Depot Maintenance in The Air Force:
How Requirements Are Determined and How They Relate to Aircraft Readiness and Sustainability

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This report presents a method to quantify the effect of depot maintenance funding on aircraft readiness and sustainability and discusses the problem of forecasting maintenance budget requirements on that basis. It concludes that, while the Air Force should pursue improvements in technical forecasting methods, that course alone would not guarantee stability and accuracy of the forecast. Given the inherent volatility in item demand rates and the effect of Air Force management decisions, the Air Force needs also to develop stronger tools and procedures to provide visibility and management control of the requirement.

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Executive Summary

DEPOT MAINTENANCE IN THE AIR FORCE: HOW REQUIREMENTS ARE DETERMINED AND HOW THEY RELATE TO AIRCRAFT READINESS AND SUSTAINABILITY

In the 1987 Implementation Review of Depot Maintenance Programs, the Defense Resources Board (DRB) called on the Services to base depot maintenance funding requirements on end-item readiness and sustainability. In large part, the DRB request was motivated by a perceived lack of credibility in Service estimates of requirements. This perception had developed over time with observations of estimates that varied unexplainably from year to year, projections of maintenance backlogs that failed to materialize, and Service reprogramming of depot maintenance funds to other accounts.

The Air Force Logistics Command (AFLC) has begun the process of basing its component repair requirement on peacetime readiness considerations with the introduction of the Aircraft Availability Model to determine reparable spares requirements. Implementation of a new model – Distribution and Repair in a Variable Environment (DRIVE) – will add explicit consideration of wartime sustainability. Neither of these actions, however, can ensure stable and accurate requirements forecasting, and it is the instability in such forecasts that contributes most to the lack of credibility.

Volatility in item demand rates and the effect of Air Force management decisions (e.g., accelerating or decelerating a weapon system phase-in or phase-out, or a major additive program) complicate the task of requirements forecasting. While the Air Force should pursue improvements in technical forecasting methods, any solution must also involve the development of stronger management controls to improve the stability of the requirement. The requirement is not simply the output of a mechanical computer model that operates on item rates and factors. It is a sum of many human judgments. Air Force managers need improved visibility to be aware of the effect of those many judgments, and they need mechanisms to impose overall.

corporate Air Force judgment and control without unnecessarily disrupting the operation of the maintenance program.

Such tools are being developed within the framework of the AFLC Logistics Modernization System (LMS). The DRIVE model in the Weapon System Management Information System (WSMIS) and the Requirements Data Bank, in particular, are crucial to the formation of the maintenance requirement. The Air Force needs to ensure that the product and processes defined by these systems will, in fact, give the necessary visibility and control of the requirement. Coupling this capability with a management commitment to minimize variability in estimates should allow the Air Force to regain credibility in its maintenance requirements process without jeopardizing support. The greater management control is particularly important in view of Air Force plans to stock fund depot-level reparables, which will greatly change financial management of spares.

We recommend that the Air Force revisit the CORONA REQUIRE study of 1982–1983. That study was a comprehensive review of the spares procurement requirements process by a team chaired by General Alton D. Slay, U.S. Air Force (Retired) and representatives from all levels of the Air Force logistics community. Although the study dealt primarily with procurement, most of the problems it addressed have parallels in depot maintenance, and those parallels will become stronger when procurement and maintenance become more closely linked under stock funding. The agenda for "CORONA REQUIRE II" would focus on the development of a requirements *process* that recognizes the innate variability and judgmental quality of the requirement and provides the necessary levers for effective management control. While some of these management tools are already in place or being developed, they must yet be integrated into the process and we must be sure that management procedures are in place to take advantage of them. The Air Force would benefit greatly from the efforts of such a study group ensuring that the developing LMS will indeed provide the tools to manage, control, and stabilize both the procurement and maintenance requirement.

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CHAPTER 1

INTRODUCTION

In recent years, the depot maintenance requirements of *all* the Services have come under increasing scrutiny from Congress and OSD. In 1987, the Defense Resources Board identified a need for an in-depth assessment of depot maintenance backlogs and the relationship of funding levels to readiness and sustainability. The House and Senate appropriations committees both questioned the credibility of depot maintenance requirements in the markup of the FY89 budget.

Within the Air Force itself, the same question of credibility persists. There is a widespread perception that the depot maintenance requirement is overstated, a perception strong enough that in FY87 the Air Force reprogrammed more than $300 million from the depot maintenance account to civilian pay, the Logistics Modernization System, and other nondepot requirements. Those Air Force actions caused early 1988 estimates of projected backlogs – unfunded maintenance requirements – of more than $800 million in FY88, growing to over $1.5 billion by the end of FY89. Although backlogs in the $150 million to $200 million range had been managed in the past with little effect on readiness, the prospect of such large backlogs was alarming. The logistics community was greatly concerned, and the Air Force Logistics Command (AFLC) even projected a potential need for furloughs of the civilian work force.

The most drastic consequences did not materialize. Early retirement programs instead of furloughs reduced the work force, workload was shifted from depot-level to base-level maintenance, programmatic requirements were deferred or canceled, and aircraft overhaul work packages were downsized. Aircraft mission capable (MC) rates were maintained in the face of diminished depot production by dint of increased workarounds – more cannibalizations, lateral supply, and the use of war reserve stocks. In brief, the Air Force demonstrated the ability to survive a dramatic shock to depot maintenance funding – partly by establishing priorities for the elements of the requirement and performing only the most necessary actions and partly by working harder and with more workarounds on the flightline.

