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TOWARD THE USE OF AVAILABILITY
MODELS FOR SPARES
COMPUTATIONS IN THE DEPARTMENT OF DEFENSE

June 1982

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EXECUTIVE SUMMARY

The purpose of Department of Defense (DoD) inventories of spare and repair parts is the readiness and sustainability of our military forces. To achieve that purpose:

- Readiness and sustainability goals for weapon systems and other end items should be specified with full visibility of the costs of those goals.
- Requirements for spare and repair parts should be computed to provide specified levels of readiness and sustainability at least cost.
- Program and budget resources should be allocated to resource categories (e.g., engines, recoverables, depot-level repair, consumables) to provide specified levels of readiness and sustainability at least cost.
- The logistics system should be viewed as an integrated whole, not as separate "wholesale" and "retail" levels.

We have examined the extent to which the inventory management systems of the Military Departments and the Defense Logistics Agency (DLA) meet each of the above criteria. We conclude that important changes in resource allocation methods and requirements computational systems are needed.

It is common practice to manage DoD inventories to satisfy supply-availability (i.e., fill-rate) goals. Such goals may apply to a class of items within a Military Department, to a specific management system, or to an organizational entity. Unfortunately, the link between supply availability and weapon-system availability is far from direct. High fill rates, for example, are meaningless if substantial numbers of weapons are not-mission-capable for want of spare parts. An expected-backorder goal is a better readiness surrogate, but it fails to account for differences in the numbers of distinct line items and the mixes of component unit prices among weapon systems; therefore, minimizing expected backorders generally results in lower

availability rates for weapon systems with relatively large numbers of components or with relatively costly components. The best approach, when feasible, is to link inventory decisions directly to weapon-system availability goals. Availability models now make that direct approach feasible when adequate data exist.

The Air Force is in the best position among the Military Departments and DLA to implement an availability model for spares requirements computations. In fact, the Air Force plans to run an availability model concurrently with its present recoverable spares requirements computation in the immediate future, and compare the results. It could, with fairly modest effort, replace the variable-safety-level (VSL) algorithm of its current recoverable spares requirements system with an availability model, and extend its application later to other such end items as ground radars and missiles.

The Army, on the other hand, faces serious problems in data collection. Its National Inventory Control Points do not have adequate visibility of assets, nor do they have the data from which component pipelines can be estimated accurately. Their highest quality data probably are those on aircraft; thus, we recommend that the Army apply availability modeling first to aircraft spares requirements. That step should be coupled with an evaluation of alternative data collection and reporting systems and early implementation of a system that will support an availability model.

The Navy needs to improve the accuracy of its data on component characteristics and end-item configuration, but its data problems are not nearly so serious as those of the Army. We recommend that the Navy expand its use of availability models beyond their limited use in initial provisioning by applying them first to computation of stock levels at all echelons for aircraft. As a next step, we recommend their extension to ships.

The DLA is responsible for procuring and managing items that are broadly termed consumable items. A large portion of DLA-managed items are common to more than one application or to more than one Military Department. Use of an availability model would require multiple weapon-system codes for many items and would necessitate prorating estimated demand or partitioning actual demand among weapon systems. Before implementing any widespread application of availability models, DLA should assess the practicability and cost of acquiring and maintaining the requisite application data.

Availability optimization models constitute the most promising approach to the problem of relating program and budget resource levels to military readiness and sustainability. Furthermore, they will compute the least-cost mix of spares to achieve specified levels of weapon-system availability. The Military Departments differ in the relative sophistication of their inventory management and requirements computational systems, the quality and completeness of their data bases, and their policy and operating directives. As a result, they also differ in the amount of difficulty they face in implementing availability models to compute spares requirements to support specified weapon-system availability objectives. Because the quality and completeness of aircraft data are generally higher than for other weapon systems, we recommend as a first step that all the Military Departments move forward aggressively to implement availability models to compute aircraft spares requirements.

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1. INTRODUCTION

The fundamental purpose of inventories of spare and repair parts in the DoD is to support military readiness and sustainability. There is a conceptual difference between these two components of military capability. Readiness is the ability of forces, units, weapon systems, or equipments to deliver the outputs for which they were designed, including the ability to deploy and employ without unacceptable delays. Sustainability is the "staying power" of our forces, units, weapon systems, and equipments, often measured in number of days. Readiness is essentially a measure of pre-D-Day status, extending at most into initial combat operations, while sustainability is a post-D-Day measure; hence, we often speak of peacetime readiness and combat sustainability.

This logic has a corollary in the management of supply systems. Inventories of spare and repair parts in defense supply systems are viewed as having two components, peacetime operating stocks (POS) and war-reserve materiel (WRM). The purpose of POS is to support readiness; the purpose of WRM is to support sustainability. The most direct and meaningful measure of the influence of POS on readiness is weapon-system (or end-item) availability.

We use the terms availability, end-item availability, and weapon-system availability interchangeably to mean the probability that an end item, such as a tank or an aircraft, selected at random, is not waiting for a component to be repaired or shipped to it. (We do not mean supply availability or fill rate.) Given that the purpose of POS is to support readiness and that availability is the best measure of readiness, it follows that POS requirements computations should be designed to achieve specified levels of availability at

least cost. This concept of POS requirements computations was stated as an objective of the DoD in the Defense Guidance related to the FY84 Program Objectives Memorandum:

"Our objective is to size and fund POS secondary item inventories to support programmed weapon system availability rates and operating tempos. ... the Services will develop and institute, by end FY85, the ability to size weapon system initial and replenishment secondary item inventories to meet explicit weapon system availability and operating tempo objectives."

We would only add to this direction the phrase "at least cost".

The logic of WRM requirements computations is not as straightforward as it is for PCS. There are two difficulties in structuring the WRM problem. The first is in specifying the objective function; the second is in specifying a scenario. These issues are beyond the scope of this report but will be addressed in a subsequent report on methodological issues in WRM requirements computations.

AVAILABILITY MODELS

In this report, we examine the supply systems of each of the Military Departments to determine the impediments to computing POS requirements to meet specified weapon-system availability objectives. We focus on the use of availability models, which we define as mathematical models that compute sets of points comprising availability-vs.-cost curves, each point of which is an optimum in the sense that it represents the least-cost mix of spares for that level of availability, and, conversely, the greatest availability achievable for that level of investment. For each point on the curve, the model computes a stockage posture which is defined as a set of line-item stock levels by quantity and location. Each location is associated with an echelon of the logistics system, e.g., base, depot, direct support unit, etc.

The kind of availability models we have in mind in our discussion in this report require detailed data on every line item. Those data include: unit

cost; removal rate (maintenance factor); application data; and resupply data. The application data, for each application, consist of the end item name; the end item population and usage rate; the quantity per application; the future application percentage; the level of indenture; and the identification of the next higher assembly. The resupply data consist of the number of echelons; the number of users (claimants) at each echelon; the order-and-ship times between the echelons; the average turnaround time (including retrograde shipment and repair) for each echelon; the percentage of component removals at each echelon; the percentage of component repairs at each echelon; the washout (condemnation) percentage; and the procurement leadtime. This set of data represents an ideal situation. In specific cases, requirements computations may be possible without every data element for every line item.

There are several availability models in use in DoD that generally satisfy our definition, but only one of them currently has the ability to allocate resources across weapon systems and take explicit account of common items. However, that common-item logic could be incorporated in other models. Another important group of spares optimization models includes those that minimize expected backorders for a specified level of investment. Our remarks about availability models throughout this report generally apply to this latter group as well. However, if a model focuses on expected backorders and cannot be used to produce availability-vs.-cost curves, its utility is dramatically reduced. We exclude such models from our discussion.

CAPABILITY TO USE AVAILABILITY MODELS

There are several other topics to consider when developing a strategy for the implementation of an availability model for initial and replenishment spares computations. These include the following:

- Organization--Reorientation of the present supply system organization from line-item to weapon-system management.

- Budgeting by Weapon System--Development of procedures to manage budgetary resources by weapon system.
- Data Availability--Collection of the item characteristic and application data described above, data relating to weapon-system programs (usage rates), and the level of readiness (availability) desired for each weapon system.
- Data Accuracy--Development of procedures for updating the data as relevant changes occur.
- Implementation Status--Current use of availability models, the sophistication of the inventory managers, and their understanding (and trust) of the models.
- Measurement of Results--Development of procedures to measure achieved availability and compare it with predicted availability.

Each of these topics is evaluated in the following chapters. The discussion of these topics will vary for each of the Military Departments and the Defense Logistics Agency (DLA) based on our assessment of their importance in the implementation of an availability model.

2. AIR FORCE

In this chapter, we describe briefly the Air Force's current requirements computational methods and discuss several steps involved in implementing requirements computations with availability models. Air Force spares requirements fall into one of the major resource classes shown in Table 2-1. Requirements for items in each of these classes are computed by a different system and, more importantly, are based on different criteria.

