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ASSETS vs. REQUIREMENTS: WHY ASSET-BASED CENTRAL LEVELING IS A GOOD IDEA

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The D028 Central Leveling System has been assigning base levels for recoverable spares in the Air Force since 1982. The D028 system assigns base levels by finding multi-echelon (depot/base) allocations of computed worldwide requirements to minimize base expected backorders (EBOs). Spares requirements, however, rarely agree with the number of spare assets actually in the system. The Air Force can reduce base EBOs another 10 to 60 percent by modifying the D028 system to take actual asset quantities into account. Final reduction in system-wide base EBOs will depend on the asset categories selected for inclusion in the system.

The report includes a description of the history, theory, and operation of the D028 system; analysis and comparison of the effects of asset-based versus requirements-based leveling for sample D028 items; and a discussion of asset categories to include in an asset-based system.

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Executive Summary

ASSETS VS. REQUIREMENTS: WHY ASSET-BASED CENTRAL LEVELING IS A GOOD IDEA

Since its implementation in the fall of 1982, the D028 Central Leveling System has been doing a good job of reducing the number of outstanding base-level backorders for recoverable spares throughout the Air Force. It could do an even better one.

For each of the 25,000 items it handles, the D028 system attempts to minimize base-level backorders by finding an optimal, base-by-base allocation of the worldwide item requirement, as computed by the D041 Recoverable Consumption Item Requirements System. This allocation, however, ignores an important fact: For most items, the number of spares in the Air Force logistics system is usually different from the computed requirement. Thus, the D028 system sets base requisitioning objectives on the basis of the spares the Air Force *would like* to have – the requirement – as opposed to those it *actually* has – its assets.

We estimate that the number of base-level backorders for reparable spares worldwide could be reduced substantially – by 10 to 60 percent – if the D028 system were to take actual assets into account. Even a reduction as small as 10 percent corresponds to making available more than 60 of the roughly 700 aircraft that the Air Force has in Not-Mission-Capable-Supply status at any given time.

Without question, moving to asset-based allocations will be difficult. Indeed, the problem of specifying which assets should be included in an asset-based leveling system was considered sufficiently difficult in 1982 that the attempt was not made – although the idea of making the D028 into an asset-based system has always been part of the long-range plan.

The benefits of reduced base-level backorders and increased aircraft readiness justify a renewed attempt to convert the system. As the Air Force gives priority to improved spares management – through the development of systems such as WSMIS (Weapon System Management Information System) and RDB

(Requirements Data Bank) – it should include an effort to make its Central Leveling System asset-based.

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CHAPTER 1

BACKGROUND

The idea of centrally determining base spares levels has its origins in the multi-echelon, system-oriented modeling techniques the Air Force adopted in the 1970s for computing supply requirements for recoverable spares.[1] Based on work of The RAND Corporation [1, 2], these techniques were designed to improve supply system performance in two ways: (1) by explicitly taking into account the tradeoff between stocking a spare at a base (the retail echelon) and stocking it at a depot (the wholesale echelon), and (2) by allowing each item's requirement to vary – according to the item's cost, demand, and resupply characteristics – in such a way as to find least-cost ways to achieve desired levels of overall system performance.

The system approach employs marginal analysis, which means that benefit-per-cost ratios are computed for each possible spares level for each item in the system. The ratios are used to determine "variable safety levels" designed to optimize overall system performance.

A system model works by starting either at zero or with existing assets and computing, for each item, the effects each time the total number of spares for the item is increased by one. In a multi-echelon setting, as the total spares level changes, there is the question of how best to allocate stocks between the depot and using bases. Stocking spares at the depot reduces, by some amount, the average depot delay for the bases when they requisition from the depot; stocking spares at the bases reduces, generally by a different amount, the average supply delay experienced by base users. The multi-echelon tradeoff involves examining which of these two options yields the greatest improvement in overall system performance. Sometimes it is better to stock the spares at a base, and sometimes it is better to stock them at the depot. Thus, for each possible number of spares in the system there is

[1] Recoverable spares are items designated XD2 and XD3 under the Air Force's Expendability, Recoverability, Repairability Category (ERRC) coding system for classifying inventories of parts. XD items are those the Air Force has identified as being economical to repair and overhaul at the depot level. The new modeling techniques for XD items were incorporated into the Air Force's D041 Recoverable Consumption Item Requirements System.

always a "best" allocation between depot and bases – that is, an allocation that minimizes the total number of expected backorders (EBOs) for base users. A multi-echelon model finds these best allocations and takes them into account when computing requirements.

Corresponding to the initiatives in requirements, the objectives for the new distribution system, the D028 Central Leveling System, were: (1) to set base and depot spares levels optimally, in the multi-echelon sense, to minimize the average number of outstanding base backorders; and (2) to do so in a way that brings base-level requirements into alignment with the new marginal analysis system for computing total requirements [3].

The new distribution system was not implemented until the fall of 1982 when approximately 25,000 subgroup master National Stock Numbers (NSNs) were selected for central leveling. Those items, which comprised the bulk of recoverable items experiencing base usage, represented slightly more than half of the more than 45,000 NSNs for which variable safety levels were being computed – the difference being items experiencing depot-level usage only.

At the time of implementation, the Air Force made a conscious decision to tie the new central leveling system to requirements rather than to assets. That decision is reflected in the official description of the D028 system [4], which notes: "The D028 system provides users the ability to pull assets (via the requisitioning process), but it cannot provide the assets."

The purpose of this report is to explain what it would mean to make the D028 system into an "asset-based" system and why it is worthwhile for the Air Force to do so. A natural question, of course, is if the idea is a good one today, it must have been a good one in 1982 – so why wasn't the system designed to be asset-based from the very beginning? In fact, it was.

The original D028 plan was to implement the new distribution system in three steps [5]. Step 1 would be to use centrally computed requirements to assign base levels; Step 2 would be to take actual asset quantities into account in deciding how to best allocate existing stocks; Step 3 would be to build into the system a way to redistribute assets among bases. Step 1 was taken and made the D028 system into

what it is today – a requirements-based system. Steps 2 and 3, which would have made the D028 into an asset-based system, were never taken.

The Air Force had both practical and systemic reasons for adopting a three-step approach. On the practical side, the problem of deciding which assets to include is troublesome: Should assets on order from suppliers be counted? Should unserviceable items at the depot be included? What about unserviceable items awaiting parts? How should assets obtained for depot overhaul programs be handled? What about assets set aside to support special programs (e.g., foreign military sales)? Further questions concern which asset tracking systems to use, their reliability and accuracy, and how they should interface with the distribution system.

The systemic reason for a stepwise approach is that, for many items, the objectives of the D028 system – to minimize base EBOs *and* bring distribution and requirements into alignment – are in conflict with one another and are difficult to achieve simultaneously. The conflict exists when assets and requirements differ – a condition that is the norm rather than the exception. When that occurs and bases requisition to meet stockage objectives that are aligned with requirements, assets are "pulled" into an allocation that is not the best possible *for that number of assets*. A different allocation, based on the actual number of assets, will usually produce a smaller number of base EBOs.

D028's developers were aware of this conflict and decided on the stepwise approach as a way to get around it. The first step would be to align distribution and requirements, and the second and third steps would bring assets properly into the picture. Why, then, haven't the second and third steps been taken? A large part of the answer is that the base-owning Commands in the Air Force are not yet convinced that asset-based central leveling can yield improvements over the current system. Until they are convinced, it is unreasonable to expect them to give up what they perceive as their control over the spares they receive via the requisitioning process.

Given this perspective on D028's development, the purpose of this report is as much to *remind* the Air Force of a good idea it has already had as it is to suggest something new. The goal is to present a convincing case that, however assets are included, the potential benefits in reduced base backorders and improved aircraft readiness are great enough to make Steps 2 and 3 of the original plan worth doing.

In the discussion thus far, the terms "expected backorders," "levels," "requirements," and "distribution system" have been used as though their meanings were universally understood and agreed upon. In fact, they are not. Confusion and misunderstanding about these terms have probably contributed as much to the slowness of D028's development as any other factor. Therefore, to ensure a common ground of understanding and to set the stage for our analysis, we revisit these terms and the key ideas underlying the D028 system in the next two chapters.

CHAPTER 2

BASE EBOs – THE RIGHT MEASURE

The D028 system was developed to minimize "base expected backorders" (base EBOs). Why are base EBOs the appropriate measure upon which to base the system? To answer this question, we start with a review of what base EBOs are.

What matters about base backorders is not just how many occur, but also how long they last. That is, if the number of new backorders occurring each day were not too large, aircraft readiness would not suffer if each new backorder could be filled in, say, 2 minutes or less. The measure we want, therefore, is one able to capture *both* the occurrence and the duration characteristics of backorders.

Base EBOs refers to the average number of outstanding backorders at Air Force bases worldwide. That is, at any given point in time, a certain number of backorders exist at bases for recoverable spares. Base EBOs refers to the average value of that number over time. Base EBOs, defined this way, gives us the measure we want. Consider an example: Suppose an average of 100 new backorders occur each day, and a backorder lasts an average of 30 days. "Expected backorders" – the average number of outstanding backorders – will be:

$$100 \times 30 = 3{,}000 \text{ backorders,}$$

a number that captures *both* the occurrence and the duration characteristics of the backorders in question.[1]

The D041 Recoverable Consumption Item Requirements System computes requirements to minimize system-wide base EBOs. (It also computes spares requirements to cover demands generated in depot overhaul programs.) EBOs at *bases* (as opposed to all backorders, which would include backorders to customers at

[1]In our example, we have used average values, allowing for the possibility of variation in both the occurrence and duration of backorders. In the deterministic case, if exactly 100 new backorders occurred each day, and every backorder lasted exactly 30 days, it is obvious that there would always be 3,000 backorders in place at all times. It is a property of backorders that the product of *average* occurrence and *average* duration yields the correct value for EBOs in the nondeterministic case as well.

depots) are the particular backorder measure of interest, because backorders at bases (for LRUs – line replaceable units) correspond directly to "holes" on aircraft. Thus, base EBOs are indeed an appropriate measure for designing and evaluating a distribution system whose goal is to maximize support to aircraft at bases.

CHAPTER 3

REQUIREMENTS, LEVELS, AND THE ROLE OF A DISTRIBUTION SYSTEM

For each of its items, the current D028 system allocates a worldwide requirements number it receives from the D041 system. The allocation process consists of finding a set of base stockage objectives and a resultant depot stockage objective that together: (1) sum to the given requirement, and (2) provide for the smallest number of base EBOs for the item.

The requirements number computed by D041 and passed to D028 represents the number of spares – extra copies of the component beyond the total number of actual installations – that the Air Force would like to have in its logistics system. It is very important here to understand what "in the logistics system" means.

As installed items fail or are removed, spares are used (i.e., become installed), and the removed items, which now become the extra, spare items in the system, enter a repair or shipment pipeline. Thus, "in the system" means somewhere in the logistics/resupply system. The system includes not just serviceable items, but items undergoing repair and shipment as well. Also, there are times when demands exceed the available supply of serviceable spares, and backorders occur. When that happens, "holes" exist where installed items are supposed to be, and the number of items in the logistics/resupply system *exceeds* the number of spares in the system. In this case, the number of spares in the system is obtained by subtracting the number of outstanding backorders from the number of items in resupply (e.g., repair, shipment, in storage awaiting repair, etc.). The general expression, therefore, for the number of spares in the system is:

the number of serviceable items on hand

plus

the number of items in resupply
(e.g., repair, shipment, storage awaiting repair, etc.)

minus

the number of outstanding backorders.

Because the D041 system employs an inventory model, it can compute and project supply performance (e.g., EBOs and fill rates) for any given number of spares in the system in the above sense. Indeed, this is the essence of how the D041 system computes the "requirement": Given the pipelines for each item, it finds – using marginal analysis and the best possible depot/base allocation – the number of spares such that, *if there were that many spares in the logistics resupply system*, the supply system would achieve the desired level of performance – for least cost.

As a consequence, the requirements number that the D041 system passes to the D028 system is conditional. It represents the number of spares the Air Force would *like* to have in its total resupply system (supply, maintenance, storage, and transportation) for providing end users with spares. Given the fluctuations that occur in spares requirements, this requirements number can be very different from the number of spares the Air Force actually has in its system.

We can now define base "levels." Base levels are very much like requirements numbers, except that they represent requirements at a particular base. That is, a level for an item at a base represents the number of extra copies of the item that the base would like to have in *its* logistics system.

The logistics system for a base corresponds to more than just the number of serviceable items in base supply at any time. A base's logistics/resupply system also includes items in base repair, items in shipment to the base from a depot, and items in depot repair that are owed to the base but not yet ready to be shipped.

Given this view of worldwide "requirements" and base "levels," the theory behind the first step in the three-step D028 implementation process makes a certain sense. Base levels, viewed as requirements, should track appropriately with total requirements and, in addition to adding up properly, should incorporate consideration of multi-echelon tradeoffs, just as total requirements do.

A distribution system, however, must take into account an important difference between the function of worldwide requirements and the function of base levels. Worldwide requirements (and funding) determine what the Air Force may order from *outside* suppliers to bring *into* the Air Forces logistics system. Base levels determine what the bases may order *within* that system. In particular, a base level serves as a requisitioning objective: It determines what a base may requisition from the Air Force Logistics Command (AFLC). It does not directly determine what

AFLC buys, nor does it cause orders to be placed automatically with outside suppliers. Thus, base levels, in their role as requisitioning objectives, serve a function that is quite different from that of worldwide requirements. Worldwide requirements determine the items that enter the Air Force's logistics system; base levels determine, through the requisitioning process, how *assets* that are already in the system get distributed.

The dual nature of base levels – as expressions of requirements *and* as requisitioning objectives that control and drive base demands on the depot – complicates the role of a centralized "distribution" system for assigning base levels. Certainly, the system should specify levels that conform with requirements. In that way, the Air Force knows what it needs (i.e., would like to have) in its system. However, the system should also establish base requisitioning objectives that enable the Air Force to get the most out of the spares it actually does have. It is this latter role that the D028 system has never assumed.