In this report, we discuss a statistical method we used to estimate the probable effects on Air Force readiness and sustainability – peacetime availability rates and wartime sortie generation – of changes in funding for depot maintenance. We examine supply and readiness indicators during FY88 and part of FY89 to see the actual effects of funding cuts on the Air Force, and we discuss how much of actual experience our method captured. Finally, we look at how the depot maintenance requirement is built and what light the events of FY88 shed on this process. That look is primarily directed at two desirable goals for the process – linking the requirement to aircraft readiness and sustainability and developing credible and defensible budget funding estimates.

CHAPTER 2

THE DEPOT MAINTENANCE REQUIREMENT

Air Force depot maintenance is responsible for the complex repair and overhaul of airframes, missiles, engines, components, and other equipment items.[1] The annual cost of these services has recently been in the $4.5 billion range. Congress appropriates funding for depot maintenance to Operation and Maintenance (O&M) accounts that are used by "customers" to buy maintenance services from the Depot Maintenance Industrial Fund (DMIF).[2]

The DMIF is a revolving fund that provides working capital for the depot maintenance industrial resources. The fund's customers include the other Military Services, many Federal agencies, and other Air Force and DoD activities, with the largest customer being the Direct Air Force (DAF) account, which supports the operations of the major operating commands and has recently hovered about the $3.1 billion level. We focus our attention on that account, commonly referred to as Depot Purchased Equipment Maintenance (DPEM)[3] although the new official term is the more illustrative DEP/REP/MOD (for depot repairs and modifications).

Air Force Logistics Command, Materiel Management (MM), determines the DEP/REP/MOD requirement, obtains appropriations, and buys maintenance services from the DMIF to execute the program. Approximately 65 percent of the program is performed organically at five major air logistics centers (ALCs) or depots. The Air Staff, Directorate of Logistics Plans and Programs, is responsible for planning, programming, and budgeting for depot maintenance.

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[1]Much of the information in this chapter on the content and management of the depot maintenance program is taken from the Air War College Report AU-AWC-88-209, *DPEM Versus DMIF: What's the Difference and Why Should We Care*, by Colonel David M. Reed, U.S. Air Force (USAF).

[2]Strictly speaking, DMIF is the Air Force Industrial Fund, Depot Maintenance Services.

[3]The DAF appropriation includes non-DPEM programs of approximately $300 million annually, including interim contractor support and depot maintenance for selected classified programs that are kept separate from both DPEM and DMIF.

CONTENT OF THE DEP/REP/MOD PROGRAM

Six major programs comprise the DEP/REP/MOD. The largest of these, typically 55 to 60 percent of the total, is the Exchangeable Component Repair Program, which repairs components for all Air Force-owned equipment. Another, the Aircraft Program, includes programmed depot maintenance of airframes; on-condition maintenance requirements for crash damage, corrosion, etc.; installation of modification kits; and other actions on airframes. It constitutes approximately 25 percent of the total DEP/REP/MOD. The third major program is the Engine Program, which includes the cost of overhauling engines and engine modules. It is typically about 10 percent of the total. Thus, those three programs comprise the bulk of the DEP/REP/MOD appropriation.

The remaining three smaller programs are the Missile Program, which provides depot maintenance in support of intercontinental ballistic missiles; the Other Major Equipment Items Program, which includes repair of such items as ground communication vans and refueling vehicles; and the Area Base Support Program, which includes precision equipment calibration and other on-site support.

In this study, we focus on the Exchangeables Program although at times we draw illustrative examples from the other programs. The Exchangeables Program is the largest of the DEP/REP/MOD programs and clearly a major contributor to aircraft readiness and sustainability. In addition, because procurement costs are on the order of seven times greater than repair costs, DEP/REP/MOD dollars have greater leverage, in a sense, than procurement dollars. Failure to perform $100 million of repair causes $700 million of assets to remain unserviceable.

DEVELOPMENT OF THE EXCHANGEABLES REQUIREMENTS

The first step in computing the exchangeables requirements is to calculate a procurement and a repair requirement for each of the 170,000 recoverable spare parts managed by the Air Force. The D041 Recoverable Consumption Item Requirements System performs that computation, and the results are used both for near-term guidance of execution (the generation of procurement requests and induction of unserviceable assets into depot repair) and for long-term projection of budget requirements.

On the basis of individual factors such as failure and condemnation rates, repair times, procurement and repair costs, the D041 projects up to 26 quarters of gross requirements for each item – so many to replace accumulated failures, so many to fill repair and transportation pipelines (i.e., the expected numbers in repair or in transit), so many for safety level to cover statistical fluctuations in demands, so many for special additive programs, and so on. It also computes the number of "candidates" for induction into depot repair – quarterly failures times percent not repairable at the base discounted by the percent condemned at the depot. The D041 also contains data on item assets as of the asset cutoff date (ACD) – i.e., the current assets at the time of the computation. It contains data on serviceable assets; assets in repair at base and depot, due-in from contractors, and on backorder (negative assets – owed to maintenance); assets repairable at depot but not yet inducted into repair; and various other categories.

The Central Secondary Item Stratification (CSIS) system uses the D041 quantities and projection to simulate (deterministically) the passage of time, quarter by quarter, and calculate quarterly item repair and procurement requirements. In the first quarter, for instance, the gross requirement for that quarter is compared with available assets and the difference becomes that quarter's net requirement. To the extent possible, the net requirement is satisfied by the candidates for depot repair, which yields the quarter's repair requirement. If repair is insufficient, the deficit becomes a "procurement requirement." Since procurement leadtimes are closer to 3 years than to one quarter, such a near-term requirement is impossible to satisfy. In fact, the procurement requirement for a quarter is actually generated by looking at the quarter a procurement leadtime in the future.