RECOVERABLES

Data on recoverable items are maintained in AFLC's D041 system. Recoverable requirements (except for aircraft engines and engine modules) are computed by the Variable-Safety-Level (VSL) algorithm of D041. The VSL model is AFLC's implementation of Sherbrooke's METRIC model.¹ It minimizes total expected backorders (EBO) at organizational and intermediate maintenance (OIM) levels for a particular investment level established by specifying the value of the Lagrangian multiplier. An objective function of minimizing expected OIM backorders is clearly superior to maximizing fill rates, but it fails to account for the numbers of essential components in various weapon systems.² Thus, the VSL model delivers less availability for weapon systems with relatively larger numbers of recoverable components (especially expensive ones) than for those with smaller numbers. The differences in availability rates among weapon systems have been shown to be substantial, and those

¹Sherbrooke, C. C., "METRIC: A Multi-Echelon Technique for Recoverable Item Control," Operations Research, Vol. 16, No. 1 (1968), pp. 122-141.

²Brooks, R. B. S., Gillen, C. A., and Lu, J. Y., Alternative Measures of Supply Performance, The Rand Corporation, RM-6094-PR, 1969.

TABLE 2-1. MAJOR AIR FORCE REQUIREMENTS SYSTEMS

Data System	Commodity Class	Optimization Criteria	Model Structure
D024	Aircraft engines	Provide 80 percent base fill rate.	Two levels of indenture (engines and engine modules), two echelons (depot and base).
D041	Recoverables	Minimize expected OIM backorders. Budget to provide 92 percent base fill rate.	Single-indenture, two echelons.
D062	Consumables	Minimize expected depot-level backorders subject to a 55-day safety stock limit.	Single-indenture, single-echelon (depot only).
SBSS*	All of the above	No stockout in 85 percent of reorder cycles.	Single-indenture, single-echelon (base only).
D039	Equipment Items	Comparison of authorized vs. available.	Modeling is off-line, on a special studies basis.

* Standard Base Supply System

availability rates are not even computed, much less made visible, by the VSL model. The VSL algorithm could simply be replaced by an availability model without additional modifications to the system. The current recoverable requirements computation system provides all of the data required to support requirements computations by an availability model for both procurement and repair except the desired availability rates by weapon system and component removal rates by weapon system. Lack of component removal rates by weapon system, however, does not preclude the use of an availability model because assumptions can be made that will facilitate the requirements computations. On the other hand, weapon system availability objectives must, of course, be specified.

WARS and the RDB

AFIC is currently involved in major changes in its approach to recoverable spares requirements computations. A system called the Wartime Assessment and Requirements Simulation (WARS) Model is being developed to compute procurement and repair requirements for aircraft recoverable spares. The WARS Model is an important step forward because it focuses on availability rather than expected backorders and it is designed to optimize the mix of repair and procurement budget resources. However, the feasibility of the optimization algorithm in the WARS Model has not yet been demonstrated. The Requirements Data Bank (RDB), designed to support the model, represents an improvement over the current DO41 data base. It will contain component removal rates that are predicted for the initial surge period of a war and for sustained combat operations, as well as historical component removal rates for peacetime. The RDB will also contain levels-of-indenture data. Serious consideration is being given to the addition of consumables data in the RDB, but this decision has not been made. WARS and the RDB may ultimately be

significant parts of the total solution to the Air Force's requirements computational needs, but their performance is still a matter of uncertainty, and they should be viewed as products of long-term development.

CONSUMABLES

Requirements for consumables are computed by AFLC's D062 system. The D062 data base contains data on more than 500,000 line items.

Two problems inhibit the Air Force's ability to include consumables in an availability model in the same way as recoverables. The first is that models such as the LMI Aircraft Availability Model, METRIC, MOD-METRIC, VARI-METRIC, and SESAME are built on the assumption of an (S-1,S) reorder policy, whereas consumables are managed with an (s,S) policy.³

The second significant problem with consumables is the relatively intractable mathematical character of the (s,S) reorder policy in a multi-echelon system. No solution has been found to the problem of optimizing such a system except for certain special cases, although approximative solutions have been developed, again only for special cases.

These two problems, though troublesome, should not be viewed as prohibiting the eventual application of an availability model to consumables requirements computations. We point them out here only to make it clear that the application is not free of technical difficulties.

An interesting characteristic of the distribution of consumables in the D062 system can be noted from Table 2-2. The dashed line in the table separates line items with a total annual dollar value of demand of \$50,000 or

³An (S-1,S) reorder policy implies one-for-one replacement; i.e., as soon as the quantity on hand plus on order minus backorders equals one less than the stock level, S, an order is placed immediately. The (s,S) policy specifies that, when the quantity on hand plus on order minus backorders is less than or equal to the reorder point, s, an order is placed to bring the inventory position up to S.

TABLE 2-2. DISTRIBUTION OF D062 LINE ITEMS BY UNIT COST AND TOTAL ANNUAL DOLLAR VALUE OF DEMAND*

Total Annual Dollar Value of Demand	Unit Cost											Total (Items)	\$ (000) Total
	\$ 0.00 to 0.99	\$ 1.00 to 4.99	\$ 5.00 to 9.99	\$10.00 to 24.99	\$25.00 to 49.99	\$50.00 to 99.99	\$100.00 to 249.99	\$250.00 to 499.99	\$500.00 to 999.99	\$1000.00 and over			
.00	15,557	37,067	26,357	47,885	36,903	76,799	39,972	70,662	11,835	9,760	277,577	0	
0.01 - 24.99	8,904	12,913	5,241	4,589	0	0	0	0	0	0	31,667	335	
25 - 99.99	2,470	7,548	6,254	9,798	7,918	3,855	0	0	0	0	37,843	2,162	
100 - 499.99	1,962	6,282	5,536	11,333	10,909	11,101	11,504	2,754	0	0	61,781	15,515	
500 - 999.99	575	1,659	1,555	3,465	3,811	4,444	5,654	3,279	1,665	0	26,127	18,761	
1,000 - 2,499.99	520	1,510	1,387	1,249	3,694	4,756	6,573	4,272	2,765	1,360	30,086	48,539	
2,500 - 4,999.99	200	647	609	1,575	3,819	2,575	4,147	2,988	2,225	1,560	18,355	65,525	
5,000 - 9,999.99	117	345	306	800	1,065	1,527	2,574	1,921	1,507	1,512	11,669	81,383	
10,000 - 24,999.99	55	212	188	577	618	1,064	1,916	1,766	1,377	1,634	9,317	146,563	
25,000 - 49,999.99	21	71	71	168	243	176	785	683	633	865	3,916	135,376	
50,000 - 99,999.99	4	26	31	68	123	177	346	335	318	531	1,956	136,180	
100,000 - 499,999.99	2	15	29	55	92	116	212	186	188	415	1,328	255,435	
500,000 - 999,999.99	0	0	2	9	12	14	22	16	15	34	122	81,891	
1,000,000 - 1,999,999.99	0	0	1	1	7	3	2	7	3	6	30	41,053	
2,000,000 or more	0	0	0	1	0	1	2	2	2	3	11	16,242	

*The "staircase" line assumes demand is distributed uniformly over 10 bases. Source: D062.M91B report, 31 March 1981

more from the other items in the system. Fewer than 0.7 percent of the line items in the system are below the dashed line (3447 line items); yet, they represent 52 percent of the total annual dollar value of demand in the system. Another characteristic of the distribution shown in Table 2-2 is pertinent. All of the line items above the "staircase" line have economic order quantities (EOQ) of one. These items comprise 80.8 percent of the line items in the D062 system; therefore, those items could be added to an availability model without violating its reorder policy assumption. Unfortunately, the line items with an EOQ of one and those with high annual dollar value of demand tend to be disjoint; only 1832 line items have both characteristics.

Consideration of all these factors together suggests that the inclusion of consumables in an availability model along with recoverables may not be practical. It might make more sense to pursue the development of a mathematical estimating relationship for consumables that would relate fill rate or investment level to weapon-system availability without any optimization logic. In order to make a sound assessment of this issue, various alternative approaches to consumable requirements need to be evaluated in terms of their contributions to the availability-cost relationship.

ENGINES

All of the data required to support the use of an availability model for engines and engine-modules requirements computations are already available. It is a step that could easily be taken now; however, it is important to note that engine removal forecasts are based on actuarial data that account for the distribution of engine operating times since new or overhaul. These data support estimates of engine removal rates believed to be more accurate than the typical component removal data in D041 (which are based upon two-year moving averages). The accuracy of the engine removal rates could be

maintained if computed as they are now; they could then be added to the file of recoverable components (or to the RDB) on which an availability model would operate.

EQUIPMENT ITEMS

This category includes a diverse collection of items ranging from oscilloscopes, automatic test equipment, and test stands to munitions trucks, ground communication equipment, and base maintenance support equipment. Requirements for Air Force equipment items are computed by AFLC's DC39 system. The category includes approximately 100,000 items with a total USAF investment of \$12 billion. Requirements computations for equipment items are based on a comparison of authorized versus on-hand quantities.

