A RAND NOTE

Alternative Concepts for Managing the Distribution of Resupply Cargo

Stephen J. Carroll, D. Robert Worley,
Gordon B. Crawford

RAND

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Prepared for the
Defense Advisory Group to the
National Defense Research Institute
Assistant Secretary of Defense
(Production and Logistics)

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PREFACE

This Note presents some alternative concepts for managing the distribution of military resupply cargo in wartime. RAND is currently evaluating these to identify those that will most effectively meet DoD's future wartime and peacetime needs. The results of the evaluation will be published later. The objective is to assist DoD in developing a resupply system that will be able to adapt rapidly to unanticipated changes in demand, during war or peace.

This work is a portion of a study aimed at formulating a conceptual design for a future DoD materiel distribution system. Other parts of the Future Distribution System Study are exploring distribution of cargo during mobilization and deployment of forces (including mixes of strategic transportation assets and the related operating procedures), the civil transportation systems on which DoD will rely in a major contingency, the transportability of military equipment, and the affordability of distribution alternatives. RAND was asked to do this study by the Under Secretary of Defense for Acquisition, who called for a "blueprint" for a materiel distribution system that would serve the needs of all the U.S. military. This call was inspired by the concerns of the Under Secretary of the Army and others about likely problems during mobilization and deployment.

This Note was prepared within the Acquisition and Support Policy Program of the National Defense Research Institute, a federally funded research and development center sponsored by the Office of the Secretary of Defense and the Joint Staff. The research reported here was jointly sponsored by the Assistant Secretary of Defense (Production and Logistics), the Services, the Joint Staff, the Defense Logistics Agency, and the institute's Defense Advisory Group, whose members are key policymakers in the Office of the Secretary of Defense and the Joint Staff.

SUMMARY

The existing Department of Defense (DoD) system for distributing resupply (non-unit-related) cargo is not well integrated. The system as a whole lacks mechanisms to ensure that it will respond well to the demand variations characteristic of wartime. This Note offers several alternatives for improving the management of resupply operations in DoD's future distribution system, along with a framework for evaluating them.

To aid in formulating our alternatives, we have classified the decisions we believe necessary for an effective resupply system into six tasks falling into two broad categories, which we discuss below. Together, these are the tasks supply managers need to accomplish to control the flows of cargo and vehicles in a way that takes full advantage of the available physical resources: stocks, storage and transportation facilities, and vehicles.

CONFIGURING THE TRANSPORTATION SYSTEM

The first broad category of tasks includes those necessary to configure the transportation system to meet the particular needs of a contingency over a multiweek period:

Forecasting Movement Requirements

Currently, wartime resupply movement requirements are forecast in peacetime on the basis of planned force deployments, expected consumption rates, and the availability of stocks. These forecasts are notional, to support the allocation of strategic transportation resources. There are no guarantees that the actual wartime resupply demands would match the forecasts. The current system does not include procedures for forecasting wartime movement requirements, beyond the initial planning.

An alternative approach would be to dynamically update movement requirements forecasts on the basis of experience and current information on resupply requirements and available stocks. The planning factors would be continuously updated to reflect actual consumption and combined with updated force densities, allowing estimates of the gross movement requirements to support the forces in a given theater. In essence, a rolling horizon would be used to update resupply movement requirements continuously.

Four kinds of information would have to be linked to provide improved movement requirement forecasts: (1) the forces involved in each theater over the foreseeable future, (2) the commanders' goals and priorities, including expected operational tempos, (3) wartime consumption to date in each theater involved in the contingency, and (4) retail and wholesale stocks.

Establishing Resupply Pipelines

Currently, strategic airlift and sealift assets are allocated among theaters. These allocations can be modified in response to commanders' needs by joint and theater transportation boards. Aside from movements of ammunition and bulk fuel, the allocation process does not attempt to define different resupply pipelines to a theater to support different movement requirements.

The alternative concept takes advantage of the fact that the performance of a pipeline varies according to the characteristics of the transportation vehicles assigned to it. Vehicles with different performance characteristics could be organized into different pipelines that are specialized in terms of the cargo they carry, the service they provide, or the destinations they supply.

The performance of a resupply pipeline also varies according to its concept of operations. For instance, a DoD rapid-response pipeline (like the Desert Express service developed in support of Operation Desert Shield) could employ a system managed origin-to-destination with high visibility and predictable turnaround time. Such a pipeline might be an effective way to meet demands for expensive or critical items that must be delivered to fighting forces quickly, on short notice.

MEETING DAY-TO-DAY RESUPPLY NEEDS

The second broad category of tasks is directly related to management of day-to-day resupply operations.

Establishing Resupply Priorities

Currently, DoD establishes resupply priorities through the Uniform Materiel Movement and Issue Priority System (UMMIPS). Priorities are determined by the requisitioner's force/activity designator and the urgency of need, as stated by the requisitioner. The system does not adequately discriminate among competing high-priority demands if stocks or transportation capacities are short.

A more objective approach to determining urgency of need could be developed, e.g., one that sets different urgency criteria for different functional areas or commodity sets. It should also be possible to vary the relationship between a requisitioner's declared urgency of need and UMMIPS priority by theater or by time to more closely reflect a systemwide view of commanders' needs.

The current system responds to needs identified and expressed by customers. As a second alternative, the DoD might consider developing management systems with the capacity to anticipate materiel requirements and establish resupply priorities accordingly.

Allocating Materiel

The current Military Standard Requisitioning and Issue Procedures require that materiel be issued on the basis of its UMMIPS priority, with two exceptions: Requisitions bearing special Office of the Secretary of Defense (OSD) or Joint Staff project codes and requisitions for parts necessary for mission capability are filled before other high-priority demands. Recent Army exercise experience suggests that stocks in several supply classes could well be exhausted before some critical demands are sorted out of the welter of "high priority" requisitions.

As one alternative, specified quantities or proportions of available stocks could be reserved for specified consumers to ensure that some stocks will be available for them. Joint Staff apportionment guidance could provide a basis for the allocation of materiel in a contingency. Service materiel managers could establish allocation strategies by commodity on the basis of their knowledge of stocks and theater requirements.

Control levels can be added to the basic notion of a stock reservation system. Available assets would be allocated to theaters. Control levels would be established within each theater to release materiel by priority group to prevent depletion of on-hand stocks.

A second alternative would be to develop weapon system availability criteria for resource allocation, together with more central visibility and improved decision-support systems, as a basis for linking the allocation of materiel to combat capability goals. A more ambitious version of this alternative would be to base materiel allocation on mission capability goals. An allocation scheme might allot equipment, consumables (fuel, munitions, etc.), and secondary items to maximize the degree to which forces can achieve mission capability goals, taking account of their personnel status.

Allocating Pipeline Capacity

UMMIPS transportation priorities do not currently take pipeline capacities into account, and the Services' airlift clearance authorities' challenge criteria are not intended to match the demands for air transport to air pipeline capacity. Nor is there any explicit link between challenge criteria and commanders' needs.

In the first alternative, the limitations of the current system could be ameliorated by establishing an authority for each theater with access to information on demands, commanders' needs, pipeline capacities, and available stocks. Such an authority could use this information to counsel the airlift clearance authorities regarding challenge criteria, or it could subsume the challenge role.

In the second alternative, the development of enhanced priority systems would provide an alternative means for allocating pipeline capacity. Service materiel managers' specialized knowledge may comprise sufficient information on the requirements to identify the relative urgency of needs. The materiel managers would assign transportation priorities for the items they manage, adjusting them as needed to respond to pipeline congestion or underutilization problems.

Managing Pipelines

Currently, resupply airlift and sealift generally operate on established schedules; cargo flows in accordance with those schedules. Surface transportation obeys the reverse logic: Vehicle schedules accommodate cargo routing. The resulting system suffers its greatest inefficiencies in passing cargo from transit segment to transit segment. Transit time is responsible for only 20 to 40 percent of the time it takes to fill a requisition.

As an alternative, either strategic lift or cargo could be routed dynamically. In the former case, schedules would be arranged so that carriers meet cargo where and when they are needed. In the latter case, the embarkation port for each package of requisitioned cargo and its route to that port would be chosen so as to minimize the total delay for all current and anticipated requisitions. Both strategic lift and cargo could instead be routed dynamically.

A FRAMEWORK FOR EVALUATING THE ALTERNATIVES

We are now evaluating the alternatives proposed above for each of the resupply system decisionmaking tasks. The standard for judging the concepts is whether, and how

much, they enhance the degree to which the materiel distribution system can respond to commanders' needs and priorities, given available transportation assets and materiel.

To investigate the value of these alternatives, we have built a simulation model of an origin-to-destination resupply distribution system. We specify the management systems and decision rules implied by each alternative and use the model to simulate the operations of the distribution system when governed by that complex of management systems and decision rules. The model provides an estimate of the system's response to a specified stream of requisitions and manages the resulting flows of materiel through the transportation system. The results will be reported separately.

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We have received valuable assistance, comments, suggestions, and advice from each of the Services, the Joint Staff, the Defense Logistics Agency, and the U.S. Transportation Command and its Transportation Component Commands. We also received helpful advice and suggestions from our RAND colleagues John Bondanella, I. K. Cohen, Myron Hura, Thomas F. Lippiatt, Richard Robinson, and John F. Schank. We are particularly indebted to David Kassing, director of the DoD Future Distribution Study, for his intellectual leadership and guidance.

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CONTENTS

PREFACE iii

SUMMARY v

ACKNOWLEDGMENTS xi

FIGURES AND TABLES xv

LIST OF ABBREVIATIONS xvii

Section

I. INTRODUCTION 1
- Purpose and Scope 1
- The Role of Resupply Management Systems 1
- The Need for Improved Resupply Management Systems 3
- Ongoing Improvements in DOD Information and Communication Systems 3
- Major Resupply Management Tasks 5
- Alternative Resupply Management Concepts 7

II. CONFIGURING THE RESUPPLY SYSTEM 8
- Forecasting Movement Requirements 8
- Establishing Resupply Pipelines 11

III. ESTABLISHING RESUPPLY PRIORITIES 16
- The Current System 16
- Alternative Approaches to Establishing Priorities 19

IV. MATERIEL ALLOCATION 23
- The Current System 23
- Alternative 1: Stock Reserve Systems 24
- Alternative 2: Allocation Linked to Combat Capability Goals 26

V. ALLOCATING PIPELINE CAPACITY 27
- The Current System 27
- Alternative 1: Theater-oriented Pipeline Allocation 29
- Alternative 2: Decentralized Control with Enhanced Priority Systems 32

VI. PIPELINE MANAGEMENT 33
- The Current System 33
- Performance of the Current Peacetime System 34
- An Alternative: Dynamic Pipeline Management 36

VII. EVALUATING ALTERNATIVE RESUPPLY CONCEPTS 38
- Method 38
- Model Characteristics 39

FIGURES

1. Resupply management systems link distribution operations to military operations 2
2. Resupply management tasks and their interrelations 5
3. Current general-purpose resupply pipelines 12
4. Establishing origin-to-destination resupply pipelines 14
5. The current system for allocating cargo to pipelines 28
6. TACA allocation scheme 30
7. TDCP allocation scheme 31