The CSIS then looks at the next quarter, updating the relevant quantities as a result of the simulated activity in the first quarter, and so on through the 26 quarters. By accumulating appropriate quarters, the CSIS can project requirements for repair and procurement by fiscal year or other desired time period.

The output from the CSIS simulation is used to develop quarterly depot induction schedules. The schedule does not incorporate raw CSIS output, however. Quantities are adjusted by item managers to reflect corrected or updated data and negotiated with maintenance to allow for maintenance constraints – workload, test equipment, and so on. Guidance from Headquarters, AFLC (HQ AFLC), responding to fiscal stringencies or setting priorities among programs or classes of requirement may also play a role.

The CSIS output is also used to develop budgets. Once a year, March D041 data are aggregated for budget purposes. An important part of this process is identifying additive, programmatic requirements that are not contained in the D041 data base. Those requirements are identified and validated jointly by AFLC and ALC personnel at Repair Management Reviews for repair or Materiel Management Reviews for procurement.

The transition statement incorporates the result of these reviews and serves to convert the raw CSIS-aggregated quantities to budget figures. The transition process also includes adjustments from the baseline computation for changes in inflation rate, aircraft inventory, and flying-hour program. Because the CSIS simulation assumes that requirements are filled as they occur, shortages in prior-year funding are carried over as a requirement to the next fiscal year. For repair, carryover is discounted by a nongeneration factor to allow for historical experience.

The transition process takes several months to complete and the product is submitted to the Air Staff in late summer for review and validation. The budget is then submitted to the DoD Comptroller and is also reviewed by OSD and the Office of Management and Budget (OMB) before submission to Congress in the President's Budget in January.

THE EFFECT OF STOCK FUNDING

Air Force plans to use the stock fund to finance depot-level reparables (DLRs) will have a significant effect on budgeting and funding sources to support depot-level maintenance (DLM). The new DLR division of the Air Force stock fund will pay the DMIF for repair of DLRs; thus, the exchangeables segment will no longer be financed with appropriated DEP/REP/MOD funds. Instead, equivalent funds will be appropriated to the O&M account so that stock fund customers (the major commands) can buy assets from the DLR stock fund. Because depot maintenance and procurement will both be financed by the DLR stock fund, it will be possible to move funds between those accounts. That capability will give the Air Force greater flexibility in applying resources where they are most needed rather than having separate, appropriated accounts for maintenance and procurement. Programmed depot maintenance (PDM), engine overhaul, and the other maintenance programs will continue to be funded through appropriations. Nothing in the stock-funding initiative, however, eliminates the necessity for a requirements computation. The requirements computation process for buy and repair will continue as it exists today.

THE DEMAND-BASED PORTION OF THE REQUIREMENT

The outline of the requirements determination methodology presented in the previous section is, of course, oversimplified in many ways. We intend for it to contain only enough detail to support the contention that using such a system for developing budgets *inevitably* leads to varying and unstable estimates and to indicate some of the difficulties in relating requirements to aircraft readiness and sustainability. Many of our observations have been made before, notably in the 1982 CORONA REQUIRE[4] study of the spares procurement requirement process. Those criticisms are applicable, with only minor modifications, to the exchangeables repair requirement.

Underlying many of the difficulties with using the D041/CSIS for budgeting is the fact that the D041 is really an execution system. Judged in those terms, it is logically sound. It provides a way for HQ AFLC to offer guidance to a decentralized corps of item managers at five separate ALCs. We do not imply that the D041 cannot be improved. It is a difficult system to understand for those who work with it. Lack of data integrity and accuracy is a problem as is lack of responsiveness and timeliness. A quarterly computation can take more than 60 days to complete. Considering the time required for error corrections and updates and off-line considerations of additions, a mid-year review of budget execution is not completed until the fiscal year is almost complete – often too late for any corrective action.

This nonresponsiveness is to be remedied by the introduction of the Requirements Data Bank, which will replace the antiquated hardware and batch-processing environment of the current system with updated hardware and software. Responsiveness is to be further improved by the implementation of the Distribution and Repair in a Variable Environment (DRIVE) system, which will establish priorities for depot repairs based on their contributions to very-near-term aircraft readiness.

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[4]USAF Report, *CORONA REQUIRE, An Analysis of the Aircraft Replenishment Spares Acquisition Process*, March 1983.

Neither of these changes can be expected to have more than a marginal effect on the stability of budget estimates. The deterministic logic of the CSIS simulation, which assumes that the item demands can be forecasted precisely, is at fault. While no one would ever claim that the CSIS assumption was completely true, we have only recently begun to appreciate how far from the truth it is.[5,6,7,8] The new Air Force Logistics Wartime Concept of Operations recognizes this uncertainty and addresses methods to deal with it, but procurement and repair budget estimates remain essentially deterministic. Even though the safety-level requirement is calculated statistically, it addresses only a small part of the variability – variation about a known demand rate. A larger part of the problem is that item demand rates change over time as does the population of items in the inventory.