Finally, it is clear that the conflict between base requisitioning objectives and base requirements exists only to the extent that assets in the system are different from requirements. Indeed, if requirements for recoverable spares never changed over time and received sufficient funding, then assets, for the most part, would eventually match requirements. The only continuing difference would be the result of condemnations, which alone are probably not enough to make changing the distribution system worthwhile.

But requirements for recoverables – the spares the Air Force has decided it needs and would like to have in its system – have not been stable over time and are not likely to stabilize in the future. The fact is that year in and year out, as new items are introduced and others become obsolete or are condemned, as demand rates and other factors change, as new management decisions are made, and as funding approved each year in the budgeting process fluctuates, a considerable and persistent difference exists between current requirements and available assets. The next chapters present evidence of this fact and quantify the penalty the Air Force is incurring by failing to recognize the difference in the operation of the D028 distribution system.

CHAPTER 4

A SINGLE-ITEM EXAMPLE

We start with a single-item example to illustrate what happens when requirements rather than assets are used to set base levels. The item we examine is one from a selected sample of items that were being processed by the D028 Central Leveling System in October 1983. In the following chapter we return to this sample – and two other, larger samples (one from August 1986) – in order to project system-wide effects. System-wide effects are simply summations – over many items – of individual item results like the one we discuss here.

In October 1983, NSN 4130011274674 was one of the roughly 25,000 components being processed by the D028 system. (The item is still in use, but is no longer being centrally leveled.) The item is a $3,600 component used in Aerospace Ground Equipment (AGE) air conditioning units. In 1983, the item had demand-based levels at 10 bases and was classified as essential to both the wartime and peacetime missions of the systems it supported. Although all demand for the item originated at the base level (there were no depot programs requiring spares), none of the bases using the item could repair it on base, so all repairs were performed at the depot [the Air Logistics Center (ALC) in San Antonio, Texas]. The bases needed spares, of course, to cover the order and shipment time from the depot, and also to cover the depot delay they experienced awaiting the completion of depot repairs, prior to shipment. (Spares stocked at the depot serve to reduce this depot delay. The multi-echelon tradeoff involves comparing, for each possible number of spares in the system, the benefits of depot stockage with the benefits if the spares are stocked at bases.)

Based on data in a September 1983 D041 data base, the average number in depot repair for the item (the depot repair pipeline) was 28.2 units, and the average number in shipment to users (the order and ship pipeline) was 3.0 units. The procurement leadtime for the item in 1983 was 18 months, consisting of 6 months administrative leadtime and 12 months production leadtime.

The D041 data also indicate that the Air Force had 45 assets for this item "in the system" as of 30 September 1983. That is, 45 units, including both serviceables and unserviceables, were either under the direct control of Air Force supply or due in to supply from another activity in the logistics/resupply system. *Not* included in the 45 assets are the 109 units that were on order from the manufacturer as of 30 September 1983 (the asset cutoff date for the September 1983 D041 computation).[1]

With this information, we can analyze the expected behavior of the item in the logistics system. To do this, we use a single-item, two-echelon inventory model that computes EBOs and fill rates for any given spares level in the system, given whatever depot and base pipelines exist. The model, which is described in detail in Appendix B, is programmed in Turbo Pascal and runs on a personal computer.

Table 4-1 shows what happens if, with 45 spares in the system, we allocate a level of 2 to each of the 10 bases that use the item.[2]

The first column of Table 4-1 shows that with a level of 2 per base and 45 spares in the system, the total base spares level is 20, and the resulting spares level at the depot is 25. To see why the spares level at the depot is indeed a de facto 25, first consider what it means to say that each base has a level (i.e., requisitioning objective) of 2. This means that at each base the algebraic sum:

(on hand serviceable) + (in resupply) − (backorders)

will always be equal to 2, and, therefore, over all 10 bases will always be equal to 20. But having 45 spares in the system means that the total number the Air Force has

[1]The D028 system is supposed to serve as a central leveling and distribution system for base-generated, organizational and intermediate maintenance (OIM) requirements only. An important characteristic of the item we are considering is that all its demands generate at the base level. In such a case, it is reasonable to consider all assets in the system. For a D028 component that has some depot-generated (non-OIM) demand – in addition to its base-generated demand – it would make sense to prorate assets in some way (e.g., by the ratio of OIM requirements to total requirements). This idea and others on the subject of deciding which assets to include in an asset-based distribution system are discussed further in upcoming chapters. Specific, technical descriptions of the D041 asset categories considered in our analysis are given in Appendix A.

[2]Model runs employed a "uniform-base" assumption, meaning that each base using the item was treated as contributing equally to the total retail requirement for the item. Choices among possible spares allocations between the depot and bases were limited to those in which each base received the same spares level. For example, with 10 bases and 45 spares, results were checked using base levels of 1 per base, 2 per base, 3 per base, and 4 per base.

TABLE 4-1

SINGLE-ITEM EXAMPLE

	Level	Average number in resupply	Average number outstanding backorders (EBOs)	Projected fill rate	Average serviceable on hand
Depot	25	28.2	5.6	38.8%	2.4
Base	20 (2/base)	8.6 (3.0 + 5.6)	0.8	78.5%	12.2

on hand, plus in resupply, minus backorders to users at bases will be 45. Thus, at the depot, the number of items on hand, plus the number in repair and not owed to a base, minus the number in repair and owed to a base (subtracted because this number has already been counted in the number in resupply to the bases) must always be equal to 25. In other words, the depot level is 25.

The row labeled "*Depot*" in Table 4-1 lists the effects at the depot with a spares level of 25. The average number of items in depot repair (the depot pipeline, which does not depend on the spares level) is 28.2, as specified. With a spares level of 25 and this pipeline, EBOs at the depot (i.e., items in repair that are backordered to bases) is 5.6. The projected fill rate (percentage of demands that can be filled upon presentation) at the depot is 38.8 percent. The average number of serviceable items on hand at the depot is 2.4, a number obtained simply by subtracting the pipeline (28.2) from the level of 25 and adding the EBO quantity of 5.6.[3]

The row labeled "*Base*" in Table 4-1 lists the effects on bases with a level of 2 at each base and a level of 25 at the depot. The total resupply pipeline to the bases is the sum of the order and ship pipeline (3.0) and the depot EBO figure of 5.6. That is,

[3]Like the EBO figure, the average number of serviceables on hand is a time-weighted average. For example, over a period of 10 days, if there were 3 spares were on hand for 4 days and 2 spares for the other 6 days, the time-weighted average number of spares on hand would be:

$$(3 \text{ spares} \times 4 \text{ days} + 2 \text{ spares} \times 6 \text{ days}) / 10 \text{ days} = 2.4 \text{ spares}.$$

Also, although the spares level at a supply site can always be determined by adding the number on hand to the number in resupply and subtracting outstanding backorders, we have computed expected values for these quantities under the assumption that serviceables on hand and backorders do not simultaneously coexist and that everything that enters a resupply process eventually leaves it.

an average of 8.6 items are either on their way to a base or are backordered to a base pending completion of a repair. Given this total base resupply pipeline, a level of 2 at each base results in 0.8 total base EBOs. That is, the time-weighted average number of outstanding backorders to customers across all 10 bases is 0.8 backorders. The average serviceable on hand across all 10 bases is 12.2 units, and the projected overall base fill rate is 78.5 percent.

To illustrate how the allocation of spares levels affects results, we next consider the effects if the 45 spares in the system are allocated differently between the depot and the bases. Table 4-2 shows exactly the same information as Table 4-1, except that now each base has been assigned a level of 4, and the de facto depot level has become 5. With this allocation, base EBOs have increased from 0.8 to 3.5 expected backorders.

TABLE 4-2

SINGLE-ITEM EXAMPLE CONTINUED

	Level	Average number in resupply	Average number outstanding backorders (EBOs)	Projected fill rate	Average serviceable on hand
Depot	5	28.2	23.2	0.03%	0.0 +
Base	40 (4/base)	26.2 (3.0 + 23.2)	3.5	71.9%	17.3

Tables 4-1 and 4-2 show that different depot/base allocations of a given total number of spares in the system lead to a different number of EBOs to base customers. Even though the bases have higher spares levels in Table 4-2 than in Table 4-1, the reduction in the depot level is such that the bases are worse off. The loss of spares at the depot means the bases must wait almost a full repair time to get a serviceable back, and the higher levels at the bases are not enough to compensate for the loss of depot support.

Tables 4-1 and 4-2 suggest that for any given total number of spares in the system, there will always be a "best" allocation that yields the lowest number of base

EBOs. This allocation can be found simply by checking all possible allocations. Indeed, this is precisely what the D028 system does.

We now consider what the D028 system actually did with this component in October 1983. At that time, based on a standard Central Leveling System (CLS) Item Summary Report [4], the D028 system received from the D041 system a worldwide OIM requirements number of 88 units for NSN 4130011274674. That is, the D041 system – given the item's pipelines and cost as of October 1983 and a system backorder constraint – determined that the desirable number of spares to have in the system was 88.[4]

Treating the number 88 as the number of spares in the system, the D028 system checked the various possible depot/base allocations to find the one that resulted in the smallest number of base EBOs. Checking allocations in a similar way with our model, we find that with 88 spares in the system, expected base EBOs are minimized when each of the 10 bases is assigned a level of 4 and the de facto depot level is 48. But there are not 88 spare units in the system. There are only 45. So, with each of the bases operating with a level of 4, the de facto depot level becomes 5 and the system is operating as described in Table 4-2. Base EBOs are NOT minimized – they are 3.5 when they could be 0.8.

[4]Since 109 units were on order as of 30 September 1983, and 45 units were already in the system, no net buy requirement would be associated with the number 88. All the number 88 signifies is that in the early fall of 1983, the Air Force, via the D041 system, decided that 88 units was a desirable number of spares to have in the system.

CHAPTER 5

ESTIMATES OF SYSTEM-WIDE EFFECTS

By repeating the analysis described in the preceding chapter for many items and summing the results, we can obtain an estimate of the reduction in system-wide base EBOs that could be achieved if the D028 system were to set base requisitioning objectives based on assets in the system rather than on requirements. This chapter contains projections of such system-wide effects.

We examined three different sets of items to estimate system-wide effects: a set of 3,435 items that were being centrally leveled in August 1986, all managed by the San Antonio ALC (Sample 1); a stratified, 106-item sample of D028 items from October 1983, including items from all five ALCs (Sample 2); and, finally, the set of all items in a September 1983 D041 data base that had at least one non-zero base resupply pipeline (base repair, order and ship, or depot delay) (Sample 3).

Different sets of items were examined because it was not feasible to perform a direct and exhaustive analysis of a full, 25,000-item D028 data base. Also, the failure of the D028 system to recognize the difference between requirements and assets is important only if the difference persists over time. By examining sets of items that were in the system at different times, we are better able to judge whether the difference between assets and requirements is really a continuing problem.

The first two sets of items were drawn from D028 CLS Item Summary Reports: on tape from the San Antonio ALC for the 3,435-item sample and on microfiche from Headquarters AFLC for the stratified, 106-item sample. Each set was examined with the single-item, two-echelon inventory model introduced in the previous chapter and described in Appendix B. Both sets have the advantage of including actual D028 items for which the actual D041 requirements numbers passed to the D028 system were available. (The D041 worldwide OIM requirements number passed to the D028 system is included as a key data element in a CLS Item Summary Report.) The only drawback posed by these first two sets is that, because of their size, they provide only sample estimates of what the effects might be across all D028 items.

The third set of items, drawn from a D041 data base rather than from D028 CLS Item Summary Reports, was examined as a surrogate for a complete set of D028 items. This set actually includes more items than those assigned to the D028 system in September 1983, because having a non-zero base resupply pipeline does not guarantee that an item will be centrally leveled. Most such items are designated for central leveling, but there are exceptions. The most convenient way to examine this set of items was with a modified version of the Aircraft Availability Model (AAM), which utilizes D041 data as its basic input information. The AAM was developed by LMI for the Air Force and has been in use for several years by both the Air Staff and AFLC as an assessment and analysis tool for recoverable spares.

No matter which set of items is being considered, to compute projected system-wide effects it is necessary – for each item – to know what its pipelines are and what assets are in the system. This information can be obtained by referring to a D041 data base that is essentially contemporary with the set of items in question. For example, for the 3,435 items drawn from the August 1986 D028 CLS Item Summary Reports from the San Antonio ALC, pipeline and asset information was obtained from a March 1986 D041 data base. That is, for the 3,435-item sample, pipelines and assets were assigned values based upon the way things looked in the Air Force logistics system as of 31 March 1986.[1]

SAMPLE 1 RESULTS

Table 5-1 presents the results of our analysis of the 3,435-item sample from the San Antonio ALC.

The results in Table 5-1 were obtained using the same procedures described for the single-item example presented earlier. That is, for each item in the 3,435-item sample, the D041 requirements number listed in the August 1986 D028 CLS Item Summary Report for the item was used to allocate assets in the system. For items in "short supply" (items with a D041 requirement that exceeded the number of assets in the system), requirements-based allocation means that base levels were set

[1] A March D041 computation produces requirements for each of 22 quarters into the future, beginning with the quarter that starts immediately following the 31 March asset cutoff date. The D041 requirements numbers fed to the D028 system for allocation in August 1986 were requirements for the second quarter in this system, which is the quarter that contains August. Thus, in our analysis there is a slight disconnect in time between the period when requirements apply (the second quarter in a March computation) and the period when pipelines and assets apply (the first quarter in a March computation). This discrepancy is technical and not likely to affect results

TABLE 5-1

ESTIMATED SYSTEM EFFECTS: SAMPLE 1

Projected base EBOs		Percentage reduction in base EBOs
With D041 requirements-based levels	With asset-based levels	
470.0	333.7	29%

according to the requirement, and the de facto depot level fell.[2] For items in "long supply" (items for which the D041 requirement was less than the number of assets in the system), base levels were set according to the requirement, and the de facto depot level rose.