TABLES

1. UMMIPS PDs 17
2. Fill rate (30 days) by OPLAN 24
3. Percentage of shipments received on time 35
4. Logistics system performance Army distribution, April–June 1989 36

LIST OF ABBREVIATIONS

ACA	Airlift clearance authority
AMC	Army Materiel Command
APOD	Aerial Port of Debarkation
APOE	Aerial Port of Embarkation
C^3I	Command, Control, Communications, and Intelligence
CINCs	Commanders in Chief
CONUS	Continental United States
DLA	Defense Logistics Agency
DRIVE	Distribution and Repair in Variable Environments
DoD	Department of Defense
EXCAP	Exercise capability
FAD	Force/activity designator
IPG	Issue Priority Group
JCS	Joint Chiefs of Staff
JMPAB	Joint Materiel Priorities and Allocation Board
JOPS	Joint Operations Planning System
JSCP	Joint Strategic Capabilities Plan
LOGAIRS	Logistics Airlift System
LOGPLAN	Logistic Plan
LSAO	Logistics Systems Analysis Office
MAC	Military Airlift Command
MILSTRIP	Military Standard Requisitioning and Issue Procedures
MODELS	Modernization of Defense Logistic Standard Systems
MSC	Military Sealift Command
MTMC	Military Traffic Management Command
NICPs	National inventory control points
NMCS	Not-mission-capable supply
OPLAN	Operations Plan
OSD	Office of the Secretary of Defense
PD	Priority designator
POD	Port of Debarkation
POE	Port of Embarkation
POL	Petroleum, oil, and lubricants
SORTS	Status of Resource and Training System
SPOD	Seaport of Debarkation

SPOE	Seaport of Embarkation
TACA	Theater airlift clearance authority
TDCP	Theater distribution control point
TPG	Transportation Priority Group
UMMIPS	Uniform Materiel Movement and Issue Priority System
UND	Urgency-of-need designator
USTRANSCOM	U.S. Transportation Command
VISION	Visibility of Improved Support Options

I. INTRODUCTION

PURPOSE AND SCOPE

This Note presents some alternative concepts for managing the distribution of military resupply cargo in wartime. The analysis focuses on techniques for effectively coordinating the day-to-day and week-to-week operations of a given set of materiel distribution resources, including supply and transportation assets. Other analyses are evaluating the alternatives described here to identify those that will most effectively serve the future wartime and peacetime needs of the Department of Defense (DoD).

This analysis is one part of a study aimed at developing a conceptual design for a future DoD deployment and resupply system. Other parts of the study are analyzing the distribution of unit-related cargo during mobilization and deployment of forces and alternative levels of investment in, and mixes of, strategic transportation assets. The overall study includes analyses of trends in the civil transportation systems on which DoD will rely in a major contingency, the transportability of military equipment, and the affordability of future distribution system alternatives. The study's output will include proposed research programs, investment levels, and operating procedures, leading to an improved DoD deployment and resupply system. The primary concern is for the effectiveness of distribution in a future wartime environment.

This section reviews the role of resupply management systems and the limitations of current approaches to managing the distribution of resupply materiel. We observe ongoing efforts to improve the current system. We then outline our analysis of the problems that remain and the means we used to identify alternative responses to them.

THE ROLE OF RESUPPLY MANAGEMENT SYSTEMS

Materiel demands arise as combat unfolds. Commanders at all levels and their staffs establish the demands. Which items are needed, where, and when? The distribution system must respond to commanders' demands as they arise, determine the distribution operations needed to meet them, and manage physical distribution activities to ensure that scarce resources are used effectively. The system must also inform commanders, in terms meaningful to their concerns, so that their plans can take into account the limitations of the materiel distribution system.

Figure 1 shows the information flows that link distribution operations to military operations. The box at the top represents the military operations, the arena in which commanders plan and execute combat operations. Although these activities are outside the purview of the distribution system, they give rise to the needs the system must serve.

The box at the bottom represents the DoD's materiel distribution operations: forklifts, boxes, aircraft, ports, containers, and so forth. The activities at this level determine what is provided where and when.

Joint and Service resupply management systems connect the military operations with the materiel distribution operations. These management systems must link the physical distribution operations to the needs and goals of the Joint Chiefs of Staff (JCS) and the supported commanders in chief (CINCs). These systems must also manage the flow of cargo and vehicles through the distribution system to maximize the timeliness of its response to wartime requirements.

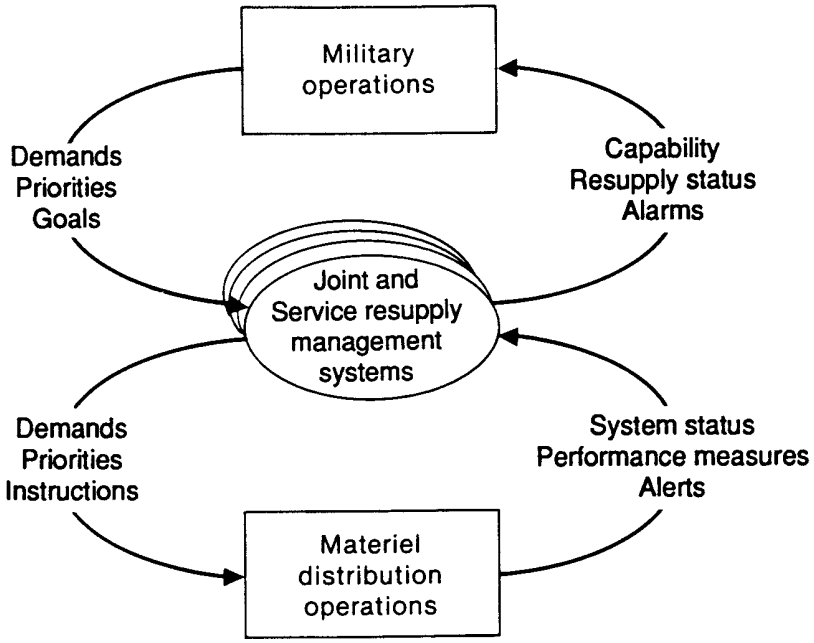

Fig. 1—Resupply management systems link distribution operations to military operations

THE NEED FOR IMPROVED RESUPPLY MANAGEMENT SYSTEMS

The systems now used to manage the distribution of resupply materiel do not integrate planning, direction, coordination, and control of supply, transportation, and traffic management effectively. Distribution of resupply cargo is currently managed piecemeal throughout DoD. Many aspects of DoD's supply, transportation, and traffic management functions are organized separately. Each of these organizations is concerned with its own limited responsibilities and judges its performance by its own standards instead of by its contribution to systemwide performance. Further, joint command and control systems are not well linked to systems that plan and manage resupply. As a result, in a conflict, the Services and defense agencies are likely to have difficulty relating requirements to their capabilities and determining their ability to support execution of operations.[1]

Improved management tools are needed to better integrate the operations of the agencies and organizations involved in materiel distribution. In particular, it will be necessary to better coordinate and connect the resupply operations of JCS, the Services, the defense agencies, and the U.S. Transportation Command (USTRANSCOM)[2] and its Transportation Component Commands. The objective of this Note is to generate alternatives with the potential to meet those needs.

ONGOING IMPROVEMENTS IN DOD INFORMATION AND COMMUNICATION SYSTEMS

Emerging improvements in communications and information technologies will provide the future DoD materiel distribution system with improved centralized visibility over materiel and the location and status of transportation assets. Communications connectivity and data-processing capacity are also improving.

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[1]This assessment is based on I. K. Cohen, et al., *Issues in Materiel Distribution: A Background Note,* RAND, N-2791-P&L, 1989; interviews with both senior DoD leaders and staff members responsible for conducting distribution planning and operations; and examinations of "lessons learned" reports from joint exercises conducted during the last decade. See also U.S. Transportation Command, *Command, Control, Communications, and Computer Systems Master Plan,* September 29, 1989.

[2]USTRANSCOM's Transportation Component Commands are the Military Airlift Command (MAC), the Military Sealift Command (MSC), and the Military Traffic Management Command (MTMC).

The Office of the Secretary of Defense (OSD) has initiated the Secondary Item Weapon System Management Concept, which requires each of the military services to develop an automated capacity for DoD-wide asset visibility at all levels of supply. The Services are developing implementation plans. Implementation of this initiative will allow managers to identify asset balances and shortfalls, worldwide.[3]

The ongoing Modernization of Defense Logistics Standard Systems (MODELS) project is working toward an on-line, interactive system to replace the existing defense logistics standard systems. MODELS will provide connectivity throughout the DoD logistics community and eliminate many of the constraints imposed by the limitations of the current logistics standard systems. As envisioned, MODELS will improve visibility by informing users about worldwide wholesale and retail activities.

Numerous support system enhancements are under way in the Services, defense agencies, and Transportation Component Commands to improve the supply provisioning, transportation planning, and traffic management processes. Additionally, the services are developing new systems to aid in computing resupply requirements, identifying available materiel, and relating availability to an operations plan. USTRANSCOM is establishing an integrated set of transportation procedures and systems and a homogeneous Global Transportation Network that will connect all transportation-related systems. The network will provide in-transit cargo visibility at all echelons. USTRANSCOM's command, control, communications, and computer system capability will improve the direction, coordination, and monitoring of wartime transportation operations.[4]

Emerging technologies for rapidly and accurately coding and transmitting information (e.g., LOGMARS, electronic data interchange) are providing new opportunities for effectively tracking items through the materiel distribution system.

While these improvements will address many of DoD's communications and information systems limitations, they will not resolve disconnects in critical resupply management processes. Resupply management systems are needed that are better integrated than existing systems.

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[3]Department of Defense, *Secondary Item Weapon System Management: Concept and Implementation Plans,* April 1986.

[4]U.S. Transportation Command, *Command, Control, Communications, and Computer Systems Master Plan,* September 29, 1989, describes support system enhancements now under way and USTRANSCOM's plan for a Global Transportation Network.

MAJOR RESUPPLY MANAGEMENT TASKS

Because of the complexity of materiel distribution, we found it useful to think of resupply management in terms of six tasks addressing two operational planning horizons. The first two tasks—forecasting aggregate movement needs and establishing resupply pipelines—set broad system parameters and resource availabilities intended to hold for several weeks. Within those parameters and allocations, the other four decisionmaking tasks should be effectively executable day to day: establishing resupply priorities, allocating materiel, allocating pipeline capacity to specific cargo flows, and controlling cargo and vehicle flows. Figure 2 shows these six tasks and the relationships among them.