Although equipment items are end items, they are generally not considered as weapon systems themselves. Rather, equipment items support specific missions (e.g., munitions trucks and ground radars), support the maintenance of weapon systems (e.g., test and calibration equipment), or provide support for other base functions (e.g., base communications equipment). Availability models could be used to compute the spares levels needed to provide a given availability level for a specific equipment item. However, what is ultimately needed is the capability to compute requirements for these items and their associated spares so as to optimize the availability of the supported weapon.

Several problems inhibit the use of availability models for equipment requirements computations. The first is the lack of data elements which define the nature of the weapon support role performed by a given equipment item. A second problem is the difficulty in accurately modeling the impact of equipment-item inventory levels (e.g., test stands) upon weapon availability. A third difficulty lies in establishing appropriate availability goals for general base support equipment.

OPTIMIZATION ACROSS COMMODITIES

The two straightforward steps of replacing the D041 VSL logic with an availability model and the addition of the engine data to the availability model's input data file would facilitate the Air Force's use of a multi-indenture availability model for requirements computations in the immediate future. The computations could be made for engines and engine modules as well as other recoverables. Only consumables would be excluded for lack of an analytically tractable mathematical model of the Air Force's multi-echelon EOQ system.

Ideally, the marginal requirements dollar should always be spent for the procurement of the greatest marginal improvement in weapon-system availability. The difficulty in doing this in the Air Force lies in relating the return in availability of the marginal dollar used to purchase consumables to that of the marginal dollar invested in recoverables (including engines and engine modules). The goal of the requirements system should be to establish budget levels and requirements such that the marginal returns in availability per dollar are equal among all commodity groupings. The problem of achieving that investment balance is complicated by the specification of availability rates by weapon system and, ideally at least, the requirements system ought to be able to find the least total budget to achieve the specified rates. Toward this end, the Air Force needs to develop a method of relating the consumable budget level to weapon-system availability so that investments can be balanced between consumables and recoverables. That method may be to include consumables in an availability model or to develop a cost-estimating relationship for consumables that will accomplish the same end.

A NOTE ON THE STANDARD BASE SUPPLY SYSTEM

It is important to optimize the distribution of stock levels across echelons of the inventory system as well as across commodity groupings. The

Air Force recognizes this need and is developing a new distribution system, D028, intended to distribute assets among the depot and all users world-wide. D028 is designed to be a "push" system, rather than a "pull" system; i.e., it would not depend upon user requisitioning. It would depend upon central visibility of all assets in the system and the status of those assets and use that knowledge to allocate assets to minimize expected base-level backorders. Thus, D028 is designed to be logically consistent with the VSL requirements computational system.

The reason D028 is being developed is that the Air Force's Standard Base Supply System (SBSS) establishes base stock levels on the basis of individual item demand rates and is, therefore, inconsistent with the logic of the requirements system. If the Air Force moves to the use of an availability model for requirements, the SBSS and the D028 system would be incompatible with the availability model's logic. Ideally, stock levels at the bases should be determined by a multi-echelon computation that takes explicit account of depot stock levels and other item characteristics determined by world-wide applications. We know that such a computation can be done centrally, and it could be imbedded in a system in which the bases requisition stocks against the centrally computed stock levels. This seems preferable to a decentralized system of computing stock levels because the bases do not have visibility of removal rates at other bases. In any case, the fundamental issue of compatibility between the requirements system and the distribution system would need to be reexamined if the Air Force implements an availability model for requirements computations.

ORGANIZATIONAL ISSUES

There is no organizational impediment that prohibits the use of an availability model for requirements computations. One troublesome issue is that

item managers do not have visibility of other than the line items they manage and may judge the computational results of an availability model to be inconsistent with the intuition they have gained from their own experience. In the Air Force case, however, the problems item managers may have with the computations of an availability model are not unlike their problems in being comfortable with the VSL algorithm's computational results. The only added complication is that an availability model takes weapon system availability objectives into account in addition to item unit prices in making tradeoffs among line items. The problems induced by the item managers' lack of total system visibility are discussed at greater length in Chapter 6 because they exist in every Military Department and in DLA.

Although individual line items are managed at the various Air Logistics Centers (ALCs), requirements computations are done centrally. It would be a simple matter to partition budget resources by materiel management code and to pass advisory shopping lists to the ALCs. The responsibility for requirements lies with a single director at Headquarters, AFLC.

A WORD ABOUT INITIAL PROVISIONING

In a previous report we discussed the use of availability models in initial provisioning and argued that their use enables decisions regarding spares investment levels and spares stockage postures (i.e., stock levels by stock number and location) to be made with full visibility of the relationship between weapon-system availability and spares costs.⁴ Except for the greater uncertainty involved, the application of an availability model to the initial provisioning problem is the same as for the replenishment scenario. An availability model can provide a smooth transition from the provisioning to

⁴Abell, John B., et al, The Use of Availability Models in Initial Provisioning, Logistics Management Institute, Task Report ML108, 1981.

the replenishment mode with no discontinuity or major adjustment required. Also, marginal requirements for components common to a new weapon system and one or more current systems could be determined by running the model twice in the replenishment mode, first without the new weapon system and then with it included. In that way, the total requirement attributable to the new system could easily be determined.

At best, current initial provisioning methodology in the Air Force is confused. The Air Force has applied the MOD-METRIC model to certain recently acquired weapon systems, but the model's optimization logic was ignored in at least one of those applications in favor of a constant fill rate across all components, LRUs and SRUs alike.⁵ The use of the same availability model for initial provisioning as for replenishment, with the addition of Bayesian logic to its algebra, would provide a unifying methodology for both computational problems that would maximize weapon-system readiness for both the provisioning and replenishment dollar. This would constitute an attractive alternative to current methods.

CONCLUSIONS

Table 2-3 summarizes the capability of the Air Force to use availability models. The Air Force is closer than any of the other Military Departments to achieving the goal of optimizing their total POS requirements system with respect to weapon-system availability. Four steps are needed:

- Replace the current DO41A VSL system with an availability model.
- Add engines and engine modules to the data file input to the availability model.
- Develop a method for balancing budget levels between recoverables and consumables. This may depend only on the development of a mathematical estimation of the availability-cost relationship for

⁵Muckstadt, J. A., "A Model for a Multi-Item, Multi-Echelon, Multi-Indenture Inventory System," Management Science, Vol. 20, No. 4 (1973), pp. 472-481.

consumables, a multi-echelon optimization algorithm for the consumables system, or a model that can treat both recoverables and consumables in a single optimization model.

- Develop modifications to the SBSS to make it operate compatibly with the multi-echelon, multi-item logic of the availability model in establishing base stock levels. An alternative to this is to redesign the DO28 system to maximize availability rather than minimize expected backorders.

TABLE 2-3. CAPABILITY FOR USE OF AVAILABILITY MODELS
IN SPARES COMPUTATIONS IN AIR FORCE SUPPLY SYSTEM

	<u>Available/ Applicable</u>	<u>Limited</u>	<u>Not Available/ Difficult</u>
Organization	√		
Budgeting by Weapon System		√	
Data Availability	√		
Data Accuracy	√		
Implementation Status		√	
Measure of Weapon-System Availability/Unavailability		√	

The third and fourth of these four steps are the only technically difficult ones in a developmental sense. The first two can be taken in the immediate future. In fact, the Air Force is already investigating the computation of recoverable requirements with the Aircraft Availability Model developed for the Air Force by LMI, an important first step towards a system that would account for levels of indenture and common components, as well as procurement and repair.

3. ARMY

The Army computes its requirements for secondary items in a variety of ways, depending on the organization level, the commodity type, requisition frequency and dollar value. The supply system can be divided into two organizational categories, wholesale and retail. The wholesale system consists of five national inventory control points (NICPs): Missile Command (MICOM), Communications-Electronics Readiness Command (CECOM), Tank-Automotive Readiness Command (TACOM), Troop Support and Aviation Materiel Readiness Command (TSARCOM), and Armament Materiel Readiness Command (AARCOM).

The NICP structure and focus of materiel management are commodity oriented. For example, although TACOM is responsible for tank support, the communications components of the tanks are managed by CECOM. At the wholesale level, only demands on the NICP are visible, and requirements computations are based on those demands. There are no management objectives at the NICP relating to weapon systems or weapon-system readiness.

The Army computes wholesale requirements with its Requirements Determination and Execution System (RD&ES), a part of its Commodity Command Standard System (CCSS). The RD&ES is the Army's implementation of DoD Instruction 4140.39, and is used to compute wholesale requirements for repairables as well as consumables. The computations are decentralized among the NICPs.

The retail level is more complex. In general, each command in the Army has some latitude in implementing the procedures promulgated by the office of the Deputy Chief of Staff for Logistics (DCSLOG). For example, each command makes some independent decisions on what to stock and how to position the stock. There are three sub-depot organizational echelons: general support

(GS), direct support (DS) and organizational. The organizational level is supported by a prescribed load list (PLL) of repairable and consumable secondary items.