Table 5-1 compares total base EBOs of 470.0, achieved under requirements-based allocation, with total base EBOs of 333.7 if assets are allocated optimally according to the actual number of assets in the system. The table shows that – given the pipelines, assets, and requirements used in the analysis – the number of base EBOs for the system is reduced by 29 percent.

The results in Table 5-1 do not imply that there is something "wrong" with D041 requirements. Indeed, if we ignore the assets that were actually in the system in the summer of 1986 and assume instead that assets were identical with computed D041 requirements, total base EBOs are 218.1, a figure substantially lower than the 470.0 and 333.7 values in the table. What the table suggests is only that, for whatever reason, actual assets in the system in the summer of 1986 differed enough

[2]Depending on the number of bases that use an item, it is possible for an item to be in such short supply that there are not even enough assets to assign every using base a level of 1. For example, consider an item that is used at 10 bases but has only 4 assets in the system. For such an item, at least 6 bases will receive a level of zero, whether the allocation system is requirements-based or asset-based. For such an item, our allocation algorithm would not split bases and assign some a level and others none. Treating users as uniform, the algorithm would assign a level of zero to each of the 10 bases and the de facto depot level would become 4. Because the D028 system treats each base individually, it would likely do better and assign the 4 spares in the system to the 4 bases where they would do the most good. The same would happen if the D028 were asset-based, however. In any case, we will see later that only a small minority of the items in the D028 system are in short supply.

from requirements that 333.7 base EBOs was the best supply performance that could be expected.

Because we are dealing with a sample, and because projected EBOs depend on both pipeline sizes and asset quantities, the 29 percent reduction in base EBOs shown in Table 5-1 is only one of several possible estimates of system-wide effects. Other estimates, for different samples and employing different ways of counting assets, are presented in the next section. First, however, some further discussion of the analysis of Sample 1 is in order.

As noted, the results in Table 5-1 depend on the asset and pipeline values used for each item in the 3,435-item sample.

Pipelines that were taken into account in computing base EBOs were base repair pipelines, depot repair pipelines for base-generated failures and removals, and order-and-ship pipelines between the depot and bases, all as recorded in the D041 system. Depot repair pipelines for non-OIM-generated demands were not included. Given that the purpose of the D028 system is to allocate spares levels to cover OIM-generated demands, the three types of pipelines taken into account are the appropriate ones to consider.

Even though the "right" pipelines were considered, however, there is still likely to be a difference between model-projected EBOs and real-world EBOs. For example, Air Force policy for the D041 system is that the repair times that underlie repair pipelines are *not* to include awaiting-parts (AWP) time nor other delay times that accumulate prior to actual induction to the repair process. Since real-world EBOs are influenced by these delays, model-projected EBOs computed with D041 pipelines cannot be expected to exactly predict real-world EBOs – even if all the data and distribution assumptions underlying the model's calculations are correct. This alone is enough to make the projected 29 percent reduction in base EBOs only an estimate – not a prediction – of what would happen if the D028 became an asset-based system.

However, in addition to pipelines, a second ingredient – assets – influences projected EBOs. Thus far, all we have said is that the assets counted in analyzing the 3,435 items from the San Antonio ALC were assets "in the system." Although determining the number of assets in the system conceptually means adding the number of items that are either serviceable or in resupply and subtracting the

number of outstanding backorders to customers at bases. in practice it is necessary to sort out many different categories of assets in the D041 system in order to actually come up with a number.

Appendix A presents a precise description of the various asset categories in the D041 system that were considered in calculating the results in Table 5-1. The approach described, although reasonable, is not meant to be definitive or even necessarily the best. To emphasize this point, Appendix A presents another estimate of the possible reduction in base EBOs for Sample 1 – a reduction of 17.7 percent – which is a result of counting assets differently. The intent in Appendix A, therefore, is not to settle the asset question, but to indicate by example the kinds of considerations that will be required to settle it.

Eventually, if the D028 system is to become an asset-based system, the problem of deciding which asset categories to include must be resolved. The D041 system and other systems that track spares categorize assets in many different ways, and these categories do not always fall neatly into one of the three basic categories (serviceable, in resupply, backordered) that inventory models – such as the one in the D028 system – use to define the asset position for purposes of calculation.

As discussed in Appendix A, the particular assets considered in analyzing the 3,435-item sample from the San Antonio ALC are such that for some reasons the estimates given in Table 5-1 may be too high and for other reasons they may be too low. So again, the results in Table 5-1 are only indicators of the potential effects of moving to an asset-based system. Final effects will depend on how assets are finally counted. The key point, which is reinforced by looking at other estimates of system-wide effects using different samples and different asset-counting rules, is that no matter how assets are finally counted, base EBOs can be reduced from their current values.

Another aspect of the results in Table 5-1 is that, although 3,435 items were considered, the reduction in base EBOs is not the same for all items. Some items show reductions as large as the one in the single-item example presented earlier, and others show much smaller reductions.[3] This suggests that if the D028 is converted to an asset-based system, the benefits will not be uniform across all items. Some items

[3]The average reduction in base EBOs is quite small: 0.0396 EBOs per item. [(470.0 – 333.7) EBOs/3,435 items = 0.0396 EBOs/item]

will benefit more than others. Final effects depend on both the absolute size of pipelines and asset quantities and on the relative size of these two variables in relation to one another.

The reduction in base EBOs illustrated in Table 5-1 is a consequence of the fact for most of the items in the 3,435-item sample from the San Antonio ALC, the number of assets in the system in the summer of 1986 was different from the requirements number for that same period as computed by the D041 system. Of the 3,435 items in the sample, 529 items had assets less than the requirement and 2,849 items had assets greater than the requirement.[4] (There were 57 items with assets equal to the requirement.)

The large number of items in long supply is perhaps surprising. Although one might expect requirements to exceed assets for most items, the opposite appears to be the case for a sizable majority of the items in the D028 system. This conclusion depends, of course, on the method used to count assets. In particular, none of our methods discounted assets that were brought into the system to meet special additive requirements. If such assets are not counted, not as many items might appear to be in long supply. Nevertheless, for both the D028 samples we considered (the 3,435-item sample from August 1986 and the stratified, 106-item sample from October 1983) and under several different asset-counting schemes, assets consistently exceed requirements for a large majority of items.

The fact that assets may exceed requirements for many items does not alter the conclusion that base backorders can be reduced with an asset-based system. It does not matter whether assets are greater or less than requirements; in either case, allocating based on requirements will lead to a suboptimal allocation of the assets.

The results in Table 5-1 reflect overall system effects taking both long- and short-supply items into account. On a per item basis, the reduction in base EBOs for items in short supply is greater than it is for items in long supply. For the 529 items with requirements greater than assets, base EBOs are reduced an average of 0.1096 EBOs per item. For the 2,849 items with assets greater than requirements, the average reduction is only 0.0275 EBOs per item. Because of their greater

[4]Asset quantities were discounted to include only OIM assets, as described in Appendix A

number, however, the long-supply items contribute more (78.28 EBOs) to the reduction in base EBOs than do the short-supply items (57.99 EBOs).

For items with assets greater than requirements, a requirements-based system will generally leave "too many" spares at the depot, producing a de facto depot level that is higher than optimal for the number of assets. However, if base requirements are already met, it may be difficult administratively to assign more spares to the base above and beyond its requirement. Also, if base requirements are reasonable, the benefits of assigning additional spares to bases are likely to be marginal (as illustrated by the long-supply items in Sample 1), because base EBOs will already be low.

Under these conditions and assuming the Air Force is satisfied with the way the requirements-based D028 system works for items in long supply, asset-based allocations might be restricted to only those items that are in short supply. The potential effects of such an intermediate approach can be examined by setting a requirements-based "cap" on base levels in the allocation algorithm. That is, we can set the algorithm so that base levels can be less than that generated by a D041 requirements number but not more. Doing this for the 3,435-item sample from the San Antonio ALC produces the results shown in Table 5-2.

TABLE 5-2

ESTIMATED SYSTEM EFFECTS WITH CAPPED LEVELS

Projected base EBOs		Percentage reduction in base EBOs
With D041 requirements-based levels	With asset-based, capped levels	
470.0	418.4	11%

SAMPLE 2 RESULTS

Sample 2 is a collection of 106 items chosen to be representative of the entire set of D028 items in the system in October 1983. At that time, approximately half of all D028 items had D028-computed levels that were higher than base-computed

levels as recorded in the Standard Base Supply System (SBSS). For about 20 percent, the D028 levels were lower, and 30 percent had equal levels. Drawn from October 1983 D028 CLS Item Summary Reports, the sample was selected to have the same percentages. The sample was also selected so that each of the Air Force's five ALCs that share management responsibilities for D028 items was proportionately represented.

A D041 data base from September 1983 was used to obtain pipeline and asset information for the sample. The sample was analyzed with the same two-echelon, single-item model (described in detail in Appendix B) used for Sample 1 and our initial single-item example. For this sample, we experimented with several different ways of specifying the number of assets in the system (the "asset position"). Table 5-3 presents the results.

TABLE 5-3

ESTIMATED SYSTEM EFFECTS: SAMPLE 2

	Base EBOs		Percentage reduction in base EBOs
	With D041 requirements-based levels	With asset-based levels	
Asset position 1	33.8	11.1	67.2%
Asset position 2	35.2	12.8	63.6%
Asset position 3	41.3	18.9	54.2%
Asset position 4	53.8	30.6	43.1%

Each of the asset positions corresponds to a different way of counting assets. The first, and largest, position includes the same assets that were included in the analysis of Sample 1 (see Appendix A for a description) *plus* all "non-OIM" assets (i.e., assets intended for the support of depot programs). The second position has non-OIM assets removed; it is identical in its definition to the asset position used in analyzing Sample 1. Asset positions 2 and 3 are like positions 1 and 2, respectively, except that assets in the category "unserviceable at the depot" are not included.

The results in Table 5-3 simultaneously illustrate two important points. First, the actual reduction in system-wide base EBOs that the Air Force can expect if D028 becomes an asset-based system will depend on which assets are included. Second, no matter how assets are counted, the reduction in base EBOs will be big enough to make the effort worthwhile.

Depending on how assets are counted, the analysis of Sample 1 suggests that base EBOs could be reduced from 17 to 29 percent. Here, with Sample 2, the projected reductions are on the order of 40 to 60 percent. These projections are not necessarily inconsistent. The two samples are from different times and contain different items. In addition, Sample 2 is small enough to be biased in its estimate by one or two components with large EBO reductions. In fact, just as was the case for Sample 1, there are a small number of items in Sample 2 that experience large EBO reductions (e.g., backorder reductions of almost 3 for a single item).

SAMPLE 3 RESULTS

Sample 3 is different from our first two samples in that it was not selected directly from the pool of D028 items. Instead, we considered the set of all items in a September 1983 D041 data base with at least one non-zero base resupply pipeline (base repair, order-and-ship, or depot delay). This criterion means that Sample 3 actually contains every D028 item from September 1983 and then some, because some items with base programs were (and are) not centrally leveled. The advantage, of course, is that by examining this surrogate for an entire set of D028 items, we obtain perhaps the most accurate projection of how base EBOs may be reduced.

The method used to analyze Sample 3 is conceptually similar to that used to analyze Samples 1 and 2. That is, assets were first allocated optimally according to their number and then suboptimally according to a requirements number that could, but usually did not, agree with the number of assets. A modified version of the Aircraft Availability Model (AAM) was used to perform the analysis. Because the items in Sample 3 were not obtained from CLS Item Summary Reports, a D041 requirements number applicable to September 1983 was not available. Instead, a requirement was specified for each item corresponding to the total, worldwide spares level necessary to achieve an 80 percent aircraft availability rate for each aircraft type (Mission/Design – M/D) in the model. This requirement was computed by the AAM, starting with zero assets in the system and incorporating multi-echelon

tradeoff logic [as in the D041 Variable Safety Level (VSL) subsystem], and multi-indenture logic (which is not in the D041 VSL subsystem).[5] The 80 percent availability rate goals lead to spares levels that correspond roughly to the worldwide requirements levels computed by the D041 system to achieve established fill rate goals.

Pipeline and asset information for Sample 3 was drawn from the same September 1983 D041 data base. Pipelines and assets were computed as of September 1983. Assets were counted using the same method (described in Appendix A) that was applied in the analysis of Sample 1 with one important exception. As discussed in Appendix A, certain war reserve assets were included in the first analysis of Sample 1 (Table 5-1). War reserve assets were *not* included in the asset position for Sample 3. (They were removed as described in Appendix A, in the discussion of the alternate analysis of Sample 1.)

The AAM was first used to allocate assets optimally to minimize base EBOs, using the same multi-echelon allocation logic that the D028 system employs. The AAM was then modified to allocate assets to the computed requirement by assigning assets to bases as called for by the requirement and assigning whatever was left to the depot. Table 5-4 displays the results.

As a general test of the validity of these results, we can ask the extent to which the projected figure of 38,500 backorders agrees with the actual number of outstanding backorders in place at bases around the world in September 1983. The agreement is surprisingly good. Each month, the Air Force Standard Systems Center at Gunter Air Force Base, Alabama, assembles a worldwide summary of the SBSS management reports (M-32 reports) that each base in the Air Force produces each month. The worldwide M-32 "Summary of Due-Outs" for recoverable items in September 1983 shows that the number of outstanding backorders (urgency-of-need codes A, B, and C combined) at bases worldwide was 38,000.

To put this in perspective, in 1983 the total active aircraft inventory in the Air Force averaged 9,500 aircraft. An average of 38,500 outstanding backorders corresponds, therefore, to having an average of four "holes" in place on every aircraft

[5]In the multi-indenture approach, backorders for lower indenture items are used to modify LRU pipelines, making it possible to trade off spare shop replaceable units (SRUs) against spare LRUs in computing requirements.

TABLE 5-4

ESTIMATED SYSTEM EFFECTS: SAMPLE 3

Projected base EBOs (rounded to nearest 00)		Percentage reduction in base EBOs
With D041 requirements-based levels	With asset-based levels	
38,500	27,000	30%

in the Air Force every day. The actual number of "holes" on any given aircraft varies over time, of course, and not every "hole" will necessarily prevent an aircraft from flying. Also, it is often the case that "holes" are transferred to WRSK/BLSS kits[6] or concentrated on selected aircraft through cannibalization, so an estimate of 38,500 base EBOs is certainly feasible.