Configuring the Resupply System

The first overall concern is to set and implement the overall design parameters for the transportation systems linking the sources of resupply materiel with its destinations. The available transportation resources must be allocated among competing demands

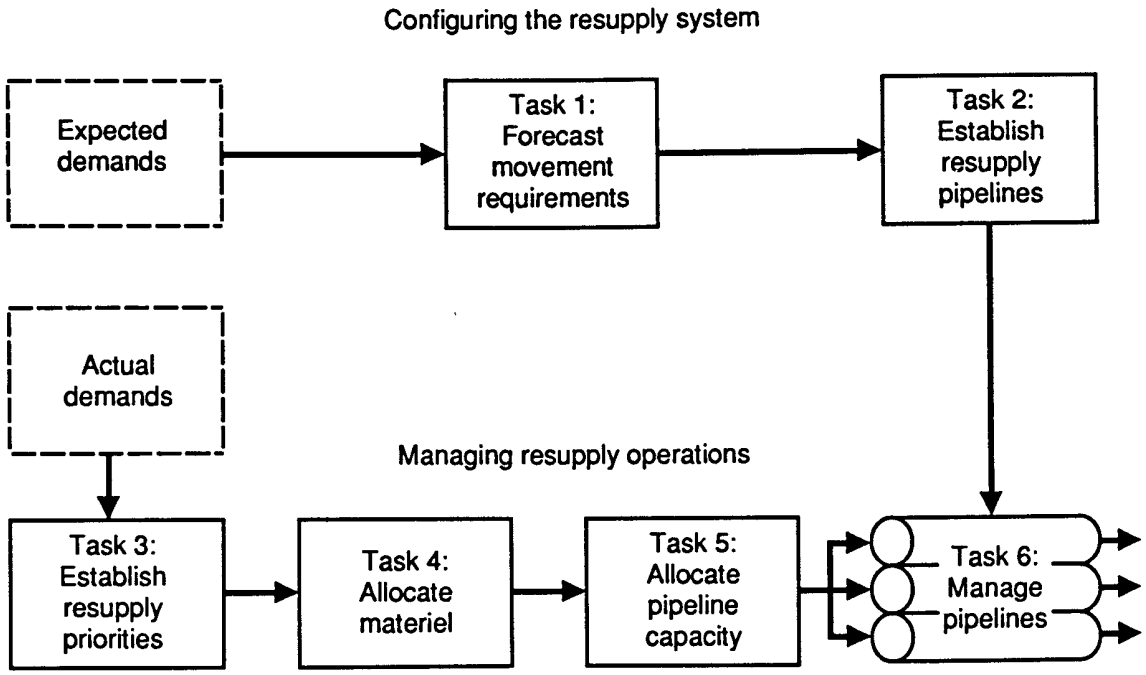

Fig. 2—Resupply management tasks and their interrelations

between and within theaters. Concepts of operations must also be defined to guide the management of those resources. We use the phrase "resupply pipeline" to refer to the transportation resources and concept of operations for any particular materiel flow requirement.

Different movement requirements to a given theater may require different pipelines. For example, the management systems and transportation resources appropriate for critical spare parts or medical supplies might be very different from those appropriate for subsistence supplies to the same theater.

The configuration process consists of two tasks, which are discussed in Sec. II:

- *Forecast movement requirements* based on expectations of resupply demands over, say, the next two to six weeks.
- *Establish resupply pipelines* by allocating transportation resources to pipelines and defining the concepts of operations that will govern their use.

Managing Resupply Operations

The second overall concern comprises the making of day-to-day operational decisions. Because the distribution system is large and complex, many decisions affecting resupply operations are necessarily decentralized. The need to make effective use of scarce resources demands management systems that will guide these diverse decisionmakers. The distribution system must be able to implement these decisions quickly.

Meeting these needs requires four tasks, which are discussed in Secs. III through VI:

- *Establish resupply priorities* to guide the allocation of scarce materiel or lift when not all demands can be met.
- *Allocate materiel* among competing demands.
- *Allocate pipeline capacity* to make best use of the available transportation resources.
- *Manage the pipelines,* controlling the flows of materiel and transportation vehicles through the resupply pipeline.

ALTERNATIVE RESUPPLY MANAGEMENT CONCEPTS

Rather than attempt to design an "optimal" resupply system in one stroke, we have developed alternative approaches to each of the above management tasks. In each case, the set of alternatives includes the current system, because its continuation is one option for the future materiel distribution system. The concepts are hypotheses—potential ways to organize and manage the distribution system's resources. We are now evaluating these options to identify the most promising. Section VII describes that work, which will be documented in a later report.

II. CONFIGURING THE RESUPPLY SYSTEM

The future distribution system must organize the use of the available transportation resources—ships, aircraft, trucks, ports, etc.—to meet the resupply demands of a contingency in the most efficient way. Transportation resources must be allocated among competing demands, between and within theaters. Concepts of operations must also be defined to guide the management of those resources. Because reallocating lift between pipelines and especially between theaters may temporarily reduce resupply capacity, we view pipelines as intended to last at least a few weeks.[1]

FORECASTING MOVEMENT REQUIREMENTS

Since pipelines must meet the movement requirements expected over a multiweek period, DoD resupply management systems must be able to forecast these requirements based on estimates of future resupply needs.

The Current System

Wartime movement requirements are established in the deliberate planning process, which is supported by the Joint Operations Planning System (JOPS).[2] Planning for resupply cargo begins when the numbers and types of units to be deployed in an operation have been identified. A Movement Requirements Generator—a JOPS model—applies Service planning factors (a series of consumption rates) to the forces to be supported, by class and subclass of supply, to estimate the quantities of resupply materiel that will be needed to sustain the force.[3] The Services then revise some of the

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[1]Sealift cannot be efficiently moved from ocean to ocean or theater to theater on a weekly basis. Although aircraft can be reallocated fairly quickly, reallocating the support infrastructure may require more time.

[2]Guidance and procedures for forecasting both wartime and peacetime movement requirements are given in Joint Chiefs of Staff, *Mobility System Policies, Procedures and Considerations,* JCS Pub. 4-04, Washington, D.C., 15 September 1983. Deliberate planning is described in Chapter 6 of the Armed Forces Staff College, National Defense University, *Joint Staff Officer's Guide 1991,* AFSC Pub 1, Norfolk, Virginia, 1991.

[3]The planning factors for items related to personnel—food, individual equipment, packaged fuel, and medical supplies—are expressed in pounds per man per day. Planning factors for equipment-related classes, such as bulk fuel, ammunition, end items,

movement requirements implied by the Movement Requirements Generator to reflect the availability of stocks.[4] The movement requirements derived through deliberate planning can differ greatly from those based on identifying the specific items to be moved in a contingency, since these take into account the availability of stocks.[5]

Movement requirement forecasts based on peacetime planning may prove inaccurate. The requirements developed in deliberate planning are notional, constructed to identify strategic transportation needs. Supplies actually are moved in response to requisitions. These requisitions might call for more, or less, materiel than the planning factors suggest. The uncertainties of combat may lead commanders to shift their goals and priorities, unit deployments, and consequent resupply needs from those anticipated when an OPLAN was prepared. Estimated combat consumption rates may not be accurate indicators of actual wartime consumption.

If a contingency extends beyond the planning horizon used in preparing an OPLAN, there will be a continuing need to forecast movement requirements for subsequent periods. Even if the movement requirements developed in peacetime planning govern the initial phase of a contingency, resupply management systems should include the capacity to incorporate the experience of war as it unfolds.

Alternative Concept: Updating Wartime Movement Requirement Forecasts

The easiest, and most direct, approach to an ongoing means for forecasting movement requirements would be to continue to use deliberate planning processes for forecasting movement requirements throughout a contingency. The planning factors would be applied to updated force densities to estimate the gross movement requirements to support the deployed forces. In essence, a rolling horizon would be used to replicate

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and repair parts, are expressed in pounds per unit-type per day. Construction material requirements are computed directly by the Service components.

[4]The Army applies this process to all classes of supply except VI (personal items) and subclass IVa (general construction materials). The other Services use a similar process for classes I (subsistence), III (petroleum, oil, and lubricants), V (ammunition), and VIII (medical). The Marines plan to extend their effort to all classes other than IVa and VI in the future.

[5]"For example, a test of the capability to provide resupply conducted by one of the Services for a major OPLAN found that 84 percent of resupply requirements could not be satisfied until after the production base was established. This meant that several hundred thousand short tons of materiel scheduled for lift were not available." Logistics Management Engineering, Inc., *Analysis of Systems Interrelationships in Supply Movements,* Annapolis, Maryland, 19 September 1986, p. 55.

continuously those aspects of the deliberate planning process dealing with resupply movement requirements. Existing organizations and data-processing systems should be capable of this task.

A more ambitious approach to forecasting movement requirements on an ongoing basis during wartime would be to develop the capacity to forecast movement requirements on the basis of experience and current information on resupply requirements and available stocks. Four kinds of information would have to be linked to improve these forecasts: (1) the forces involved in each theater over the foreseeable future, (2) the commanders' goals and priorities, including expected operational tempos for the forces, (3) wartime consumption experience and the forces and operations that generated the consumption, and (4) retail and wholesale stocks.

Given this information, it would be possible to forecast resupply demands on the basis of recent wartime consumption experience and updated expectations of the forces' operational activities. The forecasted demands would be compared to available stocks to estimate the degree to which they would be met from wholesale stocks. The resulting movement requirements forecasts would reflect the forces actually involved in each theater and the commanders' current expectations regarding their employment. The forecasts would also incorporate the most recent available information on consumption rates and stocks.

DoD's materiel managers should be able to provide much of the required information. The National Inventory Control Points (NICPs) directly observe worldwide demands and wholesale stocks for the items they manage. Wholesale systems generally have the capacity to forecast operational tempos and equipment densities and are generally supported by large-scale computers and major communications networks. In the course of processing requisitions, they could develop updated estimates of demand rates by relating requisitions for the items they manage to force and equipment densities. If the theaters provided information on force and equipment densities and planned operational tempos, these updated consumption rate estimates could be used to estimate resupply materiel requirements. The materiel managers could relate estimated total worldwide materiel requirements for all customers to wholesale stock positions. They would then forecast movement requirements for the items they manage on the basis of available stocks and expected demand.

The materiel managers' forecasts of movement requirements would have to be collected and aggregated to forecast total movement requirements to each theater. Alternatively, it might be preferable to transmit updated estimates of consumption rates and stocks to the theater and have theater personnel forecast movement requirements on the basis of their knowledge and plans.

ESTABLISHING RESUPPLY PIPELINES

Given forecast movement requirements, DoD's transportation assets—ships, aircraft, trucks, ports, etc.—must be organized and operated in ways that best meet the requirements.

The Current System

The Joint Transportation Board allocates strategic lift capability to the supported CINCs. Once capability is allocated to the supported CINC, the Theater Joint Transportation Board assigns that theater's total strategic lift capability to deployment and resupply operations. The lift assigned to resupply is then allocated to the components.

Current DoD procedures essentially establish four kinds of resupply pipelines to each theater: The Defense Fuel Supply Center manages bulk petroleum, oil, and lubricants (POL), using systems and transportation resources entirely separate from those used to support dry cargo flows. All flows of dry resupply cargo, except for ammunition, are supported by one of two general-purpose resupply pipelines, comprising strategic airlift and sealift, respectively. Neither of these pipelines is defined from origin to destination. (See Fig. 3.)

The shipment of ammunition provides an example of a special-purpose resupply pipeline. Ammunition is generally segregated from other dry cargo, moved in accordance with concepts specific to ammunition movements, and shipped through unique SPOEs and, sometimes, unique SPODs.