The PLL is tailored to the mission of a company and is generally constrained by the unit's mobility requirements to about 300 items that will fit in one van. The computations for the PLL have been upgraded recently to include combat requirements rather than only peacetime requirements.

The Division and Corps levels are supported by authorized stockage lists (ASLs). Generally, the ASL for the Division level is used for direct support and at the Corps level for general support requirements such as component repairs. A divisional DS unit supports over 100 PLLs that include some 6,000 to 10,000 repairable and consumable items.

The Army supply system is heterogeneous in structure. There are DS units at the Corps level for some weapon systems (such as missiles, trucks or aircraft), units may be moved from one corps to another causing shifts of demands, and the Army National Guard with its own PLL may be assigned to any one of a number of corps. Because the Army has flexibility in assigning command responsibility of its units, demands, even at the division level, fluctuate.

The funds for spare parts are divided into stock funds, generally used to purchase consumables, and the Army Procurement Appropriation (APA), generally used to purchase repairables. APA items are "free-issued" to the field. Recently, many items have been reclassified from APA to stock fund to reduce the number of "free" issues to the field.

MAINTENANCE DATA COLLECTION

The Army's maintenance system may ultimately provide the data needed for more efficient management of its supply system. The Army currently records

maintenance data in two ways. The first is the standard system prescribed by TM 38-750; the second is the Army's sample data collection program.

The Standard Army Maintenance Systems (SAMS)

Data describing maintenance actions are recorded on DA Form 2407, primarily for local use. Data from the form are not routinely input to a central system. Typically, the battalion maintenance officer prescribes what data will be recorded. The DA Form 2407 isn't always completed. That, too, depends heavily on local management.

The Army plans to collect data from the DA Form 2407 and, by the late 1980s, forward the data to the Materiel Readiness Support Agency (MRSA). For this plan to be useful to the Army supply system, the form needs to be revised to collect information on component failure/removal rates, DS and GS repair rates and times, and pipeline times.

The Sample Data Collection Program

The Army currently contracts for the collection of data on maintenance actions on selected weapon systems and end items of equipment at selected organizations. The data recorded in this program are much closer to what is needed by the requirements system than is the information provided for in the standard system. Even if the Army were eventually to collect the right information ("right" from the supply point of view) only on a sample basis, item managers would have far greater visibility of component characteristics than they have now.

CURRENT USE OF AVAILABILITY MODELS

The Army currently uses, at the wholesale level, an availability model (SESAME) to compute requirements for selected items on new weapon systems and to assist in budgeting. SESAME computes stockage requirements for the wholesale and retail levels to meet weapon-system availability goals. However,

SESAME only computes requirements for one weapon system at a time and does not account specifically for common items.

IMPEDIMENTS

Three major factors inhibit the Army's ability to implement an availability model for replenishment spares requirements computation. The first is that the NICPs do not have good visibility of assets at sub-depot echelons of the inventory system. A monthly report of Availability Balance Files developed from "sales" of assets by field units is provided to the wholesale system, as is a daily transaction balance report (SIMS-X) for high-cost items. However, the NICP uses the data from these reports infrequently because of the inconsistencies and inaccuracies believed to exist in the data.

The second inhibiting factor is that the NICP does not have observed data that will support the computation of item pipelines. Ingredients of that computation not known to the NICP are: item removal rate; direct support (DS), general support (GS), and depot repair percentages; DS and GS order-and-ship times and repair times; and depot retrograde shipment time. These elements of information are estimated at the time of provisioning, and some revisions are made early in a system's life, but, in the replenishment mode, they are not updated on the basis of observations. All that the NICP sees on the basis of actual observations of a replenishment item are the depot demand rate, quantities received and repaired at the depot, the depot repair time, and the depot condemnation rate. As a result of this, spares requirements can not be computed to maximize availability subject to a budget constraint.

The kind of availability model that would be suitable for computing replenishment spares requirements depends on an optimization algorithm that uses the probability distribution of the number of components of each particular type in resupply (the mean of which is the item pipeline). By

resupply we mean in repair at DS, GS, or depot, in retrograde shipment, in the order-and-ship pipeline, or awaiting condemnation replacement. In the Army supply system, sub-depot-level repairs are invisible to the NICP; yet, for many items they constitute a significant proportion of the pipeline. When sub-depot-level repair rates or repair times or component removal rates change, the NICP sees only a reflection of those changes in requisition rates or depot return rates. If the requisition rate or depot return rate changes sufficiently, the item manager updates the failure rate shown in the National Stock Number Master Data Record (NSNMDR) to express the change he sees even though, in fact, the true failure rate might not have changed. The change in the failure rate reflected in the NSNMDR affects the item manager's ability to project other factors, such as condemnations and depot-level repairs. The practice of revising the failure rate to represent changes to an item's pipeline is resorted to because many of the real changes that affect the pipeline are unknown to the item manager.

The third factor that inhibits sparing to optimize availability-vs.-investment in the Army is that the Army supply system is partitioned into wholesale and retail parts as a matter of policy. That policy represents a point of view that we believe must undergo a fundamental change before the Army can bring about the changes needed to support requirements computations that achieve specified weapon system availability objectives at least cost. Such a computational philosophy depends on a multi-echelon view of the logistics system that the Army does not now have. Although one could probably develop a spares requirements system in which stock levels were computed at one or more sub-depot echelons, such a system would be suboptimal by design because the computations would be done without complete visibility of all of the factors that influence the determination of optimal stock levels.

We believe that the cost-effectiveness of the Army's spares requirements system would be greatly enhanced by the use of a multi-echelon availability model for requirements computations, supported by a data system that would provide the NICPs with adequate visibility of assets and sound estimates of component characteristics. Our conviction is based, in turn, on analyses of many weapon systems using availability models and our experience with the computational techniques involved and with their often dramatic results. We may misjudge the cost and difficulty of collecting the data to support those computational techniques, but we are persuaded that the Army should pursue an investigation of its feasibility, whether through revision of its standard system or augmentation of sample data collection.

Table 3-1 summarizes the Army's difficulty in moving to an availability orientation of requirements computations.

TABLE 3-1. CAPABILITY FOR USE OF AVAILABILITY MODELS
IN SPARES COMPUTATIONS IN ARMY SUPPLY SYSTEMS

	<u>Available/ Applicable</u>	<u>Limited</u>	<u>Not Available/ Difficult</u>
Organization			√
Budgeting by Weapon System			√
Data Availability			√
Data Accuracy		√	
Implementation Status		√ ^a	
Measure of Weapon-System Availability/Unavailability		√	

^aLimited to initial provisioning.

A COURSE OF ACTION

The Army needs to take three steps to implement availability models for computing replenishment spares requirements. Each step is a major effort requiring careful design, planning, and execution. More importantly, perhaps,

each requires fundamental changes in management orientation. The first step is to develop a reporting system that will routinely provide asset visibility to logistics management at division level and above, but especially to the NICP. Asset data are necessary ingredients in any requirements computation.

The second step is to provide the NICP with the data elements required to compute item pipelines, as discussed in Chapter 1. Most of them are known to maintenance personnel who remove, replace, and repair components. Therefore, component removals and repairs could be routinely recorded and reported to the NICP through the standard system or the required data could be collected in a program similar to the Army's sample data collection program, with revisions to alter the set of specific data elements recorded. A sampling program could be expected to yield data of higher quality, but the design of such a program would need to account for the heterogeneity among organizations and changes in component characteristics over time. The most effective (and most costly) data collection program would encompass both approaches; i.e., it would specify the routine recording and reporting of the data elements of interest on all maintenance actions (similar to the Air Force maintenance data collection system) and would verify their accuracy with a sampling program. The feasibility and cost of these alternatives need to be assessed. The highest quality data available in the Army seem to be on aircraft and missiles, but even these data need to be improved substantially.

One might argue that neither of these two steps is necessary because the Army currently performs requirements computations without visibility of assets below the wholesale level and without routinely updated estimates of item pipelines. Our counterargument is that, although an availability model would deliver more cost-effective stockage postures than the Army's current system, using only the data presently available, we believe that it is fundamentally

important to make the requirements computation on the basis of better data than the Army now has, independent of the computational method used.

The third step the Army needs to take, independent of the use of an availability model, is to move toward management of its logistics system as an integrated whole. A requirements system that determines requirements without visibility of the whole logistics system cannot perform as well as one that has that visibility. Requirements computations should be done centrally with full visibility of assets in the system and routinely updated estimates of all of the component characteristics upon which a requirements computation is based. Again, we qualify these observations by pointing out that they are, in large part, based on our intuition about the enhanced cost-effectiveness that we believe is achievable. We wish to emphasize the need for verification through an assessment of the cost and feasibility of supporting a centralized, multi-echelon, availability-oriented requirements system with adequate data.