From the results for Sample 3 and those for Samples 1 and 2, we conclude that base EBOs for recoverable spares can be substantially reduced if base requisitioning objectives as assigned by the D028 Central Leveling System are computed on the basis of assets in the system rather than requirements. The actual reduction to be achieved will depend on how assets are counted. Even a reduction as small as 10 percent, however, is worth pursuing. In terms of aircraft, a 10-percent reduction would correspond to making available more than 60 of the roughly 700 aircraft that are in Not-Mission-Capable-Supply (NMCS) status at any given time in the Air Force (based on FY86 NMCS data).[7] In fact, because NMCS rates are already so low, the real effect of reducing base EBOs is more likely to be a reduction in the need for

[6]War Readiness Spares Kits (WRSKs) and Base Level Self-Sufficiency (BLSS) spares are packaged sets of spares designed to support combat operations in the initial stages of a conflict until wartime resupply operations can be established. It is Air Force policy to use WRSK/BLSS spares as necessary to support peacetime operations when Peacetime Operating Stocks (POS) are not available.

[7]The total NMCS rate for the Air Force midway through FY86 was 7.1 percent. The estimate of 60 aircraft was obtained from this number by assuming a corresponding aircraft availability (AA) rate of 92.9 percent and applying the approximation: EBO/aircraft = $-\ln(AA)$ to the entire fleet (9,500 aircraft), to solve for fleetwide EBOs. From this, it is straightforward to calculate the additional aircraft that become available if total base EBOs are reduced 10 percent.

WRSK withdrawals, cannibalizations, expedited repair actions, and the other extraordinary steps the Air Force must currently take to keep NMCS rates as low as they are.

CHAPTER 6

HOW WILL BASE LEVELS BE AFFECTED?

When the D028 system was first implemented, there were questions concerning what would happen to base levels: How would they change? Would the changes be large? Would the levels for some items increase and others decrease? By how much? How would levels change at a typical base?

These same questions apply if the D028 system is modified to set base levels according to assets in the system, rather than requirements. The model used to analyze Samples 1 and 2 keeps track of how base levels are affected. Following are the results for Sample 1, the 3,435 items from the San Antonio ALC that were being centrally leveled in August 1986.

For a given item, when assets in the system are allocated according to requirements (the way the D028 system works today), each base that uses the item receives a level that is determined by how the requirement "pulls" the assets. Under the uniform base assumption in our analysis, each base receives the same level. Thus, in our analysis, for each item in our 3,435-item sample, a base level is assigned under the requirements-based approach. The average value of this base level, across the entire 3,435-item sample, is 4.1 spares per base. Under the asset-based approach, the average is 6.4 spares per base. Our estimate for the entire system of D028 items, therefore, is that generally base levels would increase slightly under an asset-based approach. The reason, of course, is that there are so many D028 items with assets greater than requirements.

Although base levels would increase overall, they would not increase for every item. In our 3,435-item sample, the requirements-based level at the base was higher than their asset-based level for 213 items. The average difference between levels for the 213 items was 1.48 spares per base.[1] The asset-based level was higher than the requirements-based level for 2,037 items, and the average difference in levels for those items was 3.9 spares per base. The asset-based base level and the

[1]These 213 items are a subset of the 529 items in Sample 1 that were in short supply (i.e., with assets less than the requirement).

requirements-based base level for the remaining 1,185 items in the sample were essentially identical.

CHAPTER 7

IMPLEMENTATION ISSUES

Developing an understanding of why requisitioning objectives at bases should be based on assets in the system rather than on requirements is important, but it is only the first step in converting the D028 Central Leveling System into an asset-based system. Important implementation issues still need to be sorted out. This chapter identifies and briefly describes some of these issues.

The first issue is the asset issue. Conceptually, the number supplied to the multi-echelon tradeoff algorithm in the D028 system should be the number of assets "in the system." However, the Air Force employs many more asset categories than the three basic ones (serviceable, in resupply, and backordered) that define what it means to be in the system. The problem, therefore, is in deciding whether the assets in a given Air Force category qualify as being in the system. Clearly, on-order assets are not in the system. Their flow is neither affected nor controlled by requisitions from bases. For other categories the question is not so clear.

As a start on the asset question, Appendix A provides a detailed description of the D041 asset categories used to analyze the three sets of D028 items in the study. As an alternative to the bottom-up approach described in the appendix, however, there are other possible approaches. For example, rather than rolling up D041 asset categories, it might make sense to simply replace the gross requirements number for the quarter currently supplied to the D028 system with the gross number reduced by the buy requirement for the quarter. The idea of this approach is that the buy requirement already reflects, at least implicitly, a count of the assets that are in the system and apply against the gross requirement. Reducing the gross requirement by the buy requirement, therefore, automatically identifies the assets in the system that should be counted and considered eligible for central leveling. A drawback to this approach is that, at least in this simple form, it does not address the problem of additive requirements and the extent to which assets should be set aside to meet them. Appendix A has further discussion of the problem of asset "set asides" for additive requirements.

As a final remark on the issue of assets, in discussing system-wide effects, our results show that the magnitude of base EBO reductions will depend on which asset categories are included and which are not. Our results also show, however, that no matter which asset categories are finally included, the Air Force will be better off than it is with a requirements-based system. Consequently, the Air Force should not struggle too long trying to find the "best" answer to the asset question. Better to make some decision and be better off, than to wait a long time for an elusive best answer and never make the system better.

A second implementation issue is the practical one of deciding which data system to use to actually count assets once asset categories have been decided upon. The D041 system is not the only system that tracks assets. The Master File of the D143H Central Knowledge Subsystem, for example, provides information on the location and condition of assets on a weekly basis, and the Adjusted Stock Level File in the same system describes special levels that apply.

Other practical implementation issues have to do with how often to re-level in an asset-based system and whether to adopt a "capped" system that would constrain base levels to not exceed the level derived from a requirements number. Capping levels with the requirement would not lower base EBOs as much as the unconstrained asset-based approach (see the discussion of capping levels in the analysis of Sample 1), but such an approach might be necessary if there are limits on the quantities of stocks the bases can reasonably be expected to handle and store. The general excess of assets over requirements has bearing here, of course.

The issue of re-leveling frequency is one that has arisen with the current system. Under an asset-based system, some form of limited re-leveling may be called for whenever some decided-upon percentage of on-order assets are actually delivered into the system. On the other hand, quarterly re-leveling may be quite sufficient to properly accommodate the receipt of new assets.

Related to the re-leveling question is the issue of asset redistribution among bases. How often should that be done and which assets should be involved? In particular, to be consistent with the spirit of an asset-based system, asset redistribution should include the possibility of redistributing not-ready-for-issue (i.e., "broken") assets, in addition to serviceable assets. This raises the question of creating additional "redistribution" pipelines. It will be important to investigate whether the

benefits of redistribution will compensate for the problems these pipelines might generate.

Another interesting and potentially important technical issue involves the definition of the pipelines that are considered in the D028 system. As discussed earlier, the repair times that underlie repair pipelines do not include AWP time and other delay times that accumulate prior to induction of items into the repair process. While this policy is correct for purposes of requirements determination, for central leveling and asset distribution, the policy is not correct. If the goal really is to "make the best of what we have," the Air Force should include AWP and other delay times in the pipelines against which allocations are made. Inclusion of these times would improve the efficiency with which existing assets are used.

The final implementation issues are policy issues. An underlying theme of this analysis is that controlling the distribution of assets in the system is the *prime function* of the D028 system. The system exercises that control by assigning requisitioning objectives to bases. The problem of assigning base "requirements" – thinking of base levels as requirements rather than requisitioning objectives – should be viewed as a secondary function of the system. Under this view, it is possible that the D028 system should be assigning *two* numbers to each base – a requisitioning objective based on the number of assets in the system and a requirements number based on computed D041 requirements.

In this same vein, the Air Force has made an initial decision to include the D028 system in the Requirements Data Bank (RDB) system, which will eventually replace current requirements systems, including the D041 system. Given that the prime function of the D028 system is to control the distribution of assets rather than to set requirements, it would make sense to reconsider this decision and "include" the D028 system in the new Stock Control and Distribution System as well. This is of more than academic interest if it turns out that to do its job right, an asset-based D028 system must tap information stored in stock control and distribution files.

CHAPTER 8

FILL-RATE EFFECTS

The fill rate at a supply point – depot or base – represents the percentage of demands the supply point is able to satisfy from its stocks, measured over a given period of time. For example, an 80 percent fill rate at a base over the course of a month means that base supply has satisfied 80 percent of the demands occurring during the month and backordered 20 percent.

Although they are easy to record, fill rates are not as useful a measure of supply performance as the average number of outstanding backorders (EBOs). Fill rates measure only the occurrence (or nonoccurrence) of backorders, not their duration, and cannot be related to measures of weapon system readiness as easily as EBOs. Fill rates also tend to be relatively stable over time – partly because they are inherently less sensitive than other measures, and partly because there are pressures in the system to keep them stable. Nevertheless, as a traditional measure by which supply performance is often evaluated, fill rates must be considered, in addition to base EBOs, if the D028 system is to be changed.

This is particularly important given the Air Force's experience with the D028 system to date. Since the initiation of central leveling in 1982, depot fill rates for recoverables have fallen more than 20 points, from a stable average of 70 percent in the period FY80 to FY82 to an average of less than 50 percent in FY86. In the same period, depot EBOs for recoverables have increased more than 100 percent, from an average of 118,500 wholesale backorders in place at any given time in FY82 to more than 239,000 in place on average in FY86. A separate analysis has shown that a sizable portion of this change in wholesale supply performance can be attributed to the institution of central leveling [6].

This is not to say that the drop in depot fill rates is bad or that the D028 system has done something wrong in causing depot fill rates to fall. While depot fill rates have come down, base fill rates for recoverables have increased, and, more important, total NMCS rates for aircraft are at their lowest levels in years. Although increased spending for spares has certainly been a major factor in this

improvement, the shift in asset distribution caused by central leveling, with base spares levels generally rising and de facto depot levels falling, has also contributed to making things better at the bases.

Now the question is: What would happen to depot fill rates if the D028 were to become an asset-based system? Based on fill rate projections calculated for the 3,435 D028 items in Sample 1, depot fill rates would fall even further. For items in short supply (i.e., with assets less than requirements), an asset-based system generates base levels lower than those generated by a requirements-based system. For these items, de facto depot levels rise, and fill rates improve. For items in long supply, the opposite happens and depot fill rates fall. Because so many D028 items are in long supply in relation to OIM requirements, the overall depot fill rate comes down. The analysis shows that overall depot fill rates would probably drop another 3 to 6 percentage points under asset-based central leveling.[1]

If the Air Force were to cap asset-based levels so that they did not exceed requirements, the depot fill rate would probably increase slightly overall, from 1 to 2 percentage points.

Whatever the Air Force does, it should recognize that depot levels are always de facto in nature. They were so before central leveling was instituted and they continue to be so under central leveling. This means that depot supply performance was and will continue to be inversely related to base supply performance to a large extent. With fixed asset levels, as base levels rise, depot levels will fall and vice versa. Ideally, if requirements matched assets and the D028 system duplicated D041 calculations in every detail,[2] then depot supply performance could be expected to eventually reach the goals set for it in the requirements process. Until then, however, the Air Force should recognize that depot fill rates are essentially reactive measures that are quite difficult to control. In any case, because base EBOs are the

[1]Just as for EBO effects, final effects for depot fill rates will depend on how asset-based leveling is implemented. The estimate of a 3- to 6-point drop presented here assumes adoption of full optimization (no capping of base levels) and use of OIM assets only (via prorating).

[2]Two technical differences between D028 calculations and those in the D041 VSL system can cause base levels and corresponding de facto depot levels to be different between the two systems, even though the systems are theoretically "aligned." The VSL system assumes uniform bases and that variance-to-mean ratios for pipeline distributions are a function of the pipeline mean. The D028 treats each base individually and assumes that variance-to-mean ratios are a function of average demands in a 90-day period regardless of pipeline means.

measure of interest, depot fill rates are not the most important measures upon which to focus control efforts.

REFERENCES

[1] Feeney, G. J., and C. C. Sherbrooke. *Systems Analysis and Supply Management.* RAND Memorandum RM-4054-PR. Santa Monica, Calif.: The RAND Corporation, Apr 1964.

[2] Sherbrooke, Craig C. *A Management Perspective on METRIC: Multi-Echelon Technique for Recoverable Item Control.* RAND Memorandum RM-5078/1-PR. Santa Monica, Calif.: The RAND Corporation, Jan 1968.

[3] Pfeuffer, Howard J., Maj, USAF. "Air Force Recoverable Central Leveling System (D028)." Briefing contained in Minutes of Meeting on the Air Force Recoverable Central Leveling System (D028), Albuquerque, N.M., 2–3 Feb 1984.

[4] Air Force Manual 67-1. "Air Force Recoverable Central Leveling System (D028)." *USAF Supply Manual.* Vol. III, Part One, Chapter 18. Washington, D.C.: Department of the Air Force, 6 Sep 1982.

[5] Air Force Stockage Advisory Board. "Item #307, Marginal Analysis – Push Distribution (D028 Central Leveling System)." Minutes of Meeting #35, Tinker Air Force Base, Okla., 26–30 Apr 1982.

[6] LMI Briefing. "The Effect of D028 Central Leveling on Depot Fill Rates." *Proceedings of the Air Force Stockage Advisory Board.* Barksdale Air Force Base, Bossier City, La., 31 March–3 April 1987.

Although not referenced in the report, another useful source of information on the D028 Central Leveling System – particularly concerning problem items and how the system handles special levels – is:

Blazer, Doug, Lt Col, USAF, et al. *D028 Problem Item Analysis.* AFLMC Final Report LS840403. Gunter Air Force Base, Ala.: Air Force Logistics Management Center, Apr 1987.

APPENDIX A

COUNTING ASSETS

This appendix provides a technical description of asset categories considered in the study. All asset information was taken from D041 Recoverable Consumption Item Requirements System data bases.