An Alternative Concept: Performance-Oriented Pipelines

The current system for pipeline establishment assumes that movement requirements fall into two broad categories—those requiring and those not requiring airlift. Naturally, in a conflict, managers of resupply operations are likely to make finer

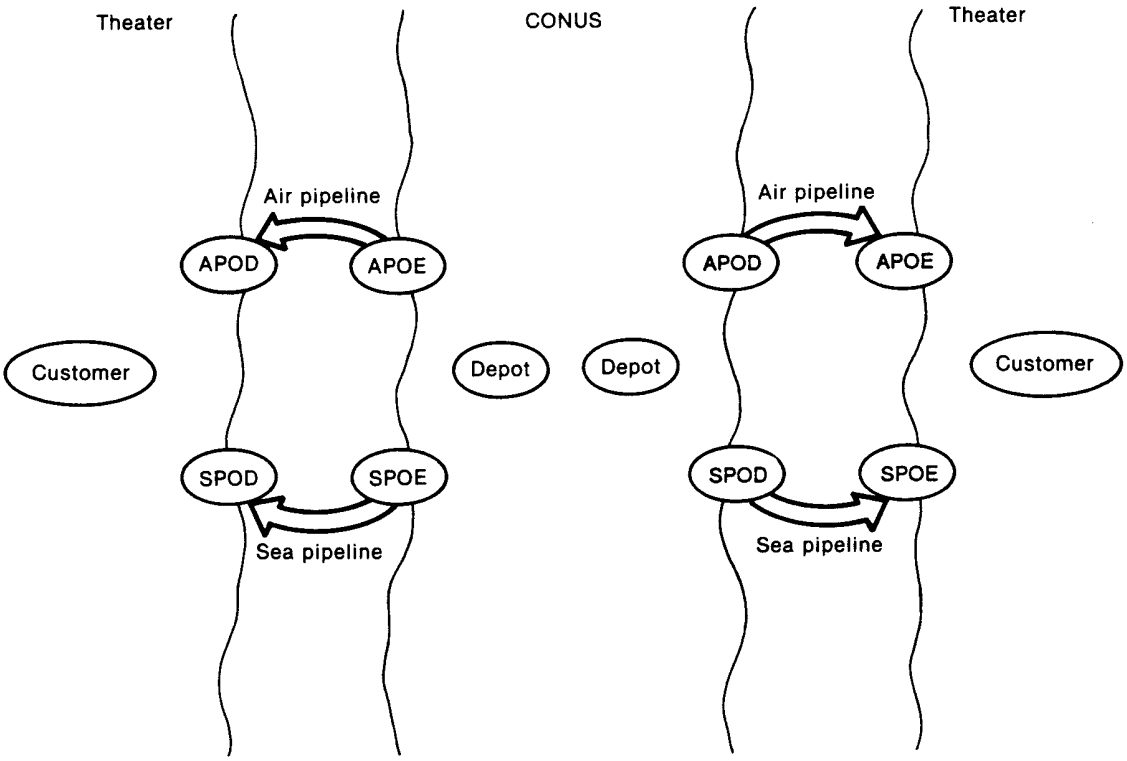

Fig. 3—Current general-purpose resupply pipelines

ad hoc distinctions based on the capabilities of available lift resources. It would be more efficient to plan in peacetime for establishing wartime pipelines that more systematically take into account variations in lift resources and provide options for more integrative resource management.

The performance of a pipeline will vary according to the characteristics of the transportation vehicles assigned to it. The primary distinction is, of course, between kinds of vehicles: aircraft versus ships versus trucks, for example. Differences among the various types of the same kind of vehicle can also have significant effects. Tracked vehicles can be loaded on roll-on/roll-off ships much more quickly than on breakbulk ships; C-5s can deliver cargo to airfields where runway length or hardness limitations preclude other strategic aircraft. Current resupply management does not match performance characteristics to materiel flow requirements.

Suppose, for example, that DoD invested in a fleet of fast ships to enhance deployment capacity. These ships would be available for resupply operations after completing force deployments. It might prove effective to define separate DoD management systems to ensure the use of fast sealift when rapid delivery would be most beneficial. The rapid movement of items that are too large or heavy to be moved efficiently by air might be a particularly effective use of these assets.[6] Similarly, any transportation assets with unique performance characteristics could benefit from such a system.

The performance of a pipeline will also vary according to its concept of operations. For example, a DoD rapid-response concept of operations (like those of express delivery services) would use strategic airlift and origin-to-destination management for high visibility and fast turnaround time. Such a pipeline might be effective for expensive or rare items that need to be delivered to fighting forces quickly, on short notice.

In support of Operation Desert Shield, MAC inaugurated the "Desert Express" fast-delivery service in November 1990. This service delivered items to Saudi Arabia in as little as 31 hours after they were requested.[7] Shipments were reserved for the most critical needs (show stoppers).

Taking full advantage of the opportunities made available by different pipelines would require origin-to-destination management to ensure synchronization of all cargo movement phases. The effectiveness of a separate pipeline organized around fast shipping would depend on well-coordinated movements of premium cargo and the ships. It would do little good to have cargo sitting on a dock awaiting arrival of a fast ship when it could have been delivered sooner on a slower vessel that was immediately available.

MAC used this approach in organizing the Desert Express. Charleston was selected as the CONUS APOE for the Desert Express service, because its joint-use runway expedited commercial air-express delivery to the port. A daily Desert Express flight departed Charleston at 1230, a time selected to dovetail with commercial overnight

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[6]Late in World War II, the War Department organized a rapid-shipping service, known as REX, around the use of particularly fast ships to speed the movement of high-priority cargo. See Roland G. Ruppenthal, *United States Army in World War II: The European Theater of Operations: Logistical Support of the Armies—Volume II: September 1944–May 1945,* Center of Military History, U.S. Army, Washington, D.C., 1987.

[7]David A. Fulghum, "MAC 'Desert Express' Rushes Priority Supplies to Mideast," *Aviation Week and Space Technology,* December 3, 1990, pp. 20–22.

mail and parcel deliveries and with Logistics Airlift System (LOGAIRS) and QUICKTRANS flight schedules.[8]

Planning for the movement of materiel to POEs and onward from PODs is also needed to ensure efficient materiel distribution.[9] Indeed, one of USTRANSCOM's goals is origin-to-destination service, i.e., coordinated planning of resupply from the CONUS source to the user in the theater.[10] This is the view that has informed our alternative pipeline concept (see Fig. 4).

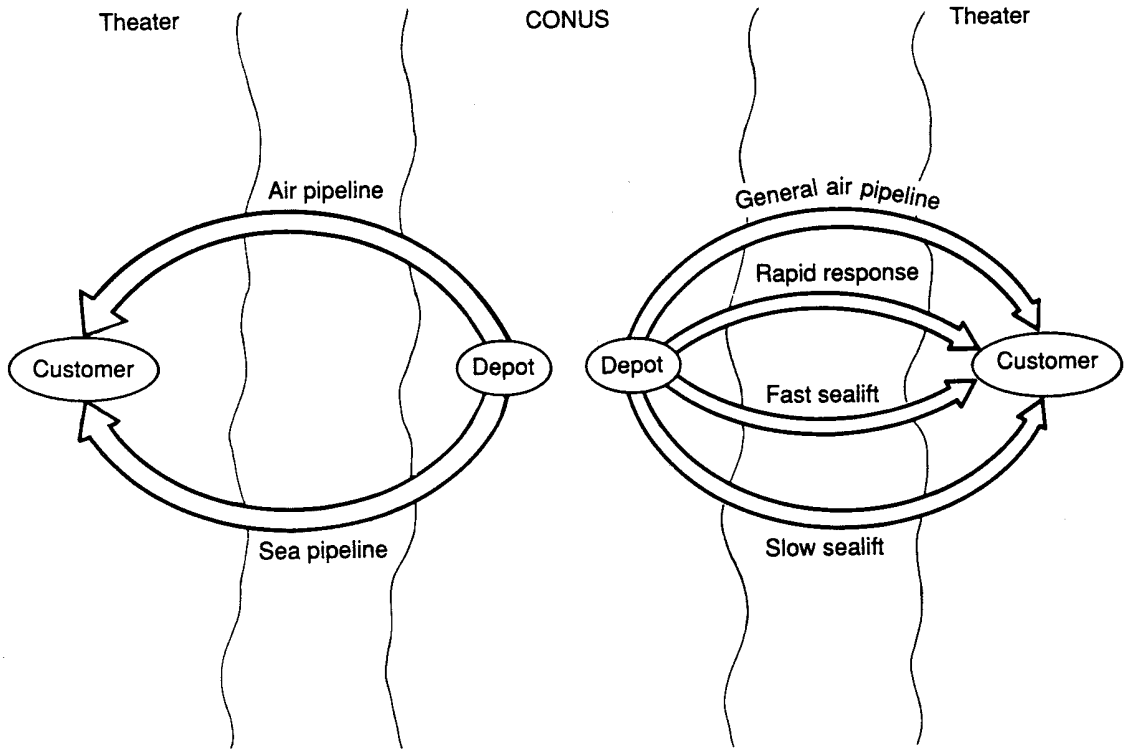

Fig. 4—Establishing origin-to-destination resupply pipelines

[8]Later, a second daily flight, departing Charleston at 1900, was added to the service.

[9]The World War II "Toot Sweet Express" was a fast rail service between European ports and forward depots. It was developed to complement the fast shipping service and provide rapid origin-to-destination movement of urgently needed items.

[10]U.S. Transportation Command, *Concept of Operations,* 22 February 1988, pp. 1–3.

No one set of pipelines would necessarily be preferred in all circumstances. Rather, we suggest the establishment of diverse pipelines that would consider the relevant factors as a contingency developed and determine what would be the most effective use of the available transportation assets over the foreseeable future.

III. ESTABLISHING RESUPPLY PRIORITIES

The materiel distribution system is huge. It operates worldwide, moving a vast array of items through numerous pipelines. Many organizations are involved in distribution. Many commodities and functions are managed separately. Unlike corps commanders implementing the orders of their theater commanders, distribution system decisionmakers are removed from the context of the commanders' intent. Priorities bridge that gap. Priorities should represent the commanders' intent in the context and language of the distribution system's decisionmakers to help them choose which actions to take first.

THE CURRENT SYSTEM

The Uniform Materiel Movement and Issue Priority System (UMMIPS) expresses the relative priority of requisitions and materiel movements.[1] It is expected to function in both peace and war.

Priority Designators

The UMMIPS assigns a priority designator (PD) to each requisition on the basis of the requisitioner's force/activity designator (FAD) and urgency-of-need designator (UND). The FAD is assigned by the Secretary of Defense, the JCS, or a DoD component. The UND is determined by the requisitioning activity. FADs range from I through V:

> FAD I: The units, projects, or forces the JCS considers most important militarily, programs that have been approved for top national priority by the President
>
> FAD II: U.S. combat, combat-ready, and direct combat support forces deployed outside CONUS or deployable within 24 hours
>
> FAD III: All other U.S. forces outside CONUS not included under FAD II and CONUS forces deployable within 30 days

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[1]Office of the Assistant Secretary of Defense (Manpower, Reserve Affairs, and Logistics), "Uniform Materiel Movement and Issue Priority System," *Department of Defense Directive 4410.6*, Arlington, Virginia, 30 October 1980.

FAD IV: U.S. forces deployable between 30 and 90 days

FAD V: All other U.S. forces or activities.

The UND indicates the requisitioner's need for an item as related to his ability to perform his assigned mission:

UND A: Materiel without which the requisitioner is unable to perform assigned operational missions

UND B: Materiel without which the requisitioner's ability to perform assigned operational missions is impaired

UND C: All other requisitions.