A good illustration of the faulty CSIS assumption that item demands can be forecast with precision is the well-known requirements "bow-wave," visible in both repair and procurement. Suppose we do a CSIS simulation using a 30 September 1990 D041 data base, so that the first four quarters of the simulation represent the FY91 requirement. (Actually, the requirement would also include additives and programmatic requirements not in the data base, but we simplify for clarity.) A deficiency would exist for a number of items on 30 September 1990, i.e., a number of items would have outstanding backorders or unfilled requirements (negative total assets). The CSIS would assume that those deficiencies would be corrected in the first quarter (a "catch-up" requirement) by the appropriate mix of repair and procurement. The remainder of the year's requirement would then be a "keep-up" or "running-in-place" requirement – repairing whenever a failure occurs and procuring when necessary. Given full funding and no capacity constraints (on maintenance or procurement) in FY91, the CSIS simulation would begin the next fiscal year, FY92, in equilibrium. The requirement for FY92 would only be a keep-up requirement (and allowances for planned increases in force strength or flying levels).

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[5]Randall M. King and Virginia A. Mattern, *The Effects of Data Base Dynamics in Estimating Spares Costs: An Analysis of the F-16*, LMI Working Note AF501-2, December 1985.

[6]Craig C. Sherbrooke, *Evaluation of Demand Prediction Techniques*, LMI Report AF601R1, March 1987.

[7]Palmer Smith and Robert Gumbert, "Item Migration and the Dynamics of Inventory Management," *Defense Management Journal*, First Quarter 1986.

[8]Gordon Crawford, *Variability in the Demands for Aircraft Spare Parts*, The RAND Corporation, Report R-3318-AF, January 1988.

However, the next year's CSIS simulation based on a 30 September 1991 D041 shows a *new* catch-up requirement that the CSIS a year ago missed altogether. New items and their new requirements have entered the inventory; items that had no projected demand a year earlier now have projected demand; some items are experiencing higher demands than expected; and some items are not being repaired at the base level as expected and have increased depot repair requirements. For a myriad reasons, unforeseen a year ago, new items are in trouble, and in some cases, old ones are still in trouble. (Off-line aggregate estimates of FY92 programmatic requirements capture some of the bow wave but not on the item level.)

The September 1991 CSIS now satisfies the catch-up requirement in the first quarter, and again, shows a stable keep-up requirement for the remainder of FY92 and beyond. However, the promised land of stable, forecastable item requirements keeps receding into the future; with each new computation, stability remains a quarter away and we never get there. LMI has previously identified and characterized the effect of this "churn" on the requirement for F-16 spares.[9]

Item demand is, in fact, volatile. Long-term predictions will never be accurate, and a system such as the CSIS that does not recognize churn but portrays item demand as deterministic is simply not realistic. Budgeting and planning as though the CSIS projections will occur in the future is a prescription for creating problems. Further, the *apparent* precision in CSIS estimates contributes to lack of credibility when projections inevitably prove incorrect.

BIAS IN DEMAND FORECASTING

Aside from the problem of volatility in item demand rates is the issue of *bias* in forecasted rates. Unpublished research by T. F. Lippiatt of The RAND Corporation suggests a tendency to overstate projected demand rates. Our analysis expands and supports this view.

Introduction

Forecasts of depot repair requirements have been the subject of controversy for the past several years because of the way estimates of a given year's funding requirement have evolved over time. In each year from FY85 through FY87, funding decreased from the Program Objective Memorandum (POM) to the President's

[9]Randall M. King, op. cit.

Budget (PB), decreased further to the President's Budget Update, and decreased yet again to the actual obligation of funds (see Figure 2-1).

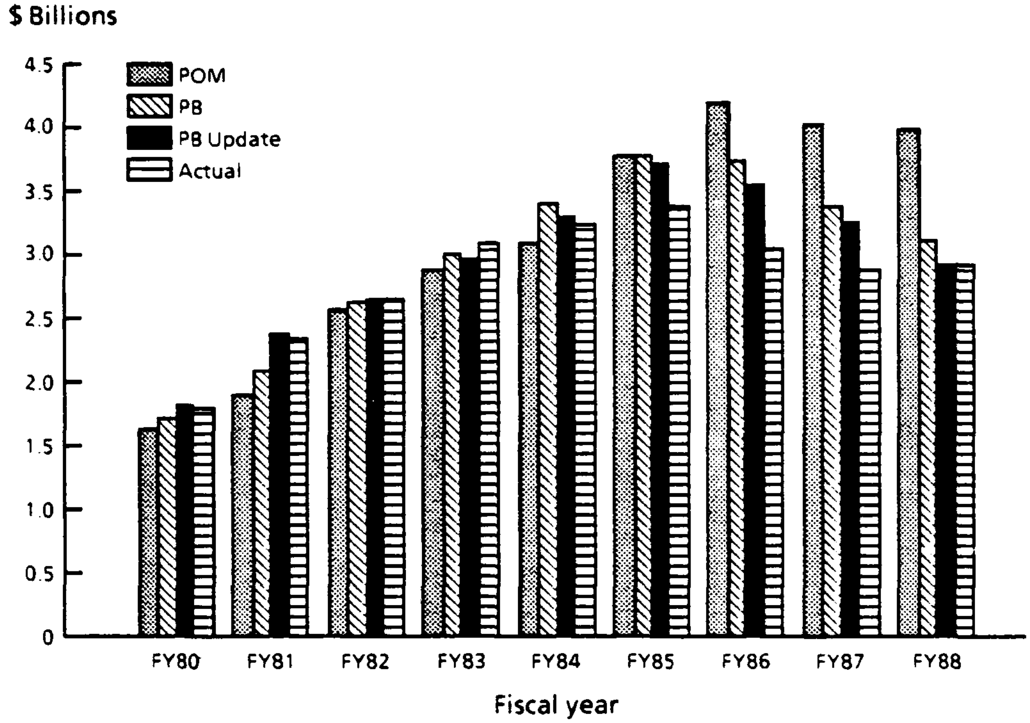

FIG. 2-1. EVOLUTION OF THE REQUIREMENT

The POM and subsequent budget estimates shown in Figure 2-1 contain allowances for additive programs, aircraft, engine, and equipment overhauls, and field support as well as for repair of failed exchangeable components. The apparent early overestimates of the total DEP/REP/MOD requirement could be due to any of those elements. We have examined only the forecasting of exchangeables.