The asset position (we will use the term "asset position" as a synonym for assets in the system) used in analyzing Sample 1 was taken from the same March 1986 D041 data base that provided pipeline values for the sample. For each item in the 3,435-item sample [and using variable names as they appear in a D041 Variable Safety Level (VSL) record],[1] the asset position was taken to be the sum of:

	MSERV	=	serviceable base and depot assets (at bases, includes serviceables on hand and due-ins from base maintenance)
		+	serviceable contractor-owned assets
		+	serviceable in-transit assets
		+	serviceable base War Reserve Materiel (WRM) assets
		+	serviceable depot WRM assets
+	MTOC	=	technical order compliance assets
+	IDUINS	=	due-in Inter-Service Supply Support (ISSP) serviceable assets
		+	due-in reclamation serviceable assets
		+	due-in Security Assistance Program (SAP) excess serviceable assets
+	UNSERVT	=	[unserviceable base assets
		+	unserviceable depot assets
		+	unserviceable bailment assets
		+	unserviceable contractor-scheduled and contractor-owned assets
		+	unserviceable in-transit assets
		+	unserviceable WRM assets] × [1 − depot overhaul condemnation rate]

[1] A description of the data elements in a D041 VSL record is given in: LMI Report AF501R4, *The Aircraft Availability Model Analyst's Manual*. Arnberg, Robert L., et al. Nov 1986

+	DIFO	=	[due-in from overhaul assets] × [1 − depot overhaul condemnation rate]
−	DOTM	=	due-out to maintenance assets

prorated by the ratio:

$$\frac{\text{OIM pipeline}}{\text{OIM pipeline + non-OIM pipeline}}$$

for each item.

The first comment concerns the prorating factor. Standing alone, the above sum does not distinguish between assets brought into the system to support base-generated [organizational and intermediate maintenance (OIM)] demands and assets brought in to support depot (non-OIM) programs. Prorating by the ratio of the OIM pipeline (base repair, order-and-ship, and depot repair of base-generated failures) to the total pipeline (the OIM pipeline plus the depot repair pipeline for depot-generated removals) is a simple way to approximate the number of assets in the system that, out of the total number, qualify as "OIM assets." If this proration or something like it is not done, then an asset-based D028 Central Leveling System will allocate all assets, OIM and non-OIM alike, which it is not supposed to do.[2]

Several comments can now be made on the various asset categories that were and were not included in the asset-counting scheme described above. In general, the decision about whether to include a given asset category depends upon whether and how assets in the category fall into one of the three basic sets: serviceable items, items in resupply (excluding on-order), and items backordered to users at bases.

First, the number of assets on order (IONOR in the D041 data base) was deliberately *not* included in the asset position, because, as discussed at length in the report, on-order assets are not yet "in the system" and should not be taken into account in a system for assigning base levels.

Next, the number of due-in *un*serviceables (the data element IDUINU in a D041 data base) was not included in the asset position. This is an example of an

[2]Interestingly, the current, requirements-based D028 system has been criticized for drawing down depot stocks intended to support depot programs. For items with "OIM assets" that are in short supply compared to OIM requirements, one would expect this to happen. OIM assets and non-OIM assets are not distinguishable in the bin, and a base requisition driven by a requirement is going to pull whatever asset it is allowed to pull.

ambiguous asset category. Are due-in unserviceables "in the logistics system" or not? We did not count them in our analysis of Sample 1, but the Air Force may decide they are "in the system" and should be included in the asset position. Likewise, similar questions can be raised about some of the asset categories that *were* included. In MSERV, for example, should assets due in from contractor maintenance be treated as being in the system, or are they equivalent to on-order assets?

Additive requirements such as foreign military sales, special levels, and other additive-type requirements were not subtracted from the asset position. Subtracting such requirements would have the effect of setting assets aside for these requirements and shielding them from allocation. Part of the asset question, therefore, involves deciding which additive requirements qualify for asset set asides. For example, the current, requirements-based D028 system already honors certain additive requirements at bases, provided they have been picked up and recorded in the D041 system. An asset-based system could do the same. It would assign base additive levels just as they are assigned now and subtract the corresponding requirements from the asset position prior to allocation.

The next comment is that MSERV includes War Reserve Materiel (WRM) assets, which probably should not be included in a central leveling system for Peacetime Operating Stocks (POS). The problem is that removing WRM assets from the MSERV data element in the D041 system involves a nontrivial D041 data processing effort. Instead, we repeated the analysis, but with MSERV reduced by the minimum of the D041 data elements:

$$\begin{aligned} \text{MWRMA} = {} & \text{serviceable base WRM assets} \\ & + \text{serviceable depot WRM assets} \\ & + \text{WRM on-order assets} \end{aligned}$$

and

$$\text{MWRMR} = \text{WRM requirement (as of the D041 asset cutoff date).}$$

Although this adjustment removes WRM assets, it potentially over-adjusts because of the presence of on-order WRM assets in MWRMA. At best, therefore, this approach allows us to "bracket" the effect of not including WRM. The minimum of WRM assets and requirements is used because the D041 requirements system considers any "excess" WRM assets (i.e., assets exceeding the requirement) to be

available for use as POS stocks. The results for Sample 1 similar to those given in Table 5-1 in the report, but with the adjustment for WRM assets, are shown in Table A-1.

TABLE A-1

ESTIMATED SYSTEM EFFECTS: SAMPLE 1 ADJUSTED FOR WRM ASSETS

Projected base expected backorders (EBOs)		Percentage reduction in base EBOs
With D041 requirements-based levels	With asset-based levels	
1,075.8	884.9	17.7%

As shown in Table A-1, with fewer assets, base EBOs increase under both approaches over what they were in the first analysis of Sample 1. The reduction in EBOs is larger in absolute terms, but smaller in the percentage reduction achieved. Assuming 17.7 and 29 percent bracket the true reduction, a revised estimate from Sample 1 is that base EBOs could be reduced 23 percent if D028 were to allocate according to assets.

As noted in the report, for most of the 3,435 items in Sample 1, assets exceeded requirements. This does not change when WRM assets are subtracted from the asset position. After removing WRM assets, 757 items in the sample have assets less than requirements, 64 items have assets equal to requirements, and 2,614 items have assets greater than requirements. For the entire sample, the average worldwide OIM requirement was 37.51 units per item, and the average number of assets was 118.52 units per item. (If assets to meet special additive requirements are set aside and not counted, the number of items with assets greater than requirements becomes smaller than the 2,614 cited here.)

The final comment on the asset position used in analyzing Sample 1 concerns the due-out-to-maintenance (DOTM) term, which was meant to cover backorders. In general, DOTM quantities involve more than base EBOs, because due outs to

depot-level maintenance are included as well. Prorating by the ratio of the OIM pipeline to the total pipeline reduces DOTMs to a figure that approximates base EBOs alone.

APPENDIX B

THE COMPARATIVE ASSET ALLOCATION MODEL

The Comparative Asset Allocation Model (CAAM) is a single-item inventory model that examines different methods of allocating assets between a depot and using bases to compare how those allocations affect base expected backorders (base EBOs). By running on a sample of items and accumulating results, the model can be used to estimate the percentage reduction in system-wide EBOs if a requirements-based system for allocating spares – such as the D028 Central Leveling System – were to be converted into an asset-based system.

The CAAM compares three different ways of allocating spares between a depot and using bases: (1) the *optimal* allocation allocates available assets based on the actual number of assets in the system; (2) the *D028* allocation allocates assets to requirements, emulating the current D028 system; and (3) the *cap* allocation allocates assets optimally, but only up to a requirements-based cap on base levels. This appendix describes each of these three allocation methods as well as the modeling assumptions, input requirements, output products, and operating procedures of the CAAM. The CAAM is programmed in Turbo Pascal and is designed to be run on a personal computer (PC). A listing of the CAAM program appears at the end of the appendix.

MODELING ASSUMPTIONS

A multi-echelon tradeoff module in the CAAM determines the optimal allocation of spares between a depot and using bases. Tradeoff analysis is performed through an iterative process that tests various possible combinations of spares at the depot and bases to find the one that produces minimum base EBOs.

A simplifying assumption in the tradeoff methodology is that all bases that use an item are considered uniform in their usage of the item. Under this approach, to determine the demand and pipeline for an item at a single base, the CAAM divides worldwide base demand and the worldwide base pipeline for the item (as recorded in a D041 Recoverable Consumption Item Requirements System data base) by the number of bases that use the item [i.e., have a stock record account number (SRAN)

for the item]. The tradeoff analysis is then done considering only those allocations in which each base using an item is allocated the same number of spares as every other base using the item. This limits the number of possible base spares levels that need to be considered in the analysis. For example, with 10 bases and 30 assets in the system, there are only four possible base spares levels to check: 3 per base, 2 per base, 1 per base, and 0 per base.

The D028 system does not make the uniform-base assumption. Because it draws on individual base data, the D028 system recognizes different demands and pipelines at each base and allows for different spares levels depending on individual base characteristics. The uniform-base assumption, therefore, prevents CAAM allocations from *exactly* matching D028 allocations. An assumption of the study, based on experience with the uniform-base assumption in other contexts, is that this does not significantly affect conclusions about system-wide EBOs.

EBO Calculations

The following formula is used to compute base EBOs:

$$\mathbf{EBO(S)} = \sum_{X > S} [(X - S) \cdot P(X)]$$

where,

- P(X) denotes the probability of having X units in resupply (assuming either a negative binomial or a Poisson probability distribution for the number in resupply)
- S denotes the spares level at the base
- X denotes the number of units in resupply (i.e., in repair at the base, in the order-and-ship pipeline from the depot to the base, or in repair at the depot and owed to the base).

Depot EBOs are computed in a similar manner, with the random variable X equal to the number of items undergoing depot-level repair (but not including items on order from suppliers outside the Air Force) and S denoting the spares level at the depot.

The variable S is the independent variable that the CAAM changes as it examines various possible depot/base allocations of the total number of spares in the system. In a CAAM analysis, the resulting sum of the depot and base spares levels is always equal to the total number of assets considered as being in the system.

A variety of other assumptions and parameters in the CAAM affect the calculation of EBOs. Some of these assumptions and parameters can be changed in a model run. In such cases, the model prompts the user for the required information. One of these parameters is the variance-to-mean ratio for resupply (pipeline) distributions.

Variance-to-Mean Ratios

The CAAM has three options for the variance-to-mean ratio (VMR). For the first two options, following current Air Force supply policies for computing VMRs for negative binomial distributions, the equation used to obtain the VMR is:

$$\mathrm{VMR} = 1.132477 \cdot \mathrm{MEAN}^{0.3407}$$

- *Option 1 – The D041 VMR.* This is the default VMR of the model and also the one used to obtain the study results. The MEAN in the equation equals the depot pipeline for calculating depot EBOs and equals the base pipeline plus the order-and-ship pipelines plus the depot delay pipeline for calculating base EBOs.
- *Option 2 – The D028 VMR.* This VMR has a MEAN in the equation equal to the depot daily demand rate (DEPDDR) times 90 days for calculating depot EBOs and total daily demand rate (DDR) times 90 days for calculating base EBOs.
- *Option 3 – The Poisson VMR.* This option inserts a VMR equal to 1, which converts the negative binomial distribution to a Poisson distribution for the number in resupply.

All VMRs are constrained to be no less than 1 and no greater than 5. It should be noted that although the D028 system is supposed to be "aligned" with the D041 requirements system, the VMR in the D028 system is set according to Option 2,[1] whereas in D041 requirements calculations the VMR is set according to Option 1.

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[1]Hill, J. M. *Central Leveling Technique Levels Computation.* XRS Working Note No. 91. Management Sciences Office, DCS/Plans and Programs, Headquarters, Air Force Logistics Command, Jun 1976.

We analyzed the 106-item sample of D028 items from October 1983 to determine how sensitive results are to VMR assumptions. Although absolute values of base EBOs varied considerably depending on the VMR option used, the percentage changes observed in base EBOs in going from requirements-based allocations to asset-based allocations were essentially unchanged from one VMR to another.

Pipeline and Demand Assumptions

Condemnations are not included in CAAM demands, nor are procurement pipelines (sometimes called condemnation pipelines) included in CAAM pipelines. This procedure is consistent with the non-inclusion of on-order assets in the asset position.

The CAAM has the option to use only organizational and intermediate maintenance (OIM) pipelines and demands, or to use both OIM and non-OIM pipelines and demands. The default option of the model uses only OIM values.

Asset Assumptions

The asset position of the CAAM is the number of spares to be allocated between the depot and bases to protect against backorders. The CAAM has a number of options for the asset position used for each item.

The default asset position for a CAAM run is described in Appendix A. The CAAM is also equipped to adopt the adjusted asset position in which certain war reserve assets are removed, also described in Appendix A. A final option is to treat the D041 worldwide requirements number from a D028 Central Leveling System (CLS) Item Summary Report as the number of assets. This option is used when determining what requirements-based levels would be. This option is employed as the first step in the procedure the CAAM follows to emulate the D028 allocation. (The second step is to allocate actual assets to the requirements-based levels, as discussed further below.)

Any asset position can be modified to reflect only OIM assets. To be consistent with the OIM-only default option for demands and pipelines, the default option for assets is to consider only OIM assets. This requires that non-OIM assets be removed from the asset position. Because the D041 data base does not differentiate between

OIM and non-OIM assets, the model prorates assets by the ratio of the OIM pipeline to total pipeline:

$$\text{OIM Assets} = \text{Total Assets} \times \left[1 - \frac{\text{DRCRR}}{\text{DEPPIPE} + \text{PIPE}} \right]$$

where,

DRCRR	denotes the D041 variable name for the non-OIM depot pipeline
DEPPIPE	denotes the total depot pipeline (OIM and non-OIM combined)
PIPE	denotes the sum of the worldwide base repair pipeline and the worldwide order-and-ship pipeline.