Table 1 shows the PD determined by each FAD and UND combination.

Issue and Transportation Priorities

Additional priority schemes are overlaid on the basic UMMIPS priority designators. Each requisition is assigned to an Issue Priority Group on the basis of its PD. Requisitions for which the PD is 01, 02, or 03 are assigned to Issue Priority Group 1 (IPG1). Requisitions for which the PD is 04 through 08 are assigned to IPG2. All other requisitions (PDs 09 through 15) are assigned to IPG3. Depots group, pick, pack, and ship materiel in order of IPG.

Transportation priorities are assigned to shipments on the same basis as issue priorities. Materiel requisitioned under PD 01, 02, or 03 is assigned transportation priority 1 (TP1), and so on. TP1 and TP2 shipments are generally considered eligible for shipment by air. TP3 shipments generally move by surface.

Table 1

UMMIPS PDs

	UND		
FAD	A	B	C
I	01	04	11
II	02	05	12
III	03	06	13
IV	07	09	14
V	08	10	15

Requisitions can be designated for special handling by project codes or by designation as not-mission-capable supply (NMCS), i.e., supply necessary for mission capability. NMCS and requisitions containing a recognized project code will be processed before all other requisitions with the same PD.

Limitations of the UMMIPS

The procedures used to establish the UMMIPS priorities have serious limitations. The FAD code provides limited means for discriminating among requisitioners. The UNDs are subjective, difficult to interpret, and frequently criticized for lack of discipline.

Except for activities designated FAD I, essentially all deployed forces are assigned FAD II. Consequently, all requisitions submitted by deployed forces will have one of three PDs: 2 (UND A), 5 (UND B), or 12 (UND C). The FAD code does not provide means for discriminating among these requisitions. Thus, for the requisition most closely related to actual military operations, UMMIPS devolves to a three-level system. The system continues to break down as TPs come into play. All air-eligible resupply shipments directed to deployed forces have a PD that is either 2 or 5. For these, the most important shipments, port operators can only distinguish between PD 2 (TP1) and PD 5 (TP2) shipments. Their ability to sort out the most critical materiel hinges on the quality of the UND. And if the forces deployed to a theater follow the natural tendency to consider almost all their resupply needs critical, the UMMIPS will devolve into a system in which every requisition has the same priority.

At the outset of Operation Just Cause, for example, Charleston Air Force Base, the primary APOE serving Panama, became inundated with cargo bound for Panama. Backlogs grew. Port operators, attempting to sort out the most important shipments, were frustrated by their inability to distinguish among the cargo awaiting shipment: Every shipment had the same UMMIPS priority and the JCS project code for Operation Just Cause. The problem continued until an expeditor representing the theater arrived and identified the materiel that should go first.[2]

The UMMIPS Improvement Study,[3] conducted by the Logistics Systems Analysis

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[2]A forthcoming Note by David Kassing, James Stucker, and Stephen J. Carroll will discuss materiel resupply during Operation Just Cause.

[3]Logistics Systems Analysis Office, Office of the Secretary of Defense, *Uniform Materiel Movement and Issue Priority System (UMMIPS): Improvement Study,* January 1986.

Office (LSAO) in 1986, found that over the prior 10 years, more than 40 percent of all peacetime requisitions were high priority (IPG1/TP1). So high a rate contradicts the purpose of a system designed to provide premium service to the most important needs of the most important DoD customers. Such a high peacetime rate raises questions regarding the system's ability to identify the most urgent needs in a wartime environment. The rate of high-priority requisitions is likely to increase sharply during war. As forces deploy, their FADs will escalate, their consumption will increase, and more of their requisitions will fall into the highest IPG and TP group.

The LSAO study also found that 61 percent of the high-priority requisitions challenged by the service air-challenge systems were downgraded from air to surface. LSAO concluded that requisitioners were inflating the UND not for urgently needed materiel, but simply to obtain release for issue.

Similarly, the DoD Inspector General's 1988 UMMIPS Audit Report[4] estimated that 47 percent of the high-priority submissions to wholesale inventory control activities had incorrect priorities and that the accuracy of another 4 percent was questionable. The primary problem was lack of compliance with UND criteria. Customers were selecting incorrect UNDs to ensure that materiel was on hand or reserved for their use, regardless of whether or not the materiel was needed immediately.

ALTERNATIVE APPROACHES TO ESTABLISHING PRIORITIES

Both of our alternative approaches focus on the method used to determine the relative importance of a resupply demand. In both cases, a designator like the UMMIPS PD would be used to indicate the priority attached to a resupply demand. Our concern is with the means used to determine whether requisition (or shipment) X should receive attention before requisition (shipment) Y.

Sections IV and V discuss the possibilities for improved management of materiel and improved pipeline allocation, respectively, that would be made possible by these alternatives.

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[4]Office of the Inspector General, Department of Defense, *Audit Report: Uniform Materiel Movement and Issue Priority System,* No. 88-118, Arlington, Virginia, 1 April 1988.

Alternative 1: Enhancing the UMMIPS

The UMMIPS would be enhanced by the development of a more objective approach to determining urgency of need. In particular, some of the ambiguity and uncertainty associated with the application of current UND criteria could be eliminated by developing UND criteria for each unit type, functional area, or set of commodities. Definitions and guidance could then be expressed in terms directly relevant to the specific unit types, functional areas, or commodities. Criteria unique to an area or commodity would not pose difficulties for the UMMIPS. Its design allows diverse methods for arriving at the UND.

The UMMIPS could also be enhanced by providing a means for discriminating among the requisitions submitted by deployed units. Specifically, the UMMIPS could be expanded to allow subdivisions within each FAD, or at least within FAD II. The theater CINC would assign a unit criticality designator to each of the units in his theater. This designator would be used to determine which shipments would be given precedence when the available lift is not sufficient to meet all demands. If, for example, there were three levels of unit criticality—a, b, or c—the theater CINC would assign each unit in the theater to the subdivision IIa, IIb, or IIc, at his discretion.

Transportation priorities would be assigned on the basis of the UMMIPS PD as in the current system, then fine-tuned according to the requisitioner's unit criticality designator. Thus, a shipment to a deployed unit (FAD II) for an UND A item is assigned PD 2 and TP1 in the current system. To take account of the CINC's evaluation of the importance of the requisitioning unit, these codes would be modified to PD 2a and TP1a, for example. If the requisition was for an UND B item, the priority codes would be PD 5a (or 5b, or 5c) and TP2a (or TP2b, or TP2c). Thus, when the available capacity is not sufficient to accommodate all TP1 shipments, TP1a shipments are given precedence over TP1b shipments, and so on for TP1c, TP2a, TP2b, and TP2c.

Materiel would be issued in accordance with current Military Standard Requisitioning and Issue Procedures (MILSTRIP)[5] on the basis of UMMIPS priorities as currently defined. The unit criticality designators would have no bearing on the issue of materiel. Similarly, transportation capability would be allocated among theaters according to current policy without regard for the expanded UMMIPS. A theater

[5]Department of Defense, *Military Standard Requisitioning and Issue Procedures;* DoD 4140.17-M, January 1984.

CINC's decisions regarding which unit criticality designator would be assigned to each of his units would thus not influence the availability of materiel or transportation to other theaters.

Alternative 2: Anticipatory Priority Systems

Increasing centralized visibility, improved decision support systems, and the development of more relevant criteria for resource allocation may permit an alternative, more sophisticated priority system. DoD might consider developing management systems that can anticipate materiel requirements and distribute resupply materiel accordingly.

RAND's Distribution and Repair in Variable Environments (DRIVE) concept is a prototype for a more sophisticated approach to priority-setting.[6] DRIVE uses information about operational requirements (weapon system availability goals and planned flying programs at each Air Force base) to guide decisions about how best to achieve these requirements. Through its decision logic, DRIVE identifies the depot repair and distribution actions that will best meet the goals within repair resource constraints.

For aircraft supplies, DRIVE computes how much the repair of unserviceables and how much the distribution of serviceables to each potential receiving location will contribute to the probability of meeting aircraft availability goals at the end of a given planning period. DRIVE computes the total expected depot demands for each item generated by each base during the planning period. The total expected demands and a variability factor are then used to assess how adding a serviceable asset at a given base affects the probability that it will meet its availability goal.

The payoff associated with adding an item at a base is related to the cost of satisfying that demand, measured in terms of repair hours. DRIVE uses a marginal analysis technique to identify the repair actions that increase the probability of availability the most for the investment (repair hours).

While the current DRIVE algorithm applies to the repair and distribution of aircraft spares, the concepts that underlie DRIVE can be extended to other weapon systems or to nonreparable items. For example, RAND's Visibility of Improved Support

[6]A forthcoming report by Louis Miller et al. will discuss the use of DRIVE for enhancing the responsiveness of depot repair.

optIONs (VISION) project is applying these concepts to devise systems aimed at improving the wartime and peacetime availability of important U.S. Army weapon systems through improved management of high-technology reparable components. More generally, the concepts that underlie DRIVE can be extended to the allocation of a variety of scarce resupply resources that can be related to weapon system availability.[7]

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[7]See, for example, Major Donald E. Hamblin (USAF), "Distribution Priority System: Time for a Change," *Air Force Journal of Logistics,* Fall 1990, pp. 17–21.

IV. MATERIEL ALLOCATION

The demands of a protracted global contingency may exceed the available stocks of some items. The materiel distribution system must be capable of allocating scarce materiel in ways that most effectively meet commanders' needs.

THE CURRENT SYSTEM

The allocation of materiel in wartime would be addressed on a management-by-exception basis by the Joint Materiel Priorities and Allocation Board (JMPAB). However, the JMPAB may be hard-pressed to render time-sensitive decisions or consider more than a few specific items. Problems of materiel allocation may never reach the JMPAB, or may be addressed too late to avoid misallocation.

Without JMPAB intervention, materiel is allocated in wartime by MILSTRIP, the Defense Logistic Standard System that governs materiel requisitioning and issue. MILSTRIP mandates that requisitions be processed in sequence of their UMMIPS PD. Within a PD, requisitions with OSD/JCS project codes and NMCS requisitions are processed first, then requisitions not designated for expedited handling are filled in order of receipt.

UMMIPS procedures for assigning a PD to a requisition do not take account of available stocks of materiel, lead times for procurement, or competing materiel requirements across theaters and military services and over time. MILSTRIP requires materiel managers to reserve stocks of critical items by restricting issues to IPG1 and to JCS-approved projects when stock balances drop below specified levels. Materiel managers may also establish higher levels below which they will not fill IPG3 requisitions. But this reserve requirement does not ensure that enough stocks will be on hand to fill all IPG1 requisitions during a given period. Nor is there any assurance that the earliest-arriving IPG1 requisitions, which will be filled first, are more important than those arriving later, which will not be filled if the bins have been emptied. It is possible that one theater or, in the case of a common-use item, one Service might "empty the bins" before another theater's, or Service's, needs are considered.