Depot reparables generated consist of those generated by organizational and intermediate maintenance (OIM) (items that failed and could not be repaired by base maintenance) and those generated by DLM itself (periodic or as-needed overhaul of airframes, engines, and other end items, as well as subcomponents generated by component overhauls). We restricted our attention to OIM depot reparables generated. We use the shorter term "OIM depot repgens" for these items.

We examined historical data from FY86, FY87, FY88, and the first half of FY89. (We refer to those years as target years, that is, the years for which forecasts were made.) For each of those target years, we looked at forecasts made in each of the preceding 3 years and compared those three forecasts with results from the target year.

For example, we compared FY85, FY86, and FY87 forecasts of the cost of repairing FY88 OIM depot repgens with the amount it would have cost to repair all OIM depot repgens for FY88 if every item was actually repaired. (Not all of OIM depot repgens are repaired by the depots during the year in which they are generated – some repairs are deferred, and some items are in long supply and do not have to be repaired.)

We call the amount the depots would have to spend to repair all OIM depot repgens the "value" of OIM depot repgens to avoid confusing it with the actual amount the depots actually spent on repairing these items. (The latter amount is subject to management decisions, funding availability, etc.) The question at hand is the forecasting of how many reparables will generate at the depots. The issue of how many will be repaired is a separate question.

Methodology

We extracted historical data and predictions for depot repgens were extracted from the March D041 data base for each fiscal year considered. We then used the following procedure:

- We selected a target year and a prediction year (in which a forecast for that target year was made).
- For each item in the prediction year data base, we multiplied the total OIM failures forecast for each quarter of the fiscal year by the forecasted base not reparable this station (NRTS) percents for those quarters and the forecasted unit repair cost. Quarterly costs were then summed to yield the forecasted value of depot repgens for the item.
- We then summed forecasted values across items and then multiplied the total by an inflation factor to account for historical inflation rates. The product was the predicted value of OIM depot repgens.
- For each item in the target year data base, we multiplied the actual OIM depot repgens for each quarter by unit repair cost and summed over the fiscal quarters of the target year. We then summed the resulting costs across items. This yielded the value of OIM depot repgens tor the target year.

- We compared the forecasted value of OIM depot repgens with the value of OIM depot repgens in the target year.[10]

Results

The value of OIM depot repgens in the target years FY86, FY87, and FY88 was in the range of $1.1 billion to $1.2 billion dollars. In contrast, predictions made 3 years before the corresponding target year were between $1.8 billion and $2.2 billion, overestimates of between 50 percent and 85 percent. Estimates made 2 years before the target year were on the order of $1.6 billion to $1.9 billion, overestimating actual value by 38 percent to 72 percent; estimates made 1 year in advance were between $1.3 billion and $1.6 billion, overestimates of 21 percent to 35 percent (see Figures 2-2 and 2-3). Hence, the tendency to overestimate the value of OIM depot repgens was consistent in all of our target years.

One possible method of compensating for the tendency to overestimate is to set all estimates made *n* years prior to the target year equal to a fixed fraction of the corresponding D041 value predictions. That fraction can be thought of as a "multiplier" that is applied to all forecasts made *n* years out; distinct multipliers would be applied to forecasts made with different values of *n*. For example, suppose the multiplier for forecasts made 1 year prior to a target year ($n = 1$) were 0.75. Each D041 prediction for the value of OIM depot repgens made 1 year in advance would then be multiplied by 0.75 to yield a revised estimate.

A natural candidate for the multiplier is the ratio of the actual value of OIM depot repgens to the predicted value. For predictions made 3 years before the target year, this ratio lies between 0.54 and 0.67; for predictions made 2 years prior to the target year, it is in the range of 0.58 to 0.68; and for predictions made 1 year in advance, it lies in the range of 0.74 to 0.83 (see Figure 2-4). Averages for these ratios are 0.61, 0.66, and 0.77, respectively. We compared value estimates revised using these average ratios as multipliers with the actual value of OIM depot repgens and with unrevised predictions.