A multi-echelon availability model derives much of its power from its view of the logistics system as an integrated whole. That system view enables the model to allocate stock levels among claimants (users), echelons of the logistics system, and line items in the inventory so that specified levels of availability can be achieved at least cost. The partitioning of the Army inventory system into "wholesale" and "retail" components militates against cost-effective inventory management since the performance of the system at the "retail" level depends on the allocation of stock levels at both the "wholesale" and "retail" levels. Redistribution of assets among users to satisfy critical shortages could also enhance system performance.

CONCLUSIONS

The Army will not be able to comply with the directions of the Defense Guidance "... to size weapon system initial and replenishment secondary item

inventories to meet explicit weapon system availability and operating tempo objectives..." without fundamental changes to its logistics management system. Some of the changes required can be accomplished in the short term; other changes will require longer-term effort. We believe that the Army should take the following steps now:

- Develop and implement a reporting system that would give the NICP asset visibility.
- Evaluate the cost-effectiveness of alternative data collection systems that would provide the basis for estimating repairable item pipelines.
- Using available data, develop, evaluate, and implement an availability optimization model for aircraft replenishment spares requirements computations.

Based on evaluation of the results of these first steps, the Army should develop a strategy for expanding its application of availability models to other kinds of weapon systems. Clearly, the next steps include the design and implementation of a data collection system to support spares requirements computations.

4. NAVY

In this chapter, we describe briefly the Navy's current initial provisioning and replenishment requirements computational methods. We also briefly describe the Navy's organization, inventory management systems, and its ability to achieve specific weapon-system availability objectives using current requirements computational methods. A weapon system is defined in the Navy supply system as a major subsystem on a ship (such as the power system), an end item (such as a helicopter), or an equipment system (such as test equipment to support electronics). The Navy also categorizes end items (such as ships, submarines and aircraft) as fighting units. Measures of operational readiness, as reported to the fleet commander level and above, relate to the readiness of a fighting unit. In this chapter, we equate a fighting unit to the term weapon system. Although spares requirements may ultimately be computed at the subsystem level, we believe that a natural level of aggregation for a planner is a fighting unit. The planner thinks of a fighting unit's capability in combat, not of the availability of various subsystems and the subsystem's relationships to the fighting unit's availability.

The Chief of Naval Materiel, under the Chief of Naval Operations (CNO) has overall responsibility for policies and principles governing materiel support in the Navy. Approximately 97 percent of the items managed by the Naval Materiel Command are managed by two agencies, the Ships Parts Control Center (SPCC) and the Aviation Supply Office (ASO). Unique items that are unstable in design or otherwise warrant special management are managed by a hardware systems command. We will describe computational methods for both initial provisioning and replenishment requirements for the two major inventory management agencies separately, though there are similarities. With

the exception of current limited use of the Availability Centered Inventory Model (ACIM) and the Initial Outfitting List (IOL), weapon-system availability is not explicitly considered in these computational methods. The use of the ACIM will be discussed separately.

SHIPS PARTS CONTROL CENTER

SPCC is responsible for conventional ammunition; shipboard, base and ordnance equipments and repair parts; and electronic equipments and repair parts. General Services Administration (GSA), other Services and the four Defense Logistics Agency's inventory control points provide the majority (75 to 85 percent) of equipment piece-parts. SPCC monitors and, in some cases, controls material issues to the fleets. The actual material flows from stock points such as U.S. Navy Supply Centers (wholesale level), supply depots overseas (intermediate level), or fleet stores ships (intermediate level).

The items managed by SPCC are usually divided into two categories: consumables and repairables. Of the total 568,000 line items carried in SPCC's inventory, approximately 79 percent are consumables and the remaining 21 percent are repairables. The wholesale inventory investment in consumables is approximately \$676 million, while the investment in repairables is \$2 billion. The requirements determination method for these two categories of items are similar, though there is more intense management for the higher cost repairable items.

Three major automated procedures are involved in computing wholesale requirements. These procedures are based on data from a system of daily Transaction Item Reports (TIRs). The TIRs are received either from SPCC's stock points (approximately 45 activities) or directly from customers. The first procedure determines a reorder level and economic order quantity for each item based on production leadtime, risk, safety levels, holding costs,

price, and other variables. Once the levels (range and depth) are set, a second procedure, the Cyclic Levels and Forecasts Program, uses actual demand information (from TIRs) to recompute requirements. Leadtimes and turnaround times observed in the past two years are used to forecast requirements. As a general rule, single exponential smoothing is used for forecasting demand and usage rates, leadtimes and turnaround times, and carcass return and survival rates. Normally, levels are computed quarterly for the wholesale level and are allocated to the wholesale stock points. New levels are stored in the Master Data File. The third program, the Supply Demand Review, monitors the status of every item, computes net deficiencies/excesses, and automatically signals a recommended buy when the reorder level has been reached. It also makes disposal or redistribution recommendations. For repairable items, a similar program (Repairables Management) additionally produces repair, referral order, and redistribution recommendations for assets reported "Not Ready for Issue".

The preceding procedures constitute the wholesale computations. The intermediate level of supply in the Navy has been established recently. For these activities, the inventory control point (ICP) computes stockage requirements based on actual demands (from TIRs) whenever possible. Consumer-level requirements computations and initial provisioning methodology are described below.

Initial Provisioning at SPCC

During the initial provisioning process each item is examined and various characteristics, such as anticipated demand, are attributed to it. For items on a new weapon system that are common to one or more other applications, the additional component of demand due to the new application is supposed to be identified and added to other observed demands. A Variable

Threshold Model or DODI 4140.42 computation (called .42) is used. The procedure is as follows:

- All items go through a .42 calculation and a budget is set by cognizance symbol (COG) that identifies the activity with the ultimate responsibility for supplying the item.
- Budget requirements for all non-demand based items are subtracted from this budget.
- Each item managed by a COG is ranked by $(1 - e^{-DDL}) / \text{Cost}$, where DDL = demand during leadtime.¹
- The depth is calculated for the highest ranking item and the cost of this quantity is subtracted from the budget. If sufficient funds are available, the next item is calculated. (Depth equals leadtime requirement plus safety level plus depot repair cycle when applicable.)

Depth is constrained to be no more than one years' worth of demand for items with high annual dollar value of demand and no more than a procurement variable plus three months' attrition demand for items with low annual dollar value of demand.

This procedure is complicated by timing problems during initial provisioning. Requirements calculations may be made before data are available on all components. This may lead to unrealistically low demand estimates for some items.

As mentioned before, these calculations do not take weapon-system readiness into account. However, the ACIM, described later, is being used on a limited basis during initial provisioning, subject to the .42 budgeting constraint. As the Navy is using ACIM, the number of items recommended for the consumer level is the larger of the number of items calculated by the ACIM and the normal consumer model (for instance, Navy Variable Threshold Model). The result is that no availability-vs.-cost relationship is used by SPCC during

¹Note that this implies that higher cost items have a lower ranking and high DDL items have a higher ranking.

initial provisioning, nor is any attempt made to maximize availability for a specified budget.

Allowance Lists

The Consolidated Shipboard Allowance List (COSAL) and the Consolidated Shore-Based Allowance List (COSBAL) are lists of items authorized for inventory on a ship or at a shore facility. For weapon-system related spares (consumables and repairables), the items on the COSAL/COSBAL are generally all that are authorized for the ship/facility. Especially for ships, the COSAL is constrained by the lack of storage space on the ships for spares. A new COSAL is designed for a ship before commissioning and again at each overhaul, approximately every four years. (Once a COSAL is established, it remains unchanged until the next COSAL, unless 1) equipment is modified, added or deleted on a ship, or 2) a major difficulty in item failures arises.)

A COSAL is determined in two steps. First, the item is a candidate for stockage if it is installed on the ship and maintenance personnel are permitted to replace it. Next, the allowance of that item is determined as follows: the Best Replacement Factor² (BRF) multiplied by the number of installations of the item, gives the item's storeroom demand parameter. Fleet Logistics Support Improvement Program (FLSIP) criteria are then followed to determine how many items are authorized on the COSAL. In FLSIP, when the demand is less than 0.25, the item is generally not allowed on the COSAL. If the demand parameter is at least 0.25 but less than 4.0, one item is allowed if it is an "insurance" item vital to its parent function or mission area; otherwise, the item is not allowed. Approximately 90 percent of items that are candidates for stockage are vital or "insurance" items, and the stockage

²Annual demand for an item divided by the number of active installations of the item, combined (by exponential smoothing) with prior year's BRF, or, for new items, an engineering estimate.

decision is to stock one item. If the demand parameter (for any candidate for stockage) is greater than or equal to 4.0, two or more items are allowed based on a 90 percent level of protection during a 90-day period and a Poisson or normal approximation to a Poisson distribution of demands.