The potential magnitude of the problem is suggested by the results of the Army Materiel Command's "exercise capability" (EXCAP) evaluations. EXCAP is an automated tool for processing requisitions to test the capability of the wholesale supply base to support an OPLAN.[1] EXCAP compares the prepositioned requisitions with available wholesale stocks to determine the capability to meet planned resupply requirements. As shown in Table 2, stocks in several supply classes fall far short of the amounts needed to sustain selected OPLANs.

ALTERNATIVE 1: STOCK RESERVE SYSTEMS

In this alternative, specified quantities or proportions of available stocks would be reserved for specified consumers to ensure that some stocks would be available for them regardless of the requisitioning activities of other consumers.

JCS apportionment guidance, including the Joint Strategic Capabilities Plan (JSCP), provides planning advice concerning the proportional distribution of available materiel in global or regional war scenarios. Materiel requirements for the OPLAN that applies to the scenario are computed and sourced. Available stocks, including war

Table 2

FILL RATE (30 DAYS) BY OPLAN
(Percentage filled by quantity)

	Class of Supply				
OPLAN	Individual Equipment	Ammunition	Major End Items	Repair Parts	All
A	17	95	6	25	85
B	13	66	20	30	44
C	0	94	*	21	84
D	9	74	17	8	54
E	1	97	3	30	85
F	24	89	38	51	79
M	16	*	100	25	22

* = No Requirement.

[1]EXCAP software is part of the automated Commodity Command Standard System and uses the same processing procedures that are applied to normal supply requisitions, except that EXCAP transactions do not enter the "live" system.

reserves, wholesale stocks, and stocks assigned to or held by a CINC, are balanced among competing demands to reflect national defense priorities. However, there is no specific provision for translating the planning apportionment scheme to an allocation scheme in wartime.

JCS apportionment guidance could provide a basis for the allocation of materiel in a contingency. The JSCP apportionment percentages would be the initial wartime allocation percentages. They could, of course, be changed as the circumstances of a crisis develop. During peacetime, the percentages would be resident in automatic data-processing systems, though transparent. When an OPLAN is executed, available stocks would be initially allocated in accordance with the apportionment guidance used in developing the plan.[2]

Without JCS allocation guidance, stock reservation would require the Services to determine the appropriate allocation of materiel among CINCs. The Services' materiel managers may have enough information on the relative requirements across theaters to accomplish a reasonable allocation. The materiel managers could establish stock reservations, using their specialized knowledge to determine an appropriate balance among theaters on the basis of relative force structure and similar factors.

The Air Force has developed a concept for a wartime wholesale allocation system that introduces control levels into the basic notion of a stock reservation system. Available stocks would be allocated among theaters on the basis of projected weapon system flying hours, an application factor, and theater demand rates. Control levels would be established within each theater to release materiel by priority group to avoid depleting on-hand stocks. For example, IPG3 requisitions might be filled so long as available stocks in the theater exceed 10 days of supply. IPG2 requisitions might be filled so long as at least 5 days' supply is available. IPG1 requisitions would always be filled.

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[2]For a comprehensive analysis of recent service capabilities to implement materiel allocation, see Robert L. Day et al., *Joint Materiel Apportionment and Allocation: Draft Report,* Systems Research and Applications Corporation, Arlington, Virginia, March 1988.

ALTERNATIVE 2: ALLOCATION LINKED TO COMBAT CAPABILITY GOALS

As discussed in Sec. III, the development of weapon system availability criteria for resource allocation, together with increasing centralized visibility and improved decision support systems, may provide the basis for more sophisticated priority systems that can be used to guide the allocation of materiel. The basic logic of the DRIVE concept, for example, allows allocation of materiel related to weapon system availability.

An even more ambitious version of this alternative would be to base materiel allocation on mission capability goals. Further extension of the logic behind DRIVE suggests a scheme that allots equipment, consumables (fuel, munitions, etc.), and secondary items to maximize the degree to which forces can achieve mission capability goals, taking account of their personnel status.

The JCS-sponsored Status of Resource and Training System (SORTS) is designed to reflect the ability of units and forces to undertake their wartime missions. The current SORTS methodology is a unit-asset-reporting system. SORTS measures units' readiness on the basis of their operational "requirements," determined by the Services. SORTS draws from other, more detailed unit-asset-reporting Systems to track asset distribution and status. Each Service, and the Defense Logistics Agency, has developed and maintains specialized data and resource management systems for keeping track of and managing different types of resources—e.g., major end items and their condition, spares, fuels, personnel, and training. SORTS draws data from these disparate data systems, summarizes them, and compares them to "requirements" for each unit's most demanding wartime mission.

In principle, SORTS, or an improved variant, could be used to relate units' and forces' stocks to their mission capabilities. It would then be possible to apply DRIVE-type logic to estimate the effects of allocation decisions on units' and forces' abilities to perform their missions and compare those estimates to specified mission capability goals. An extended DRIVE-type system might be able to help materiel allocation decisions provide the greatest marginal gain toward specified mission capability goals.

V. ALLOCATING PIPELINE CAPACITY

Resupply pipelines have limited capacities. If the amount of cargo directed to any pipeline exceeds its capacity, congestion will result. Cargo will back up, increasing the time it takes an item to get from its origin to its destination and threatening operations dependent on the timely delivery of resupply cargo. On the other hand, if the amount of materiel directed to a pipeline is less than its capacity, the transportation resources provided to that pipeline will not be fully utilized.

THE CURRENT SYSTEM

In peacetime, each of the Services controls costs by diverting shipments from air to surface transport when surface movement will be adequate. Each Service's airlift clearance authority (ACA) challenges TP1 and TP2 shipments based on criteria established by the Service. If the requisitioner insists on air transport, the materiel is generally shipped that way. Transportation priorities are automatically downgraded if there is no response to the ACA within a specified time. Figure 5 portrays the relevant portions of the current system for assigning cargo to resupply pipelines. This system has two basic limitations: it disregards both the available lift capacities and the CINCs' goals and priorities.

The system does not match the quantity of materiel assigned air-eligibility to the available airlift capacity, and the Services' air challenge criteria are not designed to identify and redirect cargo flows in excess of their airlift allocations. Since there is no way to ensure that aggregate cargo flows to APOEs will not exceed the total capacity of the air resupply pipeline, congestion and delays result.

For example, early in Operation Just Cause, some 48 tractor-trailer loads of packaged meals (not palletized for air shipment) arrived at Charleston AFB. The meals, along with all the other resupply cargo destined for Panama, overwhelmed the base's cargo-handling capacity and exceeded the capacity of the available airlift. The backlog of cargo for Panama grew quickly. Within a week, Charleston had at least 457 tons of cargo on hand, but not yet manifested for shipment. This included 86 pallets that had

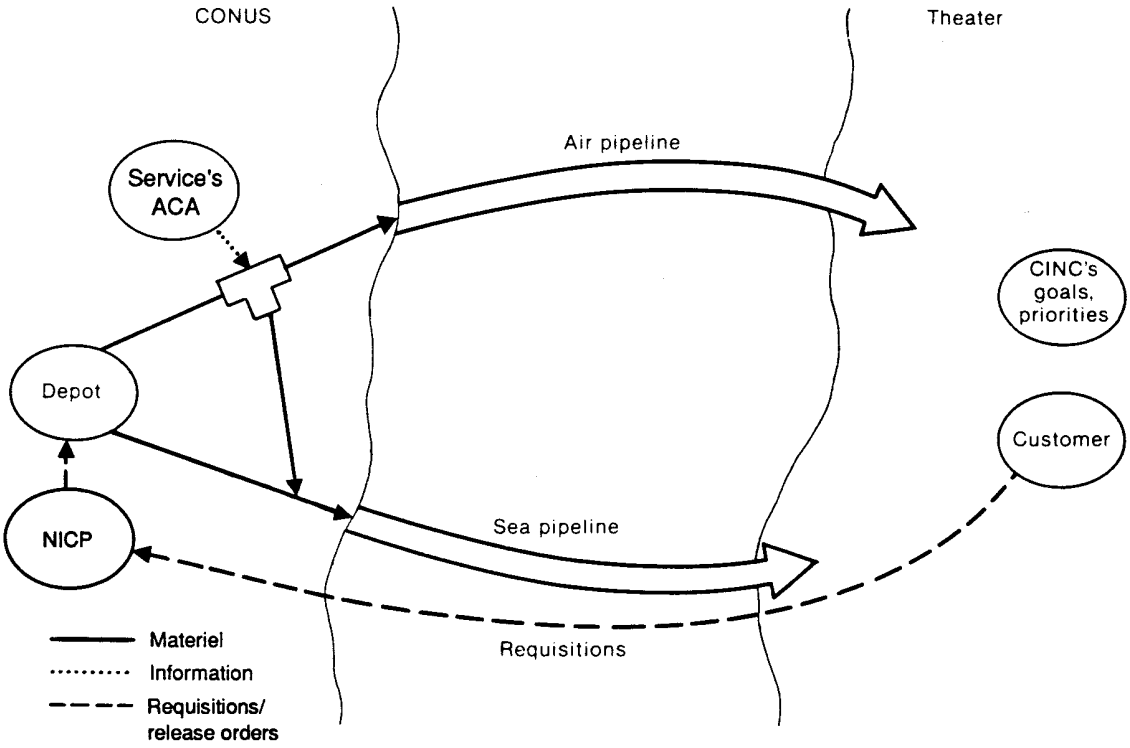

Fig. 5—The current system for allocating cargo to pipelines

been waiting for more than 48 hours. All the cargo destined for Panama had been cleared for air shipment.[1]

There is also no way to ensure that the available airlift capacity will be fully utilized. Although unlikely, it is conceivable that the combination of UMMIPS transportation priorities and the air challenge programs will divert so much materiel to surface transportation that some airlift capacity will go unused for a time.

Cargo diverted from airlift is directed to sealift, which has similar problems. There is no way to ensure that the amount of cargo flowing to SPOEs will match the available capacity. Congestion and consequent delays could build at seaports.

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[1]A forthcoming Note by David Kassing, James Stucker, and Stephen J. Carroll will discuss materiel resupply during Operation Just Cause.

The issues raised here would be further complicated if DoD adopted performance-oriented pipelines. Suppose, for example, that a rapid-response pipeline were established. The UMMIPS priority system cannot readily identify which materiels would be directed to the rapid-response pipeline. Existing clearance authority procedures would have to be modified to allow shifting of cargos between the normal air pipeline and the rapid-response pipeline and diversion of cargos to surface.[2]

Finally, there are no explicit, formal links between commanders' goals and priorities and the ACAs' challenge criteria. Commanders could have to resort to informal means to ensure that scarce transportation would be put to the use that best served their needs.

ALTERNATIVE 1: THEATER-ORIENTED PIPELINE ALLOCATION

A theater-oriented organization responsible for allocating pipeline capacity could direct shipments to pipelines to make the most effective use of each pipeline's capabilities. To accomplish its mission, this organization would use four types of information: (1) the demands for materiel (requisitions), (2) the commanders' goals and priorities, (3) resupply pipeline capacities, and (4) the available stocks.

Several variants of this alternative are possible. Figure 6 portrays one—a system with a theater airlift clearance authority (TACA). The TACA would use information on demands and stocks to estimate the likely fill rates and consequent transportation requirements. It would compare these requirements with the resupply pipeline allocations and capacities to determine whether the pipelines can meet the demands. If capacities were sufficient, the TACA need take no further action. If the capacities were not sufficient, the TACA would work with the Joint Transportation Board and Theater Joint Transportation Board to alter lift allocations.