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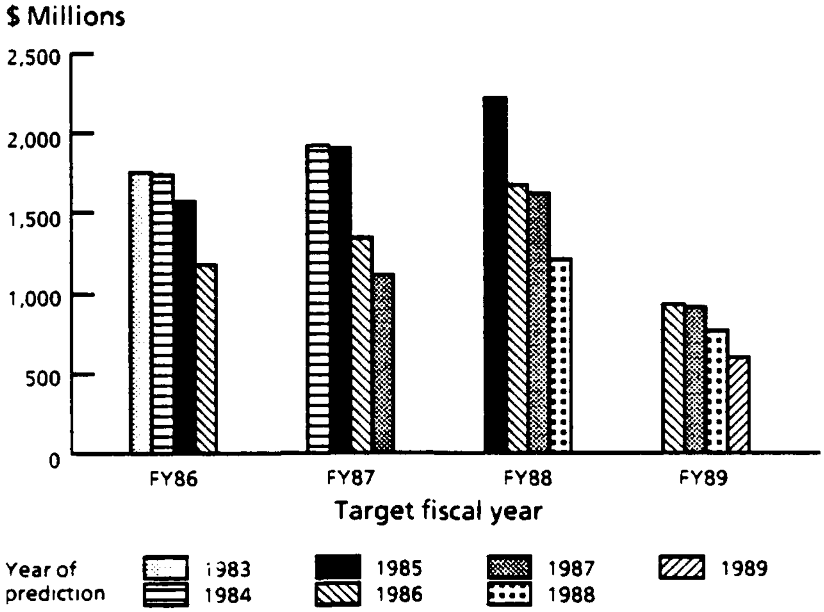
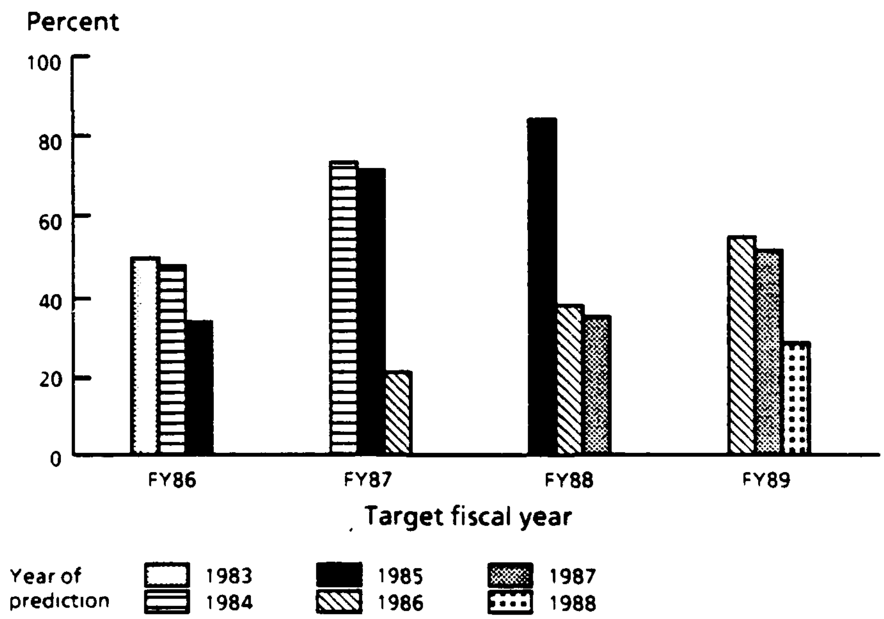
[10]Note that the set of items in the prediction year data and the target year may be different because of failure patterns for items with erratic demands, deletion of obsolete items, and the introduction of new items. This turnover in data base items is known as churn. See Randall M. King and Virginia A. Mattern, *The Effects of Data Base Dynamics in Estimating Spares Costs: An Analysis of the F-16*, LMI Working Note AF501-2, December 1985.



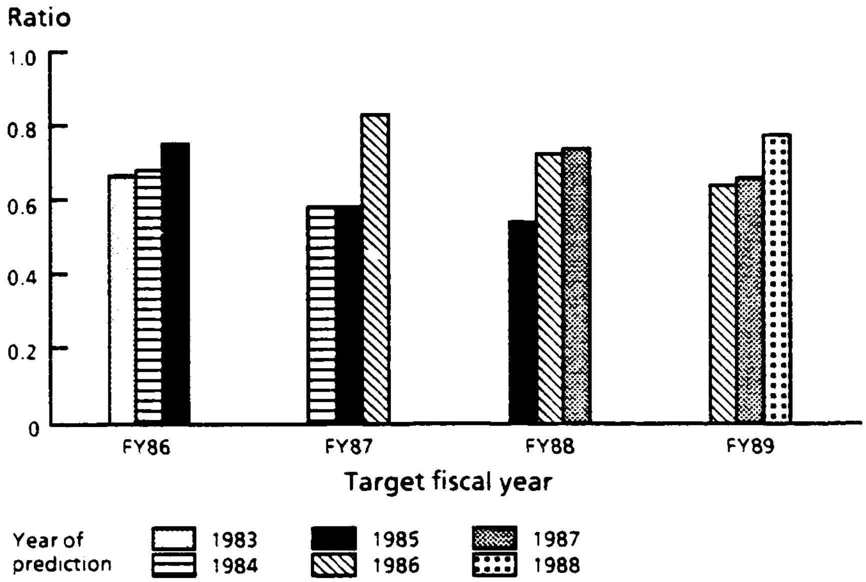
Notes: 1. Last bar in each cluster is historical data.
2. FY89 data for first half only.

FIG. 2-2. PREDICTED AND ACTUAL VALUE OF OIM DEPOT REPARABLES GENERATED



Note: FY89 data for first half only.

FIG. 2-3. PERCENT OVERESTIMATE OF VALUE OF OIM DEPOT REPARABLES GENERATED



Note: FY89 data for first half only.

FIG. 2-4. RATIO OF ACTUAL TO PREDICTED VALUE OF OIM DEPOT REPARABLES GENERATED

The revised predictions were off between $1 million and $150 million, as shown in Figure 2-5, considerably less than the $200 million to $1 billion errors in predictions not adjusted with multipliers. However, multiplier-adjusted estimates understated the value of OIM depot repgens by as much as $80 million even for predictions made only 1 year out. If the magnitude of prediction error is the sole criterion, the multiplier-adjusted predictions for our target years are better; if one takes into account the possible reduction in depot repairs because of underfunding, it is not clear which method is preferable.