There are exceptions to these stockage criteria. Mission-criticality-oriented-COSAL (MCO-COSAL) is being used for new ships, starting with the third flight of the FFG-7 class of ships. All items on the ship are categorized by their maintenance (mission) criticality and, for the established budget, protection is variable, based on demand factors, cost and essentiality (criticality). MCO-COSAL is similar to the COSAL criteria used for the TRIDENT.

Another initiative is called Modified Fleet Logistics Support Improvement Program (MOD-FLSIP). MOD-FLSIP is based on a Center for Naval Analysis study which found that changing the criteria for stocking low-demand items vital to a ship's primary mission caused a significant decrease in supply-induced degradation. The criteria were changed from stocking one item if the expected demand is one every four years (demand parameter 0.25) to stocking one item if the expected demand is one every ten years (for items coded as vital to the primary mission) and stocking two items if the expected demand is between two and four each year. MOD-FLSIP obviously allows stocks for more items (for about 40 percent of the items on a COSAL) and costs more than FLSIP stockage criteria, so its immediate use is limited by budget constraints. In FY83 MOD-FLSIP will replace the current FLSIP. The budget for FY83 reflects this change. MOD-FLSIP and MCO-COSAL currently are used in computing requirements for about 10 percent of the Navy's weapon systems. No attempt is made to relate spares requirements to weapon-system availability with these criteria. The impediments to developing such a relationship are discussed at the end of this chapter.

AVAILABILITY CENTERED INVENTORY MODEL

In March 1981 the Availability Centered Inventory Model (ACIM) was approved by CNO for use by the Navy. It is being used, when approved for a selected system, to create a consumer-level stockage quantity, usually for those new weapon sub-systems that have a high percentage of electronics equipment. The ACIM calculates operational availability, defined as Mean Time Between Failure \div (Mean Time Between Failure + Mean Time to Repair + Mean Supply Response Time).

The model assumes the following:

- One-for-one ordering.
- Continuing resupply opportunity.
- No lateral resupply.
- Palm's Theorem satisfied; that is, demands arrive according to a Poisson process, and repair times have an arbitrary distribution with a finite mean independent of the demand process.

Although ACIM models a multi-echelon system, the Navy currently uses it only for consumer-level requirements calculations. Common items are accounted for by manual intervention. Any mix of consumables and repairables is allowed, but in practice the "important" items of the weapon system are selected for analysis by ACIM. This selection process prevents a low-cost consumable item from dominating the calculation. The model also requires the equipment configuration, including multi-indenture aspects of equipment. ACIM performs a marginal analysis that iteratively selects the item that gives the greatest increase in operational availability for the least cost, thus building stock levels for all items until the operational availability goal or budget constraint is reached.

ACIM requires 38 data elements for each item. These include the item's next higher assembly, mean time to repair, failure rate, unit price, best

replacement factor, population, maintenance policy, order-and-ship time, availability/investment target, and other variables. All of these data elements exist, at least to some degree, for all items managed by the Navy.

The major concern with using the ACIM is the validity of the data elements used by the model. In particular, data relating to the configuration of weapon systems in the Navy are not current, limiting the use of ACIM to initial provisioning. The data problem will be discussed later in this chapter. However, theoretically, all the data required to run ACIM are available in existing SPCC and ASO files.

AVIATION SUPPLY OFFICE

The Aviation Supply Office (ASO) is responsible primarily for inventory management of secondary items for assigned weapon systems and equipment relating to the operating aircraft of the Navy and Marine Corps. ASO monitors and, in some cases, controls material issues to consuming activities. Material flows from stock points such as Naval Air Stations, Naval Supply Centers/Depots and Marine Corps Air Stations. GSA, other Services, the Defense Logistics Agency and other Navy Inventory Control Points provide approximately 93 percent of items related to aircraft support for the Navy and Marine Corps.

The items managed by ASO are divided into two categories, the repairables subject to scheduled overhaul and the expense items (generally consumable items). Table 4-1 shows the number of items and inventory investment levels for these two categories.

As at SPCC, the wholesale requirements determination is based on TIRs received from stock points or directly from customers. A Levels Setting Program, a Cyclic Levels and Forecasts Program and a Supply Demand Review Program interact with the Master Data File and generate on a quarterly basis order quantities and redistribution/disposal recommendations. ASO also uses a Repairable Management program.

TABLE 4-1. ASO INVENTORY AS OF SEPTEMBER 1980

	<u>Number of Items*</u>	<u>Percent</u>	<u>Supply System Inventory*</u>	<u>Percent</u>
Repairables	54,600	19	\$3,627 M	78
Consumables	230,000 ^{**}	81	\$1,046 M	22
Total	284,600	100	\$4,673 M	100

* Excludes some 10,000 items of GSE and War Consumable supply system stocks plus in-use and installs, worth approximately \$3.1 billion.

** Approximately 40 percent of these items have a demand of less than one per quarter.

There are some differences between processing at ASO and at SPCC. First, at ASO far more than at SPCC, individual items are classified into inter-related groups of item families, based on interchangeability, substitutability and modification (IS&M) data on the items. The IS&M data are added to the Master Data File and are used in computing requirement purchases. Secondly, "program data" are used by ASO. Program data provide a measure of weapon system activity that is directly correlated with item demand rates; thus, program data can be a basis for measuring past demand and forecasting future demand. Program data are usually in terms of flying hours per aircraft per month for aviation items. Hours of use or some other measure may be used for ground support equipment, bomb racks, and other items whose failures are not necessarily related to flying hours.

Aviation Consolidated Allowance List

An Aviation Consolidated Allowance List (AVCAL) is developed in a manner similar to the COSAL/COSBAL. It lists the components, repair parts

and consumable items required to support aircraft assigned to a carrier or air station. The allowance quantities are designed to provide attrition support for repair parts and repairables used at the consumer and intermediate levels of maintenance. Allowances for repairables also include a repair cycle quantity. In normal circumstances, a carrier's AVCAL is mandatory as to range and depth of material carried, except for possible upward adjustments based on local demand rates. The AVCAL is updated at intervals ranging from nine to twenty-four months.

Initial Provisioning for ASO

ASO uses an Initial Outfitting List (IOL) program developed by General Dynamics to determine consumer-level initial provisioning requirements. The mathematics of the model are similar to the mathematics in the ACIM, although the automated implementation is different. Currently, the IOL program is very sensitive to data errors. Missing data can cause the program to stop calculating requirements, resulting in data errors being discovered one at a time. Nevertheless, use of this model does represent an attempt to provision by weapon system to meet an aircraft availability goal. As at SPCC, provisioning requirements may be calculated on part of the system before all component-level data are available.

At the wholesale level ASO uses a mechanized system (program) to compute a budget target in accordance with DODI 4140.42 range and depth rules. A second program is then used to develop the wholesale stockage requirement conforming to the budget target but optimizing range and depth to minimize units short. This second program incorporates a variable safety level rather than the three-month safety level of the first program. Manual computations may also be made which provide support for leadtime attrition and repair-cycle requirements.

OPTIMIZATION ACROSS COMMODITIES

At the consumer level, COSAL, COSBAL and AVCAL items are selected according to their expected demand, maintenance plan, and other criteria. Both consumables and repairables are included. Thus, at the consumer level, a ship, air squadron or shore facility is being supplied, regardless of commodity class. The budgeting and allocation of funds are different matters. The Appropriation Purchases Account (APA), used to purchase investment items, is not budgeted by Naval Supply Systems Command (NAVSUP), but by Naval Sea Systems Command, Naval Air Systems Command, or the Strategic Systems Projects Office. However, appropriated APA procurement funds are normally obligated at the ICP level. Material is procured centrally and distributed as discussed previously in this chapter. NAVSUP budgets for the Navy Stock Fund (NSF) and suballocates obligational authority to Navy ICPs and Navy Retail Offices. NSF may be used to procure consumable items or repair depot level repairable items. Thus, although the required items are allocated without regard to the commodity class, the funds to procure/repair the mix of items needed may not be available due to the allocation and control of funds. At the wholesale level, ASO divides inventory into "repairables" (usually funded by APA) and "consumables" (usually funded by NSF). Like SPCC, ASO is moving toward reductions in the number of APA-funded items since they are "free" to the customer.

SPCC now provides budget displays by some 80 mission categories which relate to Navy systems. Supply performance will also be tracked by these categories in the near future. SPCC manages funds using these mission-oriented budget displays, but has no visibility of consumables below the intermediate level. ASO allocates funds by aircraft type. Once the funds have been assigned to the aircraft type, items are purchased to minimize expected backorders for those aircraft.

ORGANIZATION

Both SPCC and ASO have a matrix approach to managing inventory. Weapon systems, as they are brought into the inventory, are assigned to a weapon-system manager. The weapon sub-system responsibility assignment is by local routing codes (LRCs). A person or group of persons has an LRC that identifies a mission category which relates to a weapon system. For instance, an LRC may be responsible for submarine sonars or carrier power systems. There is a separate LRC for common items.