THREE ALLOCATION METHODS

The Optimal Allocation

The *optimal* allocation methodology uses only the item's asset position and the multi-echelon tradeoff module of the CAAM to determine EBOs. First, the asset position for a given item is obtained from a data file assembled from D041 data. The assets are then entered into the tradeoff module to determine the optimal allocation for that number of assets and the corresponding base EBOs for each base that uses the item. This process is performed for all the items in the sample. The model then sums each base EBO value for each item in the sample to obtain a system-wide value for base EBOs.

The D028 Allocation

To emulate the allocations that are generated by the D028 system, a two-step approach is taken. The first step is to estimate how the D028 would distribute worldwide requirements as base levels. It is in this step that the CAAM treats the worldwide requirements number as the asset position. This step mimics the allocation procedure followed by the D028 system.

The second step then allows bases to "pull" their levels in the following way if the assets are available: For each item, the base level of step one is subtracted from the actual asset position to determine the assets at the depot. If the sum of all base levels is greater than the asset position, the total base level is reduced by one spare per base until that sum is less than or equal to the asset position. When this

condition is met, the reduced base level is subtracted from the assets to obtain the depot level. Given that depot and base asset position, the CAAM then calculates base EBOs.

If the number of assets equals the worldwide requirement, the *D028* allocation and the *optimal* allocation are the same and base EBOs are equal under the two allocations. If the number of assets is greater than the D041 worldwide requirement, bases pull their allotted requirement and the depot receives the surplus. If assets are less than the requirement, the bases pull their levels until they are met or until assets are exhausted. In the former case, the number of assets at the depot will be less than the requirement; in the latter, the depot will have no assets at all (i.e., the depot level will be zero) and the bases will have less than their requirement. The CAAM is not equipped to treat negative levels (i.e., permanent backorders) at either bases or the depot. If assets are so short that the procedure above would lead to negative levels, levels are set to zero. Whatever the case, whether assets are greater or less than the requirement, the D028 allocation leads to a suboptimal allocation of existing assets.

The Cap Allocation

The *cap* allocation is a hybrid of the two previous allocations. Its purpose is to address the issue of allowing the D028 system to optimally allocate assets but only up to a requirements-based "cap" on base levels as determined by the D028 allocation. At a base, if the *optimal* allocation puts fewer spares at the base than the *D028* allocation, the *cap* allocation will equal the *optimal* allocation. If the *optimal* allocation puts more spares at the base than the *D028* allocation, the *cap* allocation will equal the *D028* allocation.

INPUT DATA AND VARIABLES

The CAAM requires data from two sources: D028 CLS Item Summary Reports and a contemporary D041 Variable Safety Level (VSL) file in "near-term" format, as used by the LMI Aircraft Availability Model (AAM) to compute "near-term" aircraft availability rates. A "near-term" VSL file is one that contains pipeline and asset information as of (or near) the asset cutoff date for a D041 data base.[2]

[2]A description of the contents and production of a near-term D041 VSL file is given in: LMI Working Note AF301-2. *Techniques for Calculating Near-Term Availability Rates*. King, R. M. Feb 1984.

A trace option in the CAAM can be used to print out all required input data, a sample of which is shown in Table B-1.

TABLE B-1

CAAM INPUT DATA

CAAM input data elements	Item (NSN)			
	1	2	3	4
DEPPIPE	0.321	0.484	0.285	0.055
BASEPIPE	0.086	0.176	0.276	1.194
DEPDDR	0.006	0.011	0.005	0.002
TOTDDR	0.006	0.014	0.029	0.168
USERS	2.000	2.000	2.000	9.000
OSTDDR	0.006	0.011	0.007	0.002
DRCRR	0.000	0.000	0.000	0.000
NBASSPR	4.000	4.000	3.000	11 000
WORLD	5.000	5.000	3.000	1.000
TASSE	101.000	17.000	115.000	55.000
TASSEWRM	48.000	16.000	28.000	46.000

The D041 worldwide requirement (labeled " W/W Requirement" on a D028 CLS Item Summary Report and "WORLD" in Table B-1) is the only data element extracted from D028 CLS Item Summary Reports that is actually used in CAAM calculations. The worldwide requirement is used as the asset position in the first step of CAAM processing to emulate D028 allocations. Other information extracted from D028 CLS Item Summary Reports, for comparison purposes, is the total base spares level (labeled "Total CLS Level" on a D028 CLS Item Summary Report and NBASSPR in Table B-1).

The majority of the required input data for the CAAM comes from the near-term D041 VSL. These data are defined below as they appear in Table B-1, with the common AAM/VSL variable name in parentheses:

- NSN (National Stock Number) is the field used by a preprocessor program to find common records between a VSL file and a D028 file.

- DEPPIPE is the total depot pipeline (DRCRQ + DRCRR).
- BASEPIPE is the base pipeline plus order-and-ship pipeline (BRCRQ + OSTRQ).
- DEPDDR is the depot daily demand rate (DEPPIPE/DRT).
- TOTDDR is the total base demand rate (BRCRQ/BRT + OSTRQ/OST).
- USERS is the number of bases (NBASE).
- OSTDDR is the order and ship daily demand rate (OSTRQ/OST).
- DRCRR is the depot non-OIM pipeline (DRCRR).
- TASSE is the total asset position (TASSE).
- TASSEWRM is the total asset position (TASSE) minus the minimum of the War Reserve Materiel Assets (MWRMA) and War Reserve Materiel Requirements (MWRMR).

CAAM OUTPUT PRODUCTS

A trace option allows the user to display various statistics and other descriptive information about the input dat · and results obtained in a CAAM run. All of the information presented in the report on base EBOs and how they change, depot fill rates, asset quantities and how they compare to requirements, and the effects on base levels was obtained from trace output. Since the CAAM was developed as a working tool to support the analytic requirements of the study, however, trace output labels do not always clearly define the nature of the data being reported. Proper understanding of trace output as currently configured requires familiarity with the source code for the model.

CAAM OPERATING PROCEDURES

The CAAM examines different methods of allocating assets for a given NSN between the depot and using bases to compare how those allocations affect base EBOs. The program is coded in Turbo Pascal from Borland International, Inc., and operates on an IBM PC or compatible machine. The program code that follows includes all of the CAAM code except trace and print statements, which were excluded to make the code more readable and understandable. A complete listing of the CAAM program can be found in the file "FILRTALC.PAS" on diskettes that are available from LMI.

To operate the CAAM and produce the analysis previously discussed, the user must follow a five-step procedure:

- *Step 1.* Identify the required D028 and D041 data sources. If the D028 data are on tape, the "LCMS5/STARS/UTIL/UTIL2COPY" program should be run to convert the tape into a System R format. For the D041 data, the appropriate near-term VSL tape is required.

- *Step 2.* Run the LCMS5/ROB/FILRT program on System R. That program reads the D041 and D028 data tapes and combines the information into one data file for use in the CAAM on the PC. The job control language (JCL) to run that program is in the file LCMS5/ROB/JCL/FILRT.

- *Step 3.* Copy the captured output file from System R to the PC and make necessary edits. (Current file saved as "FRSANAN.DAT".)

- *Step 4.* If the CAAM data file FRSANAN.DAT has been updated, perform this step; otherwise skip to Step 5. Run the first pass of the CAAM and select the last option labeled "#### WILL DESTROY FILE ON DISK ### FOR A NEW WORLD BASE SPARE OPTION". This option optimally allocates the worldwide requirements and then saves the base level value for each NSN in the sample. The option automatically sets all assumptions to the following:

  - OIM pipelines only
  - No prorating of assets to remove non-OIM component
  - Asset position to worldwide requirement.

  (*Note:* Assets are not prorated in this step because requirements are being allocated and D041 requirements are already "OIM-only" in nature.) The option will destroy any old file and create a new file called "OPTASSET.WW" with those base values.

- *Step 5.* Run the second pass of the model. In this pass of the model, you may change any default assumptions (e.g., asset position, OIM/non-OIM pipelines, or prorating of assets). Also, the user should answer yes ("Y") to the calculation-of-fill-rates query. The model will continue to query for various trace information. The user should answer yes to any other query for desired trace information. The model next considers the actual assets for the NSN and allocates them between depot and bases against the requirements-based levels computed in the first pass. This yields the D028 allocation. The model then calculates EBOs for all three of the possible allocations (*optimal*, *D028*, and *cap*), all in the course of the second pass.

As discussed, the CAAM performs an iterative process for calculating EBOs and checks all possible spare combinations. When the model checks the current combination to determine whether it yields the minimum base EBOs, it also checks to see whether the combination is the same as that in the *D028* allocation or meets the constraints of the *cap* allocation.

CAAM SOURCE LISTING

```
Program CAAM;
{The Comparative Asset Allocation Model code is listed below.  CAAM is a
 single-item inventory model that examines different methods of allocating
 assets between a depot and bases to compare how those allocations affect
 EBOs.}

CONST
   DIMBESTEBO=750;
   DIMSPARE=380; {the dimension of the spare arrays}
   NMODULE=7; {number of modules}
   D041=1;  POISSON=3;  {D028=2, for VMR ratio}
   DEPOT=1;   {access index to depot info in arrays}
   BASE=2;    {access index to base info in arrays}
   CKIND=3;  {the types of scenairos or run: optimal,D028,cap}
   WW=0; OPT=1; D028=2; CAP=3;
   FILRT=1;
   REBO=2;    {EBO index}
   DIMSRU=6; {the maximum no. of srus for a parent}
   IEBO=1; {index for ebo value}
   HIVAL=9999; {Initialization value}
   {data relevant to system R VSL file}
   CMAXNSN=100; {<<<*********no. of NSN in each ALC clump of VSL data }
   MAXALCNSN=3435;{<<*********total no. of NSN in the  whole ALC}
   MAXDATA=12;  {No. of columns of variables transfered from VSL file}
   NSN=1;    DEPPIPE=2;   PIPE=3;     DEPDDR=4;  DDR=5;    USERS=6;
   OSTDDR=7;  DRCRR=8;     NEWBASE=9;  WORLD=10;  TASSE=11; TASUSD=12;

TYPE
   MODULEPTR=^MODULEREC;
   MODULEREC=RECORD
       MODNO:INTEGER; {module number}
       NAME:STRING[15];   {module name }
       COST:REAL;  {unit cost of module}
       EBO: ARRAY[1..2,0..DIMSPARE] OF REAL; {EBO for depot and best base
                                   EBO for base, rows 1 & 2 respectively}
       PIPELINE: ARRAY[1..2] OF REAL;  {the depot demand * repair and the
                            base+order/ship time* total  base demand.
                            Notice the depot pipeline is total demand from
                            all bases (NRTS*DDR/base*bases) while the
                            base is the total base demand (NRTS*DDR*BASES)
                            and will later be divided by the no. of
                            bases.}
       MAXSPARES: ARRAY[1..2] OF INTEGER; {no. of spares at which PDF=0}
       CHILD:  ARRAY[1..DIMSRU] OF MODULEPTR;  {pointers to the modules sub
                            components or SRUs}
   END;{record type}
```

```
VAR
   LRU,MOD1,MOD2,MOD3,MOD4,MOD5,MOD6,CHILDPTR:MODULEPTR;
   DEPSPARE:INTEGER; {index to count spares at depot}
   NCHILD:INTEGER;  {index to srus or children of LRU}
   ANS:CHAR;
   BESTEBO:ARRAY[1..5,0..DIMBESTEBO] OF REAL; {stores best or lowest EBO
                of all base/depot combinations for constant total spares}
   VSL_DATA:ARRAY [1..CMAXNSN,1..MAXDATA] OF REAL;
   DEPFILMAT:ARRAY [0..DIMSPARE] OF REAL; {Hold depot filrate for
         multiple passes}
   FILRT_EBO:ARRAY[1..CKIND,1..2,1..CMAXNSN,1..2] OF REAL;
            { opt.new.cap, filrt..ebo, NSN, depot..base}
   BASE_SPARE:ARRAY[1..CMAXNSN,0..CKIND] OF REAL; {base spare level,
            optimal sol'n}
   ASSETSMAT:ARRAY[1..CMAXNSN] OF INTEGER; {contains assets reduced w/
         only OIM}
   SUM_FIL,SUM_EBO:ARRAY [1..2,1..CKIND] OF REAL; {DEP & BASE vs scenario}
   SUM_DDR:ARRAY [1..2] OF REAL;
   TEMPFE: ARRAY[1..2,1..CKIND] OF REAL;
   ROW,COL:INTEGER;
   NBASE:INTEGER; {no. of bases, varies for each engine}
   ENGINE_NAME:STRING[60];
   TRACE0,TRACE1,TRACE2,TRACE3,TRACE4,TRACE5,TRACE6,TRACE7,TRACE8,
   TRACE9,SET_OPTBAS,TRACE11,TRACE12,TRACE13:INTEGER;{trace on/off switches}
   RRTOT,RRDEPOT,RRBASE:INTEGER;{best RR answer total depot and base spares}
   FLEET:INTEGER;  {no. of aircraft in fleet for engine}
   QVMR:REAL; {the variance to mean ratio for negative binomial}
   DISTRIBUTION,TSPARE,ATNSN,MAXNSN,OLDCUMALCNSN,CUMALCNSN:INTEGER;
   TARGET,ASSETS,MAXASSETS,TARGET_FOUND:INTEGER;
   DONE,DO_OIM_ASSETS,DO_OIM_PIPE:BOOLEAN;
   VSLFILE,WWOPTFILE:TEXT; {VSL data file from systemR & opt base WW value}
   SUM_NEW,SUM_OPT:array [1..2] of REAL;
   SUMPIPE,SUMDRCRR,SUMDEP:REAL;
   SUM_INCEBO,SUM_PERASS,SUM_WW,SUM_ASS:array [1..2] of REAL;
   OPTCNT,NEWCNT,WWCNT,ASSCNT:INTEGER;
   KIND:INTEGER;  {the types of scenairos or run: optimal,D028,cap}
```

```
PROCEDURE ASSUMPTIONS;
{This procedure asks the user for information to set the 4 basic options: 1)
 asset position, 2) assets with or with out OIM component, 3)pipelines with
 or without the OIM component, and 4) the type of variance to mean
 calculation}

BEGIN
  WRITELN('******* ASSUMPTIONS ********************');
  TSPARE:=TASSE;
  WRITELN('TO CHANGE ASSETS ENTER: WORLD, TASSE, OR TASSE-UNSERD=',
     WORLD:3,TASSE:3,TASUSD:3);
  WRITELN('CURRENT ASSET POSITION =',TSPARE:3);
  ANS:='N';
  WRITELN('DO YOU WANT ASSETS CHANGED (Y/N) ');
  READLN(ANS);
  IF (ANS='Y') OR (ANS='y')
     THEN
       BEGIN
         WRITELN('TO CHANGE ENTER: WORLD, TASSE, OR TASSE-UNSERD=',
          WORLD:3,TASSE:3,TASUSD:3);
         READLN(TSPARE);
       END;
  DO_OIM_ASSETS:=TRUE;
  Writeln('using ASSETS*(& OIM PIPELINE) do you want change (Y/N)');
  ANS:='N';
  READLN(ANS);
  IF (ANS='Y') OR (ANS='y')
     THEN
       BEGIN
         WRITELN('CHANGED  TO USING FULL (OIM+NONOIM) ASSET VALUE');
         DO_OIM_ASSETS:=FALSE;
       END;
   DO_OIM_PIPE:=TRUE;
   WRITELN(' using OIM only for depot pipelines & DDR: change(Y/N)');
   ANS:='N';
   READLN(ANS);
   IF (ANS='Y') OR (ANS='y')
     THEN
       BEGIN
         WRITELN('CHANGE to using full (OIM+DRCRR) depot pipeline & DDR');
         DO_OIM_PIPE:=FALSE;
       END;
```