If additional lift could not be made available, the TACA would provide new challenge criteria to the ACA to make the best use of the available capacity. To define these criteria, the TACA would use the commanders' goals and priorities to identify the units whose performance is most critical to forthcoming operations, the commodities most needed to support those operations, or other appropriate specifications of resupply priorities. For instance, the TACA might divert certain types of cargo, even if "high

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[2]This was done for Desert Express. Rigorous enforcement of the Desert Express priority by the ACA prevented saturation and congestion.

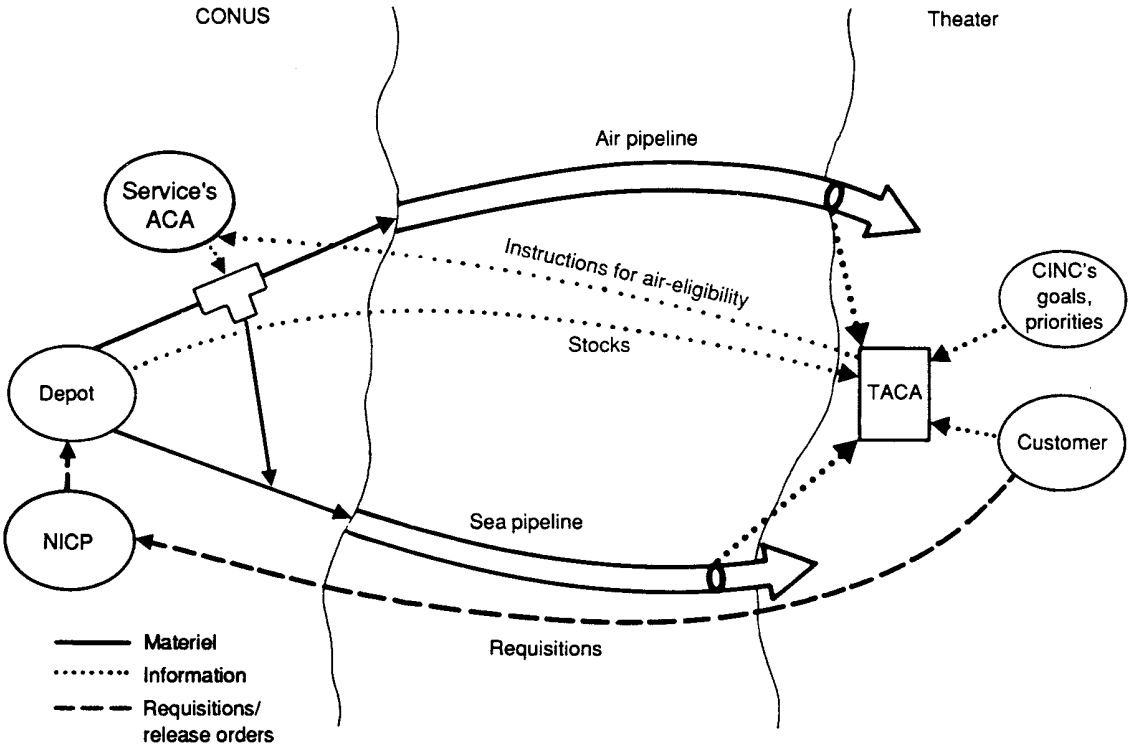

Fig. 6—TACA allocation scheme

priority" in the UMMIPS sense, if other commodities are deemed more important to the commanders' goals and priorities.

Figure 7 portrays a second variant—a system with a theater distribution control point (TDCP). This concept merges the functions of the ACAs and the TACA into a single organization. The TDCP would itself be the intermediary between the requisitioner and the national inventory control points (NICPs). It would dynamically assign issue and transportation priorities to direct cargo to appropriate pipelines rather than modify challenge criteria. The unit representatives sent to the APOEs during Operation Just Cause (see Sec. III) were an adaption of the current system in the spirit of the alternative described here. They provided a direct connection between the commanders on the scene in Panama and the distribution system's operators. When the

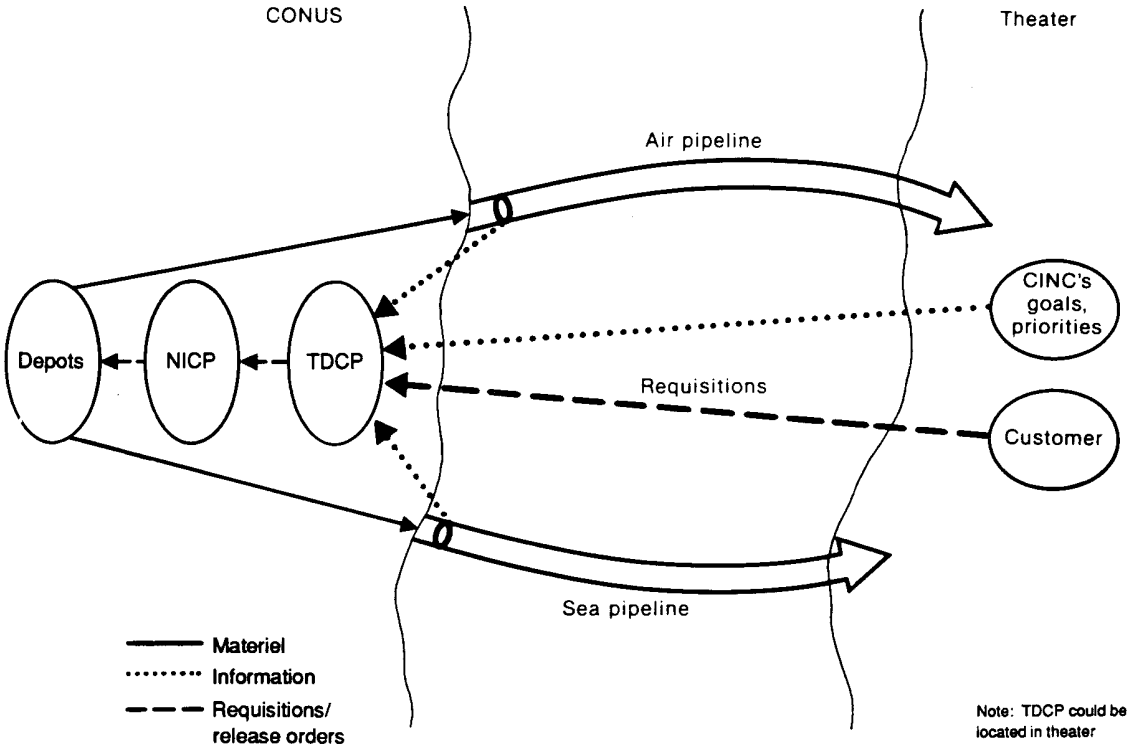

Fig. 7—TDCP allocation scheme

system couldn't meet all the demands placed upon it, these expediters identified the most important needs.

Either of these variants could be located in the theater or in CONUS. The staff would be small, fewer than 100. The organization would require secure communications links with the theater, to obtain and protect information on commanders' goals and plans. The Army's Logistics Information File now receives information on requisitions as they are transmitted to the NICPs and on fill rates as the NICPs send Materiel Release Orders to depots and vendors. Similar procedures would serve the needs of a theater-oriented organization. These organizations would require sufficient automatic data processing support to compute near-term demands for pipeline capacity.

ALTERNATIVE 2: DECENTRALIZED CONTROL WITH ENHANCED PRIORITY SYSTEMS

Enhanced priority systems are another alternative. Decentralized pipeline allocation decisions may be aided by the development of weapon system availability criteria for resource allocation, together with increasing centralized visibility and improved decision-support systems. Priorities established in a system patterned on the DRIVE concept could be used to guide decisions about which items should be directed to which pipelines to best meet weapon system availability goals.

Further extension of the DRIVE logic would support the allocation of pipeline capacity to equipment, consumables, and secondary items so as to maximize the achievement of mission capability goals, taking personnel status into account. As discussed in Sec. IV, SORTS, or an improved variant, could be used to relate the assets of units and forces to their mission capabilities. It would then be possible to apply DRIVE-type logic to estimate the effects of pipeline allocation decisions on mission performance.

VI. PIPELINE MANAGEMENT

A resupply pipeline includes transportation vehicles and the networks through which cargo flows from depots, storage areas, and vendors through a variety of transshipment nodes—consolidation points, terminals, and intermediate storage areas—to the points of issue to the customer. Pipeline management decisions direct the flows of cargo and transportation vehicles through the network to meet the performance requirements of the pipeline.

THE CURRENT SYSTEM

The current DoD materiel distribution system free-flows cargo through a wide variety of loosely coupled transportation networks that are, for the most part, independently managed. In CONUS, most cargo moves on commercial vehicles. Depot transportation officers arrange for the movement of cargo by a commercial carrier. Commercial carriers schedule vehicle flows in response to transportation officers' arrangements. Except for shipments that require special handling, such as hazardous materials or sensitive items, materiel is shipped when vehicles become available.

The Air Force and the Navy each manage a commercial contract cargo airlift network for high-priority shipments within CONUS. The Navy Materiel Transportation Office establishes air routes and flight frequencies for the Navy's QUICKTRANS system. The Air Force Logistics Command establishes route patterns and schedules for the LOGAIRS, which links the air logistics centers, the principal APOEs, and major CONUS bases. Depot transportation officers route appropriate cargo into these systems.

MAC manages all strategic airlift, via both military and civilian aircraft under contract. The command uses a large, complex strategic mobility model, FLOGEN, to develop a vehicle flow schedule that meets anticipated cargo flow requirements.[1] Channels—regularly scheduled flights—are established to serve high-frequency cargo flow patterns. Special-assignment airlift missions—one-time flights—support unusual

[1]FLOGEN was not used in Desert Shield. An improved model, ADANS, is being developed and is expected to replace FLOGEN in the early 1990s.

airlift requirements, such as outsized or bulky items, classified movements, and low-frequency cargo requirements.

MSC either uses owned or chartered ships or contracts for commercial carriage. It uses SEACOP, a large, complex strategic mobility model to schedule the ships it controls.[2] The availability of commercial capacity depends on schedules established by the commercial operators.

The organization of transportation in a theater is managed by the unified commander and his staff. The transportation officers on the theater joint staff coordinate the transportation requirements and responsibilities of the military services. In allied territory, the joint transportation staff will work with the local agencies controlling the allotment of facilities. In any case, cargo routing and transportation vehicle scheduling become the province of the theater transportation officers.

In sum, the current system by and large uses two different approaches to network management. Strategic airlift and sealift rely principally on established schedules. These schedules are determined by anticipated cargo flow requirements; they are not modified to account for the actual availability of cargo. Cargo flows through these segments of the network in accordance with established schedules. CONUS and theater surface movements are organized in the opposite order. Vehicles are scheduled in response to cargo routing decisions as cargo becomes available.

Although the current system's focus on strategic transportation assets will probably make full use of available transportation capacity, it is less likely to meet required cargo delivery times. The emphasis on scheduling and utilization of strategic transportation assets has a bias toward maximizing throughput. Further, cargo is generally routed through consolidation points that palletize or containerize materiel. Consolidation may reduce handling costs at other nodes and ensure better utilization of transportation assets, but at the expense of queuing and handling delays at the consolidation node and extra transit time to and from that node.