Since we define a weapon system as a ship or an aircraft, the current SPCC organization is not weapon-system oriented. A concept such as Platform Management, which centralizes the responsibility for supply and logistics support for an entire new construction ship or class of ships, could, however, be extended to provide weapon-system management.

IMPEDIMENTS

Part of the impediment to relating spares requirements to weapon-system readiness is due to definition. For a ship's captain, readiness is measured, roughly, by looking at the Casualty Report (CASREPT) for the ship. All the equipment on the ship is considered on the CASREPT; yet the current SPCC definition of a weapon system looks at each type of equipment separately. Unless the supply definition and organization match a logical ship readiness concept, there will continue to be areas of disconnect in efficiently supporting the Navy's operations.

Aircraft readiness is measured by the Subsystem Capability Inventory Report (SCIR). The SCIR relates subsystems (such as radar, landing gear) to mission capability (such as reconnaissance) and designates mission capable, not mission capable, and partial mission capable categories. Again, this measurement of availability focuses on subsystems rather than on the weapon system.

The current tools for calculating requirements do not take weapon-system readiness into account. However, the Navy is trying to address this deficiency by assigning essentiality codes. Items are being coded as essential to the mission of a weapon system and as essential to a next higher assembly. Items with higher essentiality codes will be supported to a greater degree than less essential items. We believe that this approach is only one step in resolving the weapon-system readiness issue. In a model, such as the ACIM, tradeoffs can be made to maximize availability for a given budget. The use of an availability model, coupled with essentiality codes would give the Navy an excellent opportunity to optimize its support of its end items. However, some impediments exist for the Navy in using an availability model.

A major problem the Navy has is in keeping its data accurate. Data bases become inaccurate at several times during the life of a weapon system. The configuration of a new weapon system is provided to the ICP. After initial provisioning decisions have been made, the configuration (application) data are not kept current in two respects. In the first place, not all engineering design changes are accurately reflected in the configuration file. Part of the reason for this is the staggered change of configurations once a weapon system is deployed, especially for shipboard systems. In the second place, if the ICP is not the COG for a piece part (item), that item may not be included in the configuration file. Since many of the Navy's items are managed by DLA, this presents a problem. Furthermore, items may never be put into the configuration file because they are commercial (general-use consumable) items. Some 25 to 30 percent of demanded items are not shown in the configuration file.

Without accurate configuration data, the levels-of-indenture that availability models require cannot be derived. The accuracy of other data, such as failure rates and repair times, is also important, both in availability models and the methods currently being used. Any requirements method could be improved by use of more accurate data.

The final impediment for the use of availability models in the Navy is the limited shipboard storage facilities, which adds another dimension to the problem of computing the optimal mix of spares.

None of the impediments are impossible to overcome. As mentioned previously, the Navy collects data on all components (at least at the wholesale level) that support the use of an availability model. Table 4-2 summarizes the impediments.

CONCLUSIONS

We conclude that the Navy needs to take the following actions before the link between requirements and weapon-system availability can be completed:

- For purposes of managing the inventory system to achieve weapon-system availability objectives define a weapon system as a ship, aircraft, or other major end item and specify availability objectives for those fighting units rather than their subsystems.
- Intensify efforts to insure data accuracy of the master data and configuration files.
- Expand use of availability models by applying them first to the total, multi-echelon requirements computational problem for aircraft, i.e., to stock-level computations for organizational, intermediate, and wholesale echelons.
- As a next step, implement availability models for computation of ship spares requirements at all echelons.

TABLE 4-2. CAPABILITY FOR USE OF AVAILABILITY MODELS IN
SPARES COMPUTATIONS IN NAVY SUPPLY SYSTEMS

	<u>Available/ Applicable</u>	<u>Limited</u>	<u>Not Available/ Difficult</u>
Organization		√	
Budgeting by Weapon System ^a		√	
Data Availability	√		
Data Accuracy			√
Implementation Status ^b		√	
Measure of Weapon-System Availability/Unavailability ^c		√	

^aUsed at SPCC and ASO to manage at wholesale level, but not translated into overall Navy budget process.

^bLimited to initial provisioning and to selected subsystems of a weapon system, but existing model could be used more extensively.

^cThe CASREPT and SCIR both have limitations.

5. DEFENSE LOGISTICS AGENCY

The Defense Logistics Agency (DLA) is responsible for procuring and managing items that are broadly termed "consumable items." DLA's management responsibility includes items in most Federal Stock Classes except explosive ordnance, major end items of equipment, and repairable items. This includes food, clothing, fuel, medical supplies, and many secondary-item spare and repair parts. In this chapter, we are interested in DLA's management of secondary-item spare and repair parts and the impediments to relating the requirements computations for these items to weapon-system availability. There are some 3.91 million active items managed by DoD and about 1.97 million items are spare and repair parts. About 1.3 million of these items are peculiar to one Service. Table 5-1 shows the distribution of DLA items among the four DLA Defense Supply Centers (DSCs)--Construction, Electronics, General, and Industrial--that manage the majority of weapon-system-related items. DLA generally manages items without regard to their end-item applications except for items in the Weapon System Support Program (WSSP). A Service may identify an item as a component of a selected weapon system. This results in assigning higher support for that item. Approximately 240,000 items are in the WSSP. At the Defense Industrial Supply Center, 95,300 of the 616,700 items (15 percent) are coded as weapon-system components; of these, 38,600 (six percent) are common to two or more weapon systems.

INITIAL PROVISIONING AT DLA

The Services determine the range and depth (quantity) of items required below the wholesale level for DLA-supported items during the initial provisioning requirements calculations for new weapon systems. The Services

TABLE 5-1. SUMMARY OF ITEMS AS OF SEPTEMBER 1981

	Number of Items (000)				<u>TOTAL</u>
	<u>DCSC</u>	<u>DESC</u>	<u>DGSC</u>	<u>DISC</u>	
Stocked Items	139.1	288.6	86.3	387.6	897.6
Non-Stocked Items	125.8	170.3	83.7	100.8	480.5
Non-Stocked, Semiactive	24.7	56.1	14.9	33.8	129.5
Stocked, Insurance/NSO	31.9	255.5	26.6	98.6	412.6
Total Managed	321.5	770.6	211.5	616.7	1,920.2

provide DLA with the requirements for items as well as estimates of demand, maintenance concept, leadtimes, and other data. DLA provides the support for the Service-specified requirement and uses the estimates of demand, etc. until actual demand data are available. These initial estimates are modified as actual demands are received. If no demands are recorded during the demand development period (DDP), the estimated demand is maintained for an additional two-year period; then, the demand for replenishment purposes is set to zero. The replenishment requirement calculations, used after the DDP, are described below.

Some recent initial provisioning conferences have included DLA personnel. DLA participation in initial provisioning allows better planning on DLA's part for either anticipating demand increases for existing items or negotiating timely delivery of new or non-stocked items.

REPLENISHMENT REQUIREMENTS

DLA computes wholesale requirements based on standard MILSTRIP requisitions from users world-wide and on forecasts of nonrecurring requirements. DLA captures the following data: demand quantity, demand frequency, the national item identification number (NIIN), the customer's service code, a routing identification code, and a customer zone code. Leadtimes are computed weekly for items for which procurement contracts have been awarded or

deliveries made. Administrative leadtime is recomputed when an award is made and production leadtime is recomputed once the first significant increment of material is delivered. These are processed weekly and maintained as exponentially smoothed averages.

All replenishment demand items are forecast quarterly (though they can be forecast monthly). A double-smoothed forecast for each item is calculated. The Quarterly Forecast of Demand, with double smoothing, models upward or downward trend in demand.

Nonrecurring requirements are only partially used in modifying the demand calculation; Special Program Requirements and direct Foreign Military Sales are added to the requirements after double exponential smoothing and do not influence the historical demand pattern. DLA has a provision for the use of program change factors provided by the Services. In practice, program data are not yet in use, and DLA depends on historical demands to predict future demands. Dependence on historical data is a problem because it may result in lack of responsiveness to sudden changes in demand that may be induced by new weapon systems in the active inventory, phaseout of existing weapon systems, or major overhauls of a class of weapon systems. DLA and the Services are working together to avoid "surprises" in the demand pattern and the supply time.

IMPEDIMENTS

The inventory managed by DLA, unlike that of the Services, presents a number of impediments to relating requirements computations to weapon-systems availability. A large proportion of items managed by DLA are common to more than one application. Thus, assigning weapon-system codes to these items in the same way the Services do for repairables would often require multiple codes per item and prorating estimated demand or partitioning actual demand

among all applicable weapon systems. Furthermore, the Service-designated level of support for the weapon system would have to be considered in the calculations. Currently, requisitions do not identify weapon systems and, especially for stock replenishment of common items, it doesn't seem feasible to require weapon system identification on requisitions.

As mentioned previously, DLA manages by commodities, not weapon systems. Were DLA to manage by weapon system, it would mean migrating toward a new organization, either a matrix organization where both commodities and weapon systems are monitored or to a weapon-system-oriented organization. Table 5-2 summarizes the impediments for DLA.