PROCEDURE ASSUMPTIONS continued....

```
  {distribution can be D028 or poisson, 1 and 2 respectively
    if D028
      then variance to mean ratio for the D028 is
        QVMR:=1.132477*(EXP(.3407*LN(PIPE)))  calculated in DO_EBOS
      else
        QVMR:=1;}
  DISTRIBUTION:=D041;
  WRITELN(' using NEGBINOM w/ VMR=mean=pipe D041: want change(Y/N)');
  ANS:='N';
  READLN(ANS);
  IF (ANS='Y') OR (ANS='y')
    THEN
      BEGIN
        WRITELN('CHANGED D041=1 (QVMR=PIPE), D028=2 (QVMR=90*DDR),
         POISSON=3');
        READLN(DISTRIBUTION);
      END;
  WRITELN('#######   ASSUMPTIONS OF RUN   #############');
  IF DO_OIM_ASSETS THEN WRITELN('1) RUN WITH  OIM ASSETS ONLY')
     ELSE        WRITELN('1) RUN WITH OIM AND NON OIM ASSETS');
  IF DO_OIM_PIPE
    THEN
      WRITELN('2) DEPOT PIPELINES AND DDR ONLY OIM (NO DRCRR) ####')
    ELSE
      WRITELN('2) DEPOT PIPELINES AND DDR BOTH OIM AND DRCRR ####');

  WRITELN('3) ASSET LEVELS ARE ',TSPARE:5,' W/ WORLD, TASSE,& TAS-USD=',
  WORLD:5,TASSE:5,TASUSD:5);
  WRITELN('4)DISTRIBUTION/QVMR IS D041=1 (QVMR=PIPE),',
         ' D028=2 (QVMR=90*DDR), POISSON=3 ',DISTRIBUTION:4);
  WRITELN;
  WRITELN('    INFORMATION FOR ALL ',CMAXNSN:5,' NSN');

END;
```

```
PROCEDURE INPUT_DATA;
{*****************************************************************}
{inputs depot and base/os pipeline, total spares data for all NSNs
  Also reduces depot pipeline and assets position to remove DRCRR
  component so results are for only OIM component}
VAR
   OIM_FRAC:REAL; {% OIM PIPE/ TOTAL PIPE}
 BEGIN
   {TOTAL PIPES  FOR ALL BASES }
   LRU^.PIPELINE[BASE]:=VSL_DATA[ATNSN,PIPE];
   IF (DO_OIM_PIPE)
     THEN
      BEGIN
         {Depot pipeline removes the DRCRR component, i.e. OIM only}
         LRU^.PIPELINE[DEPOT]:=VSL_DATA[ATNSN,DEPPIPE]
           -VSL_DATA[ATNSN,DRCRR];
         {reduce demand to include only OIM depot DDR}
         IF  VSL_DATA[ATNSN,DEPDDR]<>0
           THEN
              VSL_DATA[ATNSN,DEPDDR]:=VSL_DATA[ATNSN,DEPDDR]
                *(1-(VSL_DATA[ATNSN,DRCRR]/VSL_DATA[ATNSN,DEPPIPE]));
      END
     ELSE  {Dep pipe=DRCRR+DRCRQ}
       LRU^.PIPELINE[DEPOT]:=VSL_DATA[ATNSN,DEPPIPE];
       OIM_FRAC:=1;
       IF ((DO_OIM_ASSETS=TRUE) AND
          ((VSL_DATA[ATNSN,DEPPIPE]>0) OR (VSL_DATA[ATNSN,PIPE]>0)))
          THEN
             OIM_FRAC:=1-(VSL_DATA[ATNSN,DRCRR]/
                     (VSL_DATA[ATNSN,DEPPIPE]+VSL_DATA[ATNSN,PIPE]));
       ASSETS:=TRUNC((VSL_DATA[ATNSN,TSPARE]*OIM_FRAC)+0.999999999);
       IF ASSETS<0
         THEN {change negitive assets}
           ASSETS:=0;
       ASSETSMAT[ATNSN]:=ASSETS;

   IF VSL_DATA[ATNSN,USERS]=0
     THEN
         VSL_DATA[ATNSN,USERS]:=1;
   NBASE:=ROUND(VSL_DATA[ATNSN,USERS]);
END; {INPUT_DATA}
```

```
PROCEDURE READ_VSL_DATA;
{this procedure reads a ASCII or word processing text file (e.g.
 captured from the star) and stores it in an array of reals}

VAR
  ROW,COL:INTEGER;
  ITEM:REAL;

BEGIN
  FOR ROW:=1 TO MAXNSN DO
    FOR COL:=1 TO MAXDATA DO
      BEGIN
         READ(VSLFILE,ITEM);
         VSL_DATA[ROW,COL]:=ITEM;
      END;
END;{READ_VSL_DATA}
```

```
PROCEDURE DO_ALL_EBOS(MODPTR:MODULEPTR;ECHELON:INTEGER);
{this procedure calculates EBO for each spare level at Depot and Base}
VAR
   CDF,PDF:REAL;  {probability of X=SPARES, p(x=s)}
   FILLRATE:REAL;
   EBOTEMP:REAL; {dummy variable to temporarily store current EBO value}
   SPARES:INTEGER;  {number of spares at echelon}
   PIPE:REAL;    {the pipeline or lamda*T mean for poisson distribution}
   ATASSET,ROW:INTEGER;
   ACCURACY:REAL; {Determines the PDF cut off value .000005 or .00005}
   DEPDELAY:REAL; {Delay felt(EBO) at base from depot}
   DEMAND:REAL;  {Daily demand rate for depot or base used in D028 VMR}
PROCEDURE FIND_TARGET_LEVEL;
{this procedure stops DO_EBO when the base/depot spare combination
 equals the D028 target or CAP constraints}
 VAR
    ROW,COL:INTEGER;
    BASVAL,DEPVAL:REAL;
BEGIN
   {FIND D028 TARGET VALUES}
   BASVAL:=BASE_SPARE[ATNSN,D028];
   DEPVAL:=ASSETS-BASVAL;
   IF ((DEPSPARE=DEPVAL) AND ((NBASE*SPARES)=BASVAL))
      THEN {have found target values}
         BEGIN
            TEMPFE[REBO,D028]:=EBOTEMP*NBASE;
            TEMPFE[FILRT,D028]:=FILLRATE;
            TARGET_FOUND:=TARGET_FOUND+1;
         END;
   {FIND BEST VALUE FOR CAP RUN}
   IF (((NBASE*SPARES)<=BASVAL)  {cap constraint on max base value}
      AND (ASSETS=ATASSET) {check only asset position combos}
      AND (TEMPFE[REBO,CAP]>EBOTEMP*NBASE))
      THEN { found appropriate spare combo & new EBO value is better}
         BEGIN
            TEMPFE[REBO,CAP]:=EBOTEMP*NBASE;
            TEMPFE[FILRT,CAP]:=FILLRATE;
            BASE_SPARE[ATNSN,CAP]:=NBASE*SPARES;
            TARGET_FOUND:=TARGET_FOUND+2;
         END;
   IF  ((TARGET_FOUND=0) AND (DEPSPARE=LRU^.MAXSPARES[DEPOT]) AND
       (NBASE*SPARES=BASVAL))
       THEN {Last past and still not found, so use answer for max depot
             spare + ww base value for fillrate and EBO}
         BEGIN
           FOR COL:=D028 TO CAP DO
             BEGIN
               TEMPFE[REBO,COL]:=EBOTEMP*NBASE;
               TEMPFE[FILRT,COL]:=FILLRATE;
             END;
            BASE_SPARE[ATNSN,CAP]:=NBASE*SPARES;
            TARGET_FOUND:=-1;
         END;
   END;{FIND_TARGET_LEVEL}
```

```
PROCEDURE DO_EBOS CONTINUED...
BEGIN
   IF ECHELON=DEPOT
      THEN
        BEGIN
          PIPE:=MODPTR^.PIPELINE[DEPOT];
          DEMAND:=VSL_DATA[ATNSN,DEPDDR];
        END
      ELSE {do base+os pipe + ebo delay PER base}
        BEGIN
          {Depot Delay OIM = OIM DDR/OIM+NON OIM DEPOT DDR}
          IF (DO_OIM_PIPE)
             THEN {all depot delay is OIM }
                DEPDELAY:=MODPTR^.EBO[DEPOT,DEPSPARE]
             ELSE
                IF (VSL_DATA[ATNSN,DEPPIPE]>0.0)
                  THEN
                   DEPDELAY:=MODPTR^.EBO[DEPOT,DEPSPARE]*(1-
                    (VSL_DATA[ATNSN,DRCRR]/VSL_DATA[ATNSN,DEPPIPE]))
                  ELSE {DEPDDR=0}
                    DEPDELAY:=0;

          {Total base pipeline=BRPIPE+OSTPIPE+EBO(depot)/no. of bases}
           PIPE:=(MODPTR^.PIPELINE[BASE]+DEPDELAY)/NBASE;
           DEMAND:=VSL_DATA[ATNSN,DDR]/NBASE;
        END;
IF PIPE>600
  THEN
    ACCURACY:=0.5
  ELSE
   IF PIPE>300
    THEN
     ACCURACY:=0.005
    ELSE
     IF PIPE>40
       THEN
         ACCURACY:=0.0005
       ELSE
         ACCURACY:=0.000005;

   IF (PIPE=0)
      THEN  {DDR=0, doesn't matter what fill rate is,
          stop divide check error}
        BEGIN
          PIPE:=0.000001;
          DEMAND:=0.000001;
        END;

  {PDF(X)=(LAMBDAT**X)*(EXP(-LAMBDAT)/X!}
```

```
PROCEDURE DO_EBOS CONTINUED...
   CASE DISTRIBUTION OF
       {variance to mean ratio for the D041 where MEAN=PIPE}
      D041:    QVMR:=1.132477*(EXP(0.3407*LN(PIPE)));
       {variance to mean ratio for the D028 where MEAN=DDR*90}
      D028:    QVMR:=1.132477*(EXP(0.3407*LN(DEMAND*90)));
       {simple poisson distribution case}
      POISSON: QVMR:=1;
   END;{CASE}
   IF QVMR<1.0
     THEN
        QVMR:=1.0;
   IF QVMR>5.0
     THEN
        QVMR:=5.0;
   IF (QVMR=1.0)
      THEN {Poisson distribution}
         PDF:=EXP(-PIPE)
      ELSE {Negitive binomial distribution}
         PDF:=EXP(-(PIPE/(QVMR-1))*LN(QVMR)); {PDF:=Q**(-PIPE/Q-1)}
   CDF:=PDF;
   EBOTEMP:=PIPE;
   FILLRATE:=0;
   SPARES:=0;
   REPEAT  {calculates EBOs for each spare level}
      ATASSET:=NBASE*SPARES+DEPSPARE;
      IF ECHELON=DEPOT
         THEN {store ebos for base calculation}
           BEGIN
            MODPTR^.EBO[DEPOT,SPARES]:=EBOTEMP;
            DEPFILMAT[SPARES]:=FILLRATE;
           END
         ELSE {print and check
          to see BESTebo for spare level}
           BEGIN
              IF (ATASSET<=DIMBESTEBO)
                 THEN
                   BEGIN
                    IF SET_OPTBAS<>1
                      THEN
                        FIND_TARGET_LEVEL;
                    IF (BESTEBO[2,(ATASSET)]>EBOTEMP*NBASE)
                      THEN {insert current ebo as best}
                        BEGIN
                         BESTEBO[2,ATASSET]:=EBOTEMP*NBASE;
                         BESTEBO[1,ATASSET]:=DEPSPARE;
                         BESTEBO[3,ATASSET]:=CDF;
                         BESTEBO[4,ATASSET]:=QVMR;
                         BESTEBO[5,ATASSET]:=FILLRATE;
                         IF MAXASSETS<ATASSET
                           THEN  MAXASSETS:=ATASSET;
                       END;
                   END;
           END;{IF}
```

```
PROCEDURE DO_EBOS CONTINUED...
      SPARES:= SPARES+1; {EBO(SPARES+1)=EBO(X)}
      {EBO(X)=EBO(X-1)-(1-CDF(X-2))}
      EBOTEMP:=EBOTEMP-(1-CDF);
      {EBO:=EBO-RCDF daam's method}
      {PDF(X-1) = PDF(X-2)*PIPE/X-1 = PDF(X-1)*PIPE/SPARES}
      {PDF(X):=PDF*((Q-1)/Q)*((X+(PIPE/(Q-1))-1)/X
       see pg D-7 AAM math framework document       }
      PDF:=PDF*(((((QVMR-1)/QVMR)*(SPARES-1))+(PIPE/QVMR))/SPARES);
      FILLRATE:=CDF;
      {CDF(X-1)=CDF(X-2)+PDF(X-1)}
      CDF:=CDF+PDF;
   UNTIL ((SPARES>PIPE) AND (PDF<ACCURACY));
   {for the first few spares PDF maybe very small, so need to keep going
    for at least pipe tries.  Once move through much of the PDF then
    small values (<.0005) means you've done enough}

     {store maximum spares required for echelon for later use}
   MODPTR^.MAXSPARES[ECHELON]:=SPARES-1;
END;{procedure DO_ALL_EBOS}
```

```
PROCEDURE STORE_NSN_INFO;
{this procedure stores the base and depot fill rates and EBO, and also
 keeps track of the cummulative rates and ebo for entire NSN sample}

VAR
   IDEP,ROW,SCN,SCENAR,TASST:INTEGER;
   OIMDDR_FRAC:REAL;

BEGIN
 IF (TARGET_FOUND=0)
     THEN
       BASE_SPARE[ATNSN,CAP]:=BASE_SPARE[ATNSN,D028];
 FOR SCENAR:=1 TO KIND DO
   BEGIN
   IF (((VSL_DATA[ATNSN,TSPARE]>MAXASSETS) AND (SCENAR=OPT))
    {base levels too high for D028 & CAP}
    OR ((TARGET_FOUND=0) AND (SCENAR>1))
    OR ((TARGET_FOUND=2) AND (SCENAR=D028)))(when CAP found but not D028}
     THEN {opt assets too large or target base value too large}
       BEGIN
         IF (TRACE7=1)
            THEN
              WRITELN('ASSETS TOO HIGH AT NSN SCEN MAXASS  DEPOT',
             ATNSN:4,SCENAR:4,MAXASSETS:7,BESTEBO[1,MAXASSETS]:6:1);
         FILRT_EBO[SCENAR,FILRT,ATNSN,DEPOT]:=0.9999999;
         FILRT_EBO[SCENAR,FILRT,ATNSN,BASE]:=0.9999999;
         FILRT_EBO[SCENAR,REBO,ATNSN,DEPOT]:=0;
         FILRT_EBO[SCENAR,REBO,ATNSN,BASE]:=0;
         {for optimal base spare level}
        IF (SCENAR=OPT)
          THEN {adjust opt spares to biggest value}
             BASE_SPARE[ATNSN,OPT]:=MAXASSETS-BESTEBO[1,MAXASSETS];
       END
     ELSE
       BEGIN
        TASST:=ROUND(ASSETS);
        IF SCENAR=1
           THEN
             IDEP:=ROUND(BESTEBO[DEPOT,ASSETS])
           ELSE  {for D028 & Cap }
             IF (TARGET_FOUND=-1)
               THEN
                 IDEP:=LRU`.MAXSPARES[DEPOT]
               ELSE
                 IDEP:=TASST-ROUND(BASE_SPARE[ATNSN,SCENAR]);
```