Multiplier-adjusted predictions could actually lead to a larger error than the standard D041 predictions if, instead of all D041 estimates being too high (as we observed), a year in which the D041 prediction was too low followed a number of years in which the D041 prediction was too high. In that case, the multiplier, an average (or weighted average) of the ratio of actual value to predicted value in prior years, would be less than one. Applying such a multiplier to the most recent year – a year in which the predicted value was already too low – would lower the cost estimate still further. Thus, the error in the multiplier-adjusted prediction would be larger than the error in the original prediction. Without evidence that D041

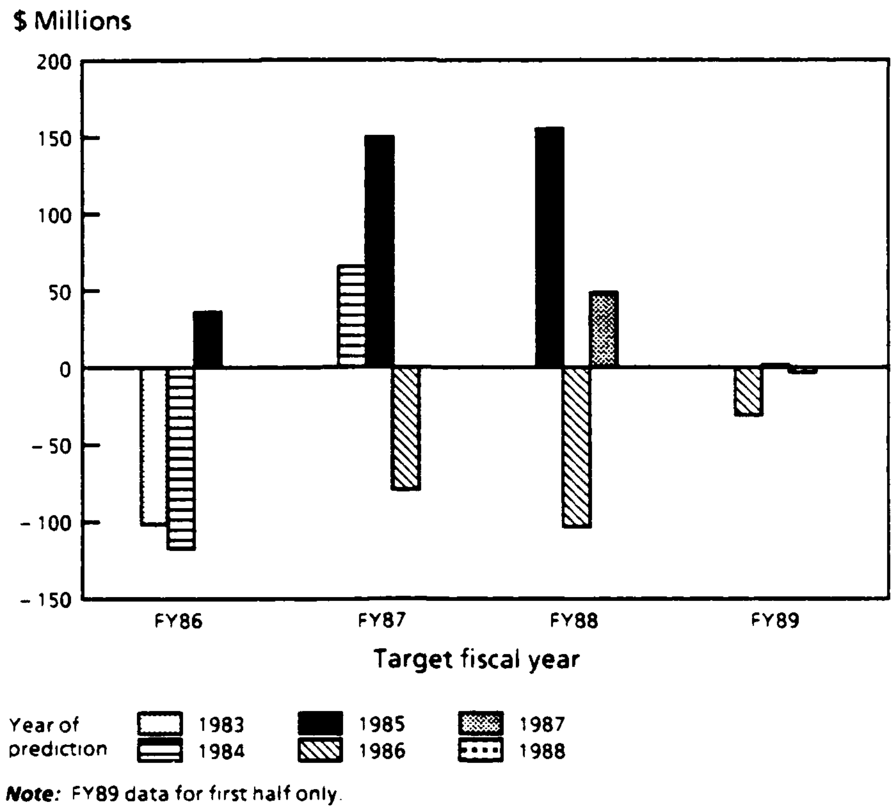


FIG. 2-5. DIFFERENCE BETWEEN MULTIPLIER-ADJUSTED FORECASTS AND ACTUAL VALUE OF OIM DEPOT REPARABLES GENERATED

projections will continue this bias, an arbitrary application of multipliers to the requirements estimate would be hazardous.

Why were the predicted values of OIM depot repgens for our set of target years too high? While we have not compared predictions versus actuals for all of the factors used in the D041 forecasts of the value of OIM depot repgens, we did do such a comparison for the quantity of OIM depot repgens.

Our computation of the predicted quantity of OIM depot repgens followed the outline given earlier for computation of the value of OIM depot repgens with the exception that quantities of each item were not multiplied by unit repair cost.

Actual OIM depot repgens were in the range of 930 thousand to 1 million parts; estimates made 3 years out were in the range of 1.5 million to 1.6 million (overestimates of 56 percent to 61 percent); estimates made 2 years out were in the range of 1.2 million to 1.5 million (overestimates of 28 percent to 47 percent); estimates made 1 year in advance were in the range of 1.1 million to 1.4 million (overestimates of 19 percent to 39 percent) (see Figures 2-6 and 2-7).

The D041 projected quantities of OIM depot repgens are computed as products of the projected item program (measured in flying hours, sorties, firings, or other appropriate units), the projected OIM failure rate, and the projected base NRTS percent. We have not investigated the extent to which each of these factors contributed to the overestimates of OIM depot repgens quantity, but it is clear that one or more of these factors was overestimated for some items. (Lippiatt's unpublished work for RAND showed the extent that changes in item population, flying programs, and repair costs contributed to the overestimate of the FY87 requirement for selected weapon systems.)

Summary

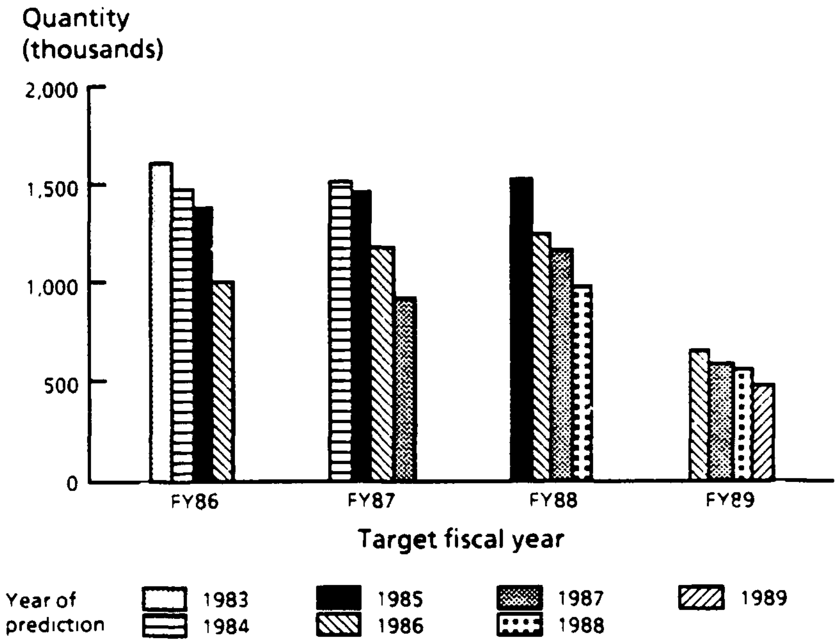
Predictions of the value of OIM depot repgens for the target years FY86 through FY89 were overestimates. Estimates made 2 and 3 years out were too high by an average of 53 percent and 70 percent, respectively; estimates made 1 year out were too large by an average of 30 percent.

