPPORT RELATIONSHIPS

As explained in Chapter Four, we model four AHBs in this analysis: 1/82, 1/24, 1/101, and 2/229. Using the Martin Marietta unit identifier codes, we put these in Dyna-METRIC code as: 2182, 2124, 2101, and 2229.

These four AHBs were supported by two deployed AVIMs, each with one EETF. These were I Co./159th and K Co./159th, for which we use the identifier codes 259I and 259K. The support relationships were identified in the same manner as described in Appendix C. This resulted in the following relationships:

259K supported 2124 and 2101;

259I supported 2182 and 2229.

Base to CIRF Retrograde Time

Same as in Appendix C.

Retrograde Time to the Depot (DFRA)

ODS data showed the same average 13-day retrograde time to the FRA as in ODSt. We used this factor. However, the reader should also note that the FRA was not fully operational until late September; furthermore, when a three-day admin time, plus time for repair, plus a six-day OST from the FRA are all taken into consideration, it is obvious that the FRA would have little role to play in this 30-day scenario.

Transportation Time from the Depot

Same as in Appendix C.

FLYING PROGRAMS FOR UNITS

Number of Weapon Systems

We assumed 18 helicopters for each of the four AHBs.

Flying Hours per Day

We used a flat assumption of three hours per helicopter per day.

Attrition

As in the Chapter Five analyses, we assumed no attrition of Apaches, just as we assumed no loss of logistical resources from enemy attacks.

Flying Hours per Sortie

This feature of Dyna-METRIC was handled the same way as in Appendix C.

Maximum Flying Hours (Sorties) per Weapon System

This is the same as in Appendix C.

SUSTAINED DEMAND START TIME

This analysis used the ODSt removal rates (which were higher than those from the lower-tempo ODS itself). These were identified as “offshore rates” in the Dyna-METRIC data input set, and were assumed to begin on Day 1.

DETAILED LRU AND SRU INFORMATION

Level of Testing

Same as Appendix C.

Demand Rates

Same as in Appendix C.

Resupply

Base Case and Cross-Leveling Case. An OST from CONUS of 40 days is assumed. CONUS resupply would play only a small role, although since the model uses an exponential distribution to determine resupply times, a few components would be received in the 30-day time frame.

Cross-Leveling with Fast Resupply Case. Resupply times of 20, 10, and five days were modeled. We assume that spares would be sent from CONUS to an APOD in the theater and then on to the units or to a central supply point. Given the structure of Dyna-METRIC, the natural progression would be to move items from CONUS to the FRA, then to the intermediate support echelon. To get around this problem (the FRA would play little if any role in performing repairs), we modeled the FRA echelon as if it were CONUS itself. We established a very large stock of spares at the FRA echelon and then assigned OSTs from the FRA to the intermediate points of 20, 10, or five days.

Base, CIRF, and Depot-Related LRU, SRU, and SubSRU Data

We believe that in this scenario, the EETFs would have been more productive than in the ODSt base case. At the start of the operation, the EETFs would have been generally collocated and close to APODs, facilitating receipt of spare parts and repair parts for the test equipment. It is possible that they would not have been required to move as much as in ODSt. We chose to be conservative in estimating EETF productivity by giving them parameters between the ODSt performance and a Fort Rucker-type operation, which, as shown in Chapter Five, is at the Ft. Hood level. These parameters were used for all three cases.

SPECIFIC LRU INFORMATION**Test Equipment**

Same as in Appendix C.

VTMR

Same as in Appendix C.

Sustained Demand Rates

Same as Appendix C.

Application Fractions

Same as in Appendix C.

LRU Stockage

LRU stocks are only at the unit level. The Dyna-METRIC inputs are drawn from the MMFSS of October 1, 1990, as described in Chapter Four. To capture the effects of fast CONUS resupply, large supplies of spares were placed at the FRA, with OSTs of 20, 10, or five days, depending on the case. In these analyses, the FRA was substituted for CONUS wholesale stocks (necessitated by the limits of Dyna-METRIC modeling).

As explained in Chapter Four, Dyna-METRIC cannot truly model cross-leveling of the kind OSC shows promise of doing. To estimate (optimistically) OSC's ability in Dyna-METRIC, we placed all unit spares at one location and assumed a period of one day to move spares from that location to the unit in need.

Test Stands

Each AVIM had one EETF, which (as in Appendix C) we took to be operational 12 hours a day. Again, we take the TADS/PNVS part of the load of the EETF to be 60 percent. Thus, we established one test stand at each AVIM with an availability of 0.3 (yielding 0.3 test-stand-days per day of the scenario for TADS/PNVS testing).

FRA Stands and Availability

We assumed no test capability at the FRA until Day 15 and then one stand operational 12 hours a day from that point on.

Prioritization Rules

All repair in this scenario is accomplished at AVIMs belonging to the divisions and corps. As was discussed above for the ODSt base case, we assume that the repair and supply personnel would keep in daily contact with maintainers in the fighting units, and so would have good knowledge of the AHBs' needs. Therefore, we use Dyna-METRIC's prioritization capability for both repair and distribution in all the cases examined in this scenario.

Queue Overflow

Dyna-METRIC will not allow requisitioning a higher source of supply until an item has been NRTSed or condemned. Thus, we set queue overflow factors according to the order and ship times used. For the base, cross-leveling, and 20-day resupply cases, the queue overflow factor was set at four days; for the 10-day resupply case, the overflow limiter was two days; for the five-day resupply case, the queue overflow limiter was set at one day.

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