PROCEDURE STORE_NSN_INFO CONTINUED...

```
        WHILE (IDEP=HIVAL) DO
          BEGIN {matrix not filled in at point}
             WRITELN('### NO VALID DEPSPR SWITCHED TO ',TASST,MAXASSETS:5,
             'NSN= ',ATNSN+OLDCUMALCNSN:7);
             TASST:=TASST-1;
             IDEP:=ROUND(BESTEBO[DEPOT,TASST]);
          END;
        IF (SCENAR=OPT)
          THEN
           BEGIN
             BASE_SPARE[ATNSN,OPT]:=TASST-IDEP;
             TEMPFE[FILRT,OPT]:=BESTEBO[5,TASST];
             TEMPFE[REBO,OPT]:=BESTEBO[REBO,TASST];
          END;

        FILRT_EBO[SCENAR,FILRT,ATNSN,DEPOT]:=DEPFILMAT[IDEP];
        FILRT_EBO[SCENAR,FILRT,ATNSN,BASE]:=TEMPFE[FILRT,SCENAR];
        FILRT_EBO[SCENAR,REBO,ATNSN,DEPOT]:=LRU_EBO[DEPOT,IDEP];
        FILRT_EBO[SCENAR,REBO,ATNSN,BASE]:=TEMPFE[REBO,SCENAR];
         {for optimal base spare level}
     END;{IF}
  END;{FOR}

   FOR ROW:=1 TO 2 DO
     BEGIN
       FOR SCN:=1 TO KIND DO
         BEGIN
          SUM_FIL[ROW,SCN]:=SUM_FIL[ROW,SCN]+
            (FILRT_EBO[SCN,FILRT,ATNSN,ROW]*VSL_DATA[ATNSN,ROW+3]);
          SUM_EBO[ROW,SCN]:=SUM_EBO[ROW,SCN]
               +FILRT_EBO[SCN,REBO,ATNSN,ROW];
         END;
       SUM_DDR[ROW]:=SUM_DDR[ROW]+VSL_DATA[ATNSN,ROW+3];
     END;
  END;{STORE_NSN_INFO}
```

```
PROCEDURE WRITE_BASWW_OPT;
{this procedure writes the base spares level for uniform bases(given the
World wide requirements as the asset position) for the initial pass of the
model.  An ASCII or word processing text file is stored so that the D028 and
CAP scenarios can use this value in later runs }
VAR
  ROW,COL:INTEGER;
  ITEM:REAL;

BEGIN
  IF  (SET_OPTBAS=1)
    THEN
      FOR ROW:=1 TO MAXNSN DO
         WRITELN(WWOPTFILE,BASE_SPARE[ROW,OPT]);
 END;{WRITE_BASWW_OPT}
```

```
PROCEDURE READ BASWW_OPT;
{this procedure reads the ASCII or word processing text file
  created above}
VAR
  ROW,COL:INTEGER;
  ITEM:REAL;
BEGIN
  IF (SET_OPTBAS<>1)
     THEN {can read WW opt file of base spares}
       FOR ROW:=1 TO MAXNSN DO
         READ(WWOPTFILE,BASE_SPARE[ROW,WW]);
 END;{READ_BASWW_OPT}
```

```
PROCEDURE OIMPERCENT;
VAR
  ROW:INTEGER;
BEGIN

   FOR ROW:=1 TO MAXNSN DO
     BEGIN
       SUMPIPE:=SUMPIPE+VSL_DATA[ROW,DEPPIPE]+VSL_DATA[ROW,PIPE];
       SUMDRCRR:=SUMDRCRR+VSL_DATA[ROW,DRCRR];
       SUMDEP:=SUMDEP+VSL_DATA[ROW,DEPPIPE];
     END;
   WRITELN;WRITELN;
   WRITELN('*******  PERCENT OIM PIPELINE TO TOTAL PIPELINE (W/DRCRR)');
   WRITELN(' % OIM PIPE/BAS+TOTDEP ',(1-(SUMDRCRR/(SUMPIPE)))*100:8:3);
   WRITELN(' % OIM OF DEPOT PIPE ',((SUMDEP-SUMDRCRR)/SUMDEP)*100:8:4);
   WRITELN('SUMPIPE, SUMDEP, SUMDRCRR ',SUMPIPE:10:4,SUMDEP:9:3,
      SUMDRCRR:9:4);
END;{OIMPERCENT}
```

```
PROCEDURE ADJUST_BASE_SPARE;
{this procedure adjusts the D028 and Cap base spares when the optimal
world base level is greater than scenario assets}

VAR
   BASED028:REAL;
BEGIN
   BASED028:=BASE_SPARE[ATNSN,WW];
   WHILE BASED028>ASSETS DO
     BASED028:=BASED028-NBASE;
   IF (BASED028<0)
      THEN
         BASED028:=0;
   BASE_SPARE[ATNSN,D028]:=BASED028;
END;{ADJUST_BASE_SPARE}
```

```
PROCEDURE START_INITIALIZE;
{ data initialized w/in, at start of program only, i.e. once only}
VAR
  DIM,ROW,COL,PLANE:INTEGER;

BEGIN
  RRTOT:=9999;
  {DO28 DATA }
   NEW(LRU);
   LRU^.NAME:='LRU';
   CUMALCNSN:=0;
   OLDCUMALCNSN:=0;
   MAXNSN:=CMAXNSN;
   DONE:=FALSE;
  {for procedure STORE_NSN_INFO}
  FOR ROW:=1 TO DIMSRU DO
      LRU^.CHILD[ROW]:=NIL;
  FOR ROW:=1 TO 2 DO
    FOR DIM:=1 TO KIND DO
       BEGIN
        SUM_FIL[ROW,DIM]:=0;
        SUM_EBO[ROW,DIM]:=0;
        SUM_DDR[ROW]:=0;
     END;
   {for procedure PRINT_BASE_SPARE}
   OPTCNT:=0;
   NEWCNT:=0;
   FOR ROW:=1 TO 2 DO
      BEGIN
        SUM_NEW[ROW]:=0;
        SUM_OPT[ROW]:=0;
      END;
  {for procedure OIMPERCENT}
   SUMPIPE:=0;
   SUMDRCRR:=0;
   SUMDEP:=0;
  {for procedure Print_Assets}
   ASSCNT:=0;
   WWCNT:=0;
   FOR ROW:=1 TO 2 DO
      BEGIN
        SUM_WW[ROW]:=0;
        SUM_ASS[ROW]:=0;
        SUM_INCEBO[ROW]:=0;
        SUM_PERASS[ROW]:=0;
      END;
 WRITELN(ENGINE_NAME);
 END;{Procedure start_initialize}
```

```
PROCEDURE IOCLUMP_INITIALIZE;
{do to large no. of NSN for an entire ALC, data is read in & out
 in clumps, this procedure intializes data forthose events, e.g.
FILLRT_EBO matrix,etc}
VAR
   ROW,COL,PLANE,DIM:INTEGER;
BEGIN
  FOR ROW:=1 TO MAXNSN DO
    FOR COL:=0 TO KIND DO
      BASE_SPARE[ROW,COL]:=-HIVAL;

  FOR DIM:=1 TO KIND DO
   FOR PLANE:=1 TO 2 DO
      FOR ROW:=1 TO MAXNSN DO
         FOR COL:=1 TO 2 DO
             FILRT_EBO[DIM,PLANE,ROW,COL]:=-999;
END;{procedure IOCLUMP_INTIALIZE}
```

```
PROCEDURE NSN_INITIALIZE;
{data initialized for each NSN pass}
VAR
   ROW,COL:INTEGER;
BEGIN
LRU^.MAXSPARES[BASE]:=0;
LRU^.MAXSPARES[DEPOT]:=0;
TARGET_FOUND:=0;
FOR COL:=0 TO DIMBESTEBO DO
     BEGIN
       BESTEBO[1,COL]:=HIVAL;
       BESTEBO[2,COL]:=HIVAL;
       BESTEBO[3,COL]:=HIVAL;
       BESTEBO[4,COL]:=0;
       BESTEBO[5,COL]:=-999;
     END;
   FOR ROW:=0 TO DIMSPARE DO
    BEGIN
      DEPFILMAT[ROW]:=-999;
      LRU^.EBO[DEPOT,ROW]:=-999;
    END;
MAXASSETS:=0;

FOR ROW:=1 TO 2 DO
  FOR COL:=1 TO KIND DO
    TEMPFE[ROW,COL]:=HIVAL;
END;{NSN_INITIALIZE}
```

```
PROCEDURE IOFILE_INTIALIZE;
{assign file names and opens all files for Input/output operations}
VAR
  ROW,COL:INTEGER;
  ITEM:REAL;
BEGIN
  ASSIGN(VSLFILE,'FRSAN123.DAT');
  RESET(VSLFILE);
  ASSIGN(WWOPTFILE,'OPTASSET.WW');
  IF (SET_OPTBAS=1)
    THEN {initial model run, use WW as asset position $ store result}
      BEGIN
        KIND:=1;
        REWRITE(WWOPTFILE);
        TSPARE:=WORLD;
        DO_OIM_ASSETS:=FALSE;
        DO_OIM_PIPE:=TRUE;
        WRITELN('## OVERRIDING OIM & ASSET ASSUMP:
          STORE OPTIMUM BASE VALUES');
      END
  ELSE {Prepare to read WW base level position}
     BEGIN
      KIND:=3;
      RESET(WWOPTFILE);
     END;
END;{IOFILE_INTIALIZE}
```

```
PROCEDURE CLOSE_IOFILE;
BEGIN
   CLOSE(VSLFILE);
   CLOSE(WWOPTFILE);
END;{CLOSE_IOFILE}
```

```
{MAIN PROGRAM}
BEGIN
   ASSUMPTIONS;
   IOFILE_INTIALIZE;
   START_INITIALIZE;
   REPEAT
         OLDCUMALCNSN:=CUMALCNSN;
         IF (CMAXNSN+CUMALCNSN>MAXALCNSN)
           THEN{last clump not = to CMAXNSN}
             BEGIN
               MAXNSN:=MAXALCNSN-CUMALCNSN;
               DONE:=TRUE;
             END;
         CUMALCNSN:=CUMALCNSN+MAXNSN;
         READ_VSL_DATA;
         READ_BASWW_OPT;
            FOR ATNSN:=1 TO MAXNSN DO
              BEGIN
                INPUT_DATA;
                NSN_INITIALIZE;
                DO_ALL_EBOS(LRU,DEPOT);
                DEPSPARE:=0;
                IF SET_OPTBAS<>1
                  THEN
                   ADJUST_BASE_SPARE;
                REPEAT
                  DO_ALL_EBOS(LRU,BASE);
                  DEPSPARE:=DEPSPARE+1;
                UNTIL (DEPSPARE>LRU^.MAXSPARES[DEPOT]);
                STORE_NSN_INFO;
              END;{FOR}
    WRITE_BASWW_OPT;
    OIMPERCENT;
  UNTIL  (DONE) OR (CUMALCNSN=MAXALCNSN);
  CLOSE_IOFILE;
END. {MAIN PROGRAM}
```

END

DATE

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