TABLE 5-2. CAPABILITY FOR USE OF AVAILABILITY MODELS IN SPARES COMPUTATIONS IN DLA SUPPLY SYSTEMS

	<u>Available/ Applicable</u>	<u>Limited</u>	<u>Not Available/ Difficult</u>
Organization			✓
Budgeting by Weapon System			✓
Data Availability ^a		✓	
Data Accuracy		✓	
Implementation Status			✓
Measure of Weapon-System Availability/Unavailability			✓

^aThe data that are available do not necessarily provide visibility to the retail level. Configuration data are also not generally available.

ADDITIONAL COMMENTS

DLA and the Services are beginning to evaluate additional line items for possible transfer to DLA for supply management. DLA may become responsible for all stable, non-nuclear items. This would mean management of an additional 1.5 million items for DLA, and would drop the number of items managed by the Services to some 400,000 items. The Services combined would then

manage only about 10 percent of all DoD-managed items and would become even more dependent on DLA for support. This would make end-item availability even more difficult to relate to spares investments.

A COURSE OF ACTION

The problem of computing requirements for DLA-managed items with an availability model is essentially the same as the Air Force's problem of dealing with consumables, but its Herculean dimensions make it more difficult. There are two reasonable approaches to the problem. One involves the creation and maintenance of accurate, detailed application data on all items that are used on weapon systems or end items and for which availability objectives would be specified. Those application data could support availability computations. Again, there would be a need to account explicitly for common items, and, in DLA's case, the extent of the commonality problem is more severe than in any of the Military Departments.

The second approach, as in the Air Force's consumables case, is to develop an estimating relationship that would not depend on detailed, line-item-level data. It seems feasible to develop a mathematical model or collection of models that could estimate the loss of weapon-system or end-item availability induced by shortages of DLA-managed items on the basis of some set of system-level characteristics, fill rate, and investment level (i.e., level of inventory capitalization).

Both approaches could be explored and the final choice made on the basis of the cost of creating and maintaining accurate, detailed application data on all the line items of interest and the relative worth of an availability model that depends on such data compared with a simpler, system-level availability estimating relationship.

CONCLUSIONS

We believe that DLA should undertake the following tasks so that a spares requirements/weapon-system availability link may be established:

- Assess the cost of creating and maintaining accurate, detailed application data on all line items applicable to weapon systems or end items for which availability objectives would be specified.
- Develop a mathematical estimating relationship that would estimate availability loss induced by shortages of DLA-managed items as a function of inventory capitalization and system-level parameters.

6. AN IMPLEMENTATION STRATEGY

The logistics systems of the Military Departments have evolved over a long period of time, with their major growth and development occurring during World War II. Each of them has a line-item-oriented organizational structure, despite the existence of system management roles. In large part, item managers throughout the DoD make the day-to-day operating decisions and, therefore, influence spares stockage postures in important ways. Despite the wealth of experience that resides in these item managers, their judgments are shaped not only by the intuition they develop from their experience, but also by their lack of visibility of the rest of the logistics system. This intuition is an important factor that must be considered if availability models are to be implemented successfully, because an availability model will compute stockage postures that are very different from those that result from the line-item-oriented methods traditionally used by item managers. For example, an availability model will compute greater requirements for relatively inexpensive items than for expensive ones, and greater requirements for items that are applicable to more complex weapon systems (i.e., those with larger numbers of components) than for items that apply to less complex weapon systems. As a result of these differences, if an item manager were to comment on the stock levels computed by an availability model on the individual items he manages, he would very likely express dissatisfaction with them because they would be, for him, counter-intuitive. An availability model takes a system view, not a line-item view. For any specified level of investment or set of availability objectives, it will trade off stock levels among line items to compute the most cost-effective mix of stock levels among items and

across all echelons of the logistics system, giving up a few, very expensive items in favor of relatively generous amounts of many, less expensive ones. Thus, the item manager who manages inexpensive consumables may sense that the availability model's results are about to bury him in nuts and bolts, so to speak, while the person who manages very expensive inertial navigation units is likely to complain vociferously about the model's inadequate levels that make it impossible for him to carry out his support responsibilities. The worth of an availability model cannot be judged on the basis of its recommended stock levels of individual line items; it must be judged on the basis of the performance of the logistics system as an integrated whole.

We make these observations because we believe that they are fundamentally important, in fact, crucial to the success of any attempt to implement the use of availability models for spares requirements computations. If item managers and others throughout the system are asked to implement and operate a technique they don't understand, no implementation strategy, however well conceived, will be able to overcome the entrenched resistance that will surely develop. It is vital, therefore, that an effective educational program be devised within each of the Military Departments and DLA.

A ROADMAP

The Air Force is well ahead of the other Services because of its experience with the VSL algorithm and its sponsorship and use of the Aircraft Availability Model. The Air Force has the data to support requirements computations by an availability model and some experience with the problems of implementing requirements computational methods that yield results that may be counter-intuitive to item managers. Furthermore, a solution to the problem in the Air Force system of balancing investments among recoverables, engines, and consumables is likely to suggest the solution to balancing spares investments

among various resource classes in the other Military Departments, and among the Military Departments and DLA. The Air Force plans to run the Aircraft Availability Model and D041 in parallel on the same data base to evaluate the differences in stockage postures that result. OSD personnel should participate actively in that evaluation. As a next step, the Air Force should be asked to repeat the evaluation on a data base containing engines and engine modules. The Air Force should also estimate the cost of creating and maintaining detailed, line-item data, especially application data, on consumable items that are applicable to weapon systems or other end items for which availability objectives would be specified. The detailed ingredients of that estimate should, of course, be shared with all interested agencies. Recommendations should also be developed on the problem related to balancing investments between recoverables and consumables. This task would require the cost estimate just mentioned, and would also involve the evaluation of the two alternative strategies described in Chapter 2, i.e, the development of an availability-vs.-cost estimating relationship that would not depend on line-item-level data, and a method for modeling the Air Force's multi-echelon EOQ system for consumable item management.

The Air Force should also determine how changes could be made to the Standard Base Supply System so that it would compute stock levels that would be consistent with weapon-system availability objectives or, alternatively, decide how to implement centrally computed stock levels. A logical future step for the Air Force would be the addition of end-items other than aircraft, e.g., ground radars and missiles, in the availability model's computations.

OSD should task the Army to design and implement a credible asset reporting system that would give the NICP adequate visibility of at least repairable assets. The Army also needs to devise a maintenance reporting

system to support accurate estimates of component removal rates, repair rates, condemnation rates, and other pipeline ingredients. The design of the maintenance reporting system, whether intended to collect information on all component removals, repairs, and condemnations of interest or only sample data, should be based on a cost-effectiveness analysis of reasonable alternatives.

The Army should begin to move toward the use of availability models for spares requirements computations on aircraft first by developing and validating a model and evaluating its performance in actual use. In the process of implementation, the operational issues and problems associated with the use of availability models will need to be addressed, thus providing the experience needed for expanded application to other kinds of weapon systems later.

We recommend that the Navy, for purposes of managing its inventory system to achieve weapon-system availability objectives, define a weapon system to be a fighting unit such as a ship, aircraft, or other major end item, and specify availability objectives for those fighting units rather than their subsystems. To move toward implementation of availability models for spares requirements computations, we recommend that the Navy apply them first to the total, multi-echelon requirements computational problem for aircraft, i.e., to computation of stock levels for organizational, intermediate, and wholesale echelons. As a next step, extend the application to ship spares requirements at all echelons. To support these applications adequately, the Navy should intensify its efforts to provide accurate data on component characteristics and end-item configuration.

We recommend that DLA be tasked to estimate the cost of acquiring and maintaining detailed application data at the line-item level on DLA-managed items that are applicable to weapon systems and end items for which availability objectives would be specified. OSD personnel should participate in this analysis.

TECHNICAL ISSUES

In addition to the strategic issues of implementation discussed here, there are several technical problems that should be addressed. They include modeling lateral supply and cannibalization in availability models; the addition of Bayesian logic to availability models; modeling multi-echelon EOQ systems; and, perhaps most importantly, formulating the problem of computing war-reserve materiel requirements.

THE INTERDEPARTMENTAL WORKING GROUP

In his letter of 10 March 1982 to the Military Departments and DLA, the Principal Deputy Assistant Secretary of Defense (Manpower, Reserve Affairs, and Logistics) established a working group "to identify and assess the tasks required to bring explicit consideration of end-item readiness to inventory management." We recommend that this group undertake these specific tasks:

- Develop a strategy for coordinated implementation of multi-echelon requirements computational methodology based on availability optimization models throughout the DoD.
- Define the most useful role for each of the Military Departments and DLA in this effort.
- Recommend to the ASD(MRA&L) any policy changes needed to support the fundamental change in orientation of DoD requirements computations from supply performance to military readiness and sustainability.
- Review and assess the feasibility of proposed improvements in requirements computational methods.

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