PERFORMANCE OF THE CURRENT PEACETIME SYSTEM

The UMMIPS specifies delivery time standards. Table 3 presents the percentage of fiscal year 1988 shipments that met these standards. There are differences by shipper and by priority group, but on the whole, the current system does not perform well against

[2]An improved model, SEASTRAT, is being developed and is expected to replace SEACOP in the early 1990s.

the UMMIPS standards. In the best case, for the highest priority cargo (IPG1), fewer than one-third of the shipments met UMMIPS time standards.

Why does the system fail to meet the UMMIPS performance standards? Table 4 provides a more detailed picture, using data derived from the Army Logistics Intelligence File for Army shipments to Europe and Africa during the third quarter of fiscal year 1989.[3] The delays are mostly in cargo handling and management, rather than cargo movement. CONUS, transoceanic, and theater transit times account for one-quarter to one-third of the time required to fill an air-eligible requisition. The remainder of the time is consumed by various processing and hold operations. Similarly, nearly half the time required to fill a requisition via seavan is spent in processing and holding. Carrying the cargo on faster land vehicles, ships, or aircraft would not greatly reduce the current delivery times. Improved pipeline performance thus depends upon some combination of means for reducing handling times and queuing delays.

The pressures of wartime may improve system performance. On the other hand, a resupply system that is not responsive in peacetime may become irrevocably clogged as a result of the surges and confusion of war. Congestion and queuing may occur at depot and storage area loading docks, ports of embarkation (POEs), and ports of debarkation (PODs). Such impediments may reduce throughput tonnage and increase delivery times and may also reduce or eliminate the feasibility of expediting urgently needed commodities.

Table 3

PERCENTAGE OF SHIPMENTS RECEIVED ON TIME
(Fiscal year 1988, all destinations)

Shipper	IPG1	IPG2	IPG3
Army	8	17	82
Navy	26	16	69
Air Force	32	28	70
Marine Corps	2	4	51
DLA	21	29	79

SOURCE: MILSTEP Highlights, DOD MILSTEP Central Data Collection Point 17 February 1989

[3]Results for overseas shipments to other destinations exhibit similar patterns.

Table 4

LOGISTICS SYSTEM PERFORMANCE
Army Distribution, April–June 1989
Area 2 (Europe and Africa)

Activity	Average Time (days)		
	IPG1	IPG3 (Air)	IPG3 (Seavan)
Requisition submission and ICP processing	5.9	5.2	6.9
Processing and hold (depot, container consolidation point [CCP], POE, POD, supply support activity)	15.2	16.8	22.1
In transit(depot to CCP to POE to POD to supply support activity)	8.9	9.1	31.4
Totals	30.0	31.1	60.4
UMMIPS standard	12.0	33.0	74.0

SOURCE: Army Logistics Intelligence File

The current system also does not include a transportation plan for handling the Army's precut requisitions. If they were dropped into the current system, the resulting surge of cargo flows could defeat the priority system in the early days of a war and create serious congestion problems.

AN ALTERNATIVE: DYNAMIC PIPELINE MANAGEMENT

In this alternative, cargo would be dynamically routed through the system; vehicle schedules would be arranged to meet the cargo where and when needed. Such a system would evaluate the competition for the available carriers. Requisitions would be released, with a routing, to the depot or storage area in time to be shipped to the designated POE. The POE and routing would be chosen to minimize the total delay for all requisitions currently in the system or anticipated. The schedules of overseas carriers and the availability of CONUS trucking and rail transportation would have to be completely visible to system managers, as would the requisitions competing for space on each leg with inadequate capacity.

The backlog and resulting congestion and delays at the Charleston APOE during Operation Just Cause stimulated an ad hoc adaption of the current system that was similar in spirit to the alternative proposed here. The shipments of packaged food that choked Charleston originated at the Defense Logistics Agency depot in Memphis, Tennessee. As Charleston's backlog grew, the idea of flying the packaged meals directly from Memphis to Panama emerged. The adaptation both eased pressure on Charleston, allowing more rapid processing and onward movement of the materiel that continued to flow through there, and eliminated delays in moving the meals to Panama.[4]

This alternative system would deal with congestion by queuing computerized requisitions instead of queuing materiel. The queuing of requisitions would also have the advantage of facilitating allocation of scarce materiel resources.

Materiel in transit should be visible to resupply managers. So every container, regardless of type, would be marked with a machine-readable and visually obvious identification number. Documentation would be automatically updated as each package is loaded into larger carriers or into a different vehicle. The resulting documentation would be forwarded to the destination as the bill of lading. The bill would show which carriers are transporting the item, its scheduled arrival, which container it is in, and which subcontainer it is in. Supply computers could be updated from the computerized bill of lading. These records could be corrected and updated if necessary as the container is unloaded and as items are stored.

By contrast, the current practice is to update the supply computer and make each recently arrived item available as it is discovered in the process of unloading a container. This procedure is time consuming and does not provide a reliable way of finding an urgently needed commodity.

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[4]A forthcoming Note by David Kassing, James Stucker, and Stephen J. Carroll will discuss materiel resupply during Operation Just Cause.

VII. EVALUATING ALTERNATIVE RESUPPLY CONCEPTS

Over the long term, DoD and civilian investments in transportation infrastructure and vehicles determine the assets that will be available in a contingency.[1] Similarly, long-term procurement policies and programs affect the kinds and quantities of military materiel that will be available at the outbreak of a conflict. When a contingency does arise, the materiel distribution system must be able to effectively organize and manage whatever assets and materiel are then available. The standard for judging the concepts considered here is, accordingly, *whether, and how much, they enhance the degree to which the materiel distribution system is able to respond to commanders' needs and priorities, given available transportation assets and materiel.*

The distribution system's mission is to meet the customers' resupply requirements—to deliver the materiel they need by the required delivery date. The importance of delivering any particular item on time depends on the urgency of the requisitioner's need for the item. Given resupply demands and corresponding deliveries, *an index of the distribution system's performance is the number of days late in meeting each demand, weighted to reflect the importance of the item to the specific commander's goals, aggregated over all demands.*

METHOD

To investigate the value of the alternatives sketched out above, we designed and built a simulation model of an origin-to-destination transportation system comparable to the resupply distribution system. The transportation system is expressed in terms of numbers, types, and capacities of transportation vehicles; capacities and connectivity of nodes; and other relevant factors. Although the model represents only a fraction of the total system, it provides a means of quantifying the value of different management mechanisms and different assumptions about transportation and handling times.

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[1]Other parts of the DoD Future Distribution System Study have examined trends in civilian investments in transportation facilities and vehicles and the need for DoD investments to obtain distribution capacities that will not be available from the civilian sector.

We specified a time-phased list of resupply demands for various commodities. These demands are described by commodity class, UMMIPS priority, tons, day of requisition, and required delivery date. We also defined a delay-weighting function for each requisition. This function measures the importance of meeting the required delivery date and allows computation of a penalty for each day the delivery is late.

We are now testing the alternative concepts described in this Note. We specify the management systems and decision rules for each. We use the model to simulate the operations of the distribution system when governed by that complex of management systems and decision rules. The model provides an estimate of how long it would take to respond to each of the resupply demands. Whenever the model estimates that a requisition would not be filled by the required delivery date, we use the requisition's delay-weighting function to compute a delay penalty. Finally, we aggregate the delay penalties over the entire time-phased list of resupply demands to determine the total delay penalties that arise from using the specified alternative to respond to the requisitions and manage the resulting flows of materiel through the transportation system.

We are evaluating each of the alternative management concepts in a number of situations, invoking different demand streams and different transportation characteristics, such as infrastructure and distances. The model assumes two types of conflicts: a large war with heavy demands for resupply materiel and a smaller war with smaller demands but requiring transportation over greater distances. In some cases, we treat these as entirely independent tests of a concept, in others as simultaneous conflicts. The latter allows us to explore the effects of the alternatives on the distribution system's ability to respond in a multitheater contingency.

MODEL CHARACTERISTICS

We have specified resupply demands, transportation system characteristics, and other relevant factors only to the level of detail necessary to test the alternative concepts. In particular, the model does not address the capability of the distribution system to sustain any particular scenario. Rather, we are examining the effectiveness of alternatives in different "situations" characterized by notional demands and a limited transportation system.

Resupply Demands

We generate a time-phased list of resupply demands for a conflict in three steps: First, we estimate consumption by commodity class by applying a series of planning factors to an assumed profile of forces in the theater. Second, we estimate the amount of materiel that would have to be delivered to the theater to meet the estimated consumption and to maintain theater stocks at desired levels. Third, we develop a series of requisitions for the needed materiel, introducing uncertainty by random variations in requisition dates, quantities demanded, and required delivery dates.

We develop several different sets of time-phased requisitions for each situation. We vary the assumed planning factors to explore the effectiveness of various concepts when consumption is systematically greater, or less, than anticipated. We assume different levels of initial theater stocks and different theater stock-level objectives to test the sensitivity of the results to these concerns.

Transportation Assets and Capabilities

The transportation system comprises five CONUS depots, one APOE on each coast, two SPOEs on the east coast, and one SPOE on the west coast. We assume that one APOD and two SPODs are available in the large war and one APOD and one SPOD in the smaller conflict. This system is much simpler than the actual numbers of depots and CONUS and theater aerial ports and seaports. Nonetheless, it suffices to pose the basic issues: allocating transportation assets to establish pipelines to each theater, allocating materiel between competing demands, and assigning each shipment to an appropriate pipeline.

The model assumes that depots have sufficient outload and CONUS transportation capacity. Each transit time depends on the depot and port combination, but is invariant for that combination. The model assumes that POEs and PODs have limited throughput capacities and that congestion sets in, slowing throughput time, as the volume of materiel in the port approaches its capacity. Airlift and sealift capacities approximate current capacities. Airlift is assumed to be fully devoted to deployment for the first fifteen days of a contingency and is assumed to be fully available for resupply operations thereafter. Sealift gradually becomes available over time. Air and sea transit times between each POE-POD combination do not vary. Theater transportation has limited capacity and fixed transit times.

We size the total expected demands so that the available transportation assets are just sufficient to handle the demand streams, if effectively managed. The actual demands in a given evaluation average to these expected values, with an adjustable degree of random variation. The evaluation thus quantifies the importance and ability of management systems to mitigate the effects of variability in the demands for materiel.

One set of tests evaluates each alternative, assuming that transit times between any two nodes in the transportation system equal the average transit times actually observed for Army shipments between those nodes. As noted earlier,[2] these times generally exceed UMMIPS time standards. A parallel set of tests evaluates each alternative, assuming that transit times between nodes never exceed UMMIPS time standards. That is, we use observed average transit times for segments on which they beat, or at least meet, UMMIPS standards, and UMMIPS standard transit times on segments on which the observed average times exceed UMMIPS standards.

Delay-Weighting Functions

The commanders' resupply priorities are represented in the model by delay-weighting functions. These functions are used to test the relative effectiveness of alternative concepts. We use diverse functions to simulate the diversity of pressures placed on the distribution system and explore different functions to check the robustness of the results.

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[2]See Tables 3 and 4.