Use of multipliers (multiplication of cost predictions by a constant less than 1.0) to compensate for the observed overestimation reduced the magnitude of the error but also resulted in underestimates as large as $100 million.

In the absence of an understanding of why the overestimates exist or any confidence that they will continue in the future, we cannot recommend that requirements estimates be automatically reduced by the historical multiplier. Certainly, this study has not established that such a bias exists for the additive portion of the exchangeables requirement. This finding emphasizes the shortcomings of the CSIS, or similar bottom-up estimate of the repair requirement.

MANAGEMENT DECISIONS AND THE REQUIREMENT

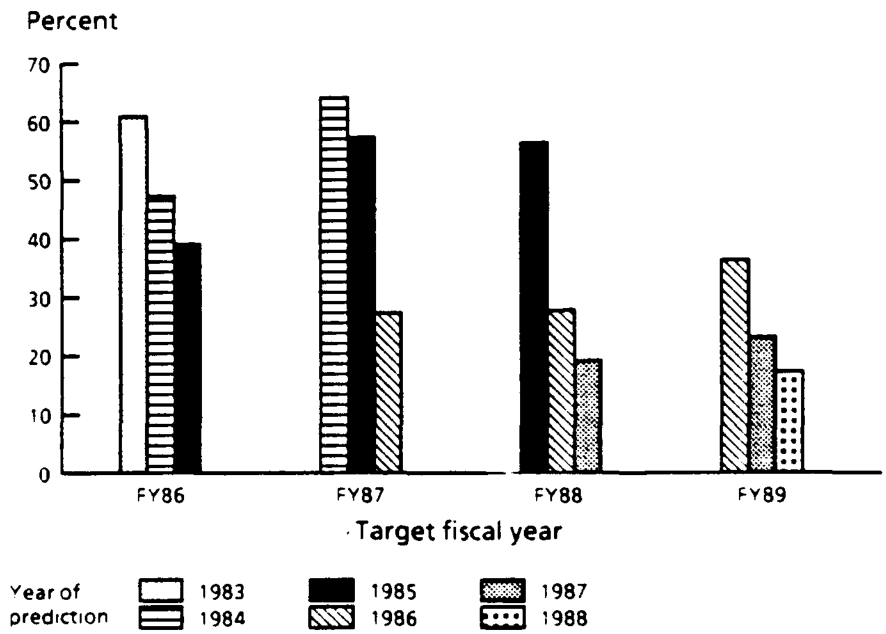
Thus far, we have dealt only with the computed part of the requirement – demand-based, item-specific results of D041 and CSIS system logic. In fact, significant portions of both the procurement and repair requirements are composed of nonrecurring demands, additive and programmatic requirements resulting from management decisions at various levels of authority in the Air Force. The CORONA REQUIRE study estimated that 40 percent of the 1982 procurement requirement was



Notes: 1 Last bar in each cluster is historical data.

2 FY89 data for first half only.

FIG. 2-6. PREDICTED AND ACTUAL OIM DEPOT REPARABLES GENERATED



Note: FY89 data for first half only

FIG. 2-7. PERCENT OVERESTIMATE OF OIM DEPOT REPARABLES GENERATED

(Quantity)

the result of management decisions rather than demand-based item calculations. We find approximately the same proportions in recent procurement requirements. In fact, the F-100 engine core upgrade program alone generated procurement requirements of more than $700 million over the FY87 through FY89 time period. (The total cost of that program was much higher.) Replacement of C-5 pylons accounted for $70 million of the FY88 through FY90 procurement requirement.

We do not have as much visibility into maintenance additives, nor did we have the resources of the CORONA REQUIRE study team to identify and examine maintenance additives in detail. However, we see evidence that additives play a significant role in the maintenance requirement although we have not been able to verify that they make up as large a proportion as in the procurement case.

In FY87, for example, projections of maintenance requirements for FY88 through FY90 included $270 million for upgrading (inspecting to new, tighter limits) the F-100 Augmentor external nozzle and $170 million for the divergent seal. A new program to overhaul TF30–P3/P9 afterburner added $19 million to the requirements estimate.

Additives are not the *only area* in which management decisions affect the requirement. Increases in KC-135R flying hours drove an $8 *million increase* in F-108 engine exchangeables for FY90. Decisions by the engine logistics community on inspection intervals for life-limited parts have significant effects on requirements. So can modification programs being stretched out or accelerated. Force growth or the phasing out of weapon systems is yet another factor. In fact, the phasing out of the F-4C was accelerated in FY88 partly to reduce the maintenance requirement in light of the dire funding situation. It saved $20 million at Oklahoma City ALC and $27 million at Ogden ALC. San Antonio ALC changed its policy of overhauling all available engine exchangeables, saving $18 million in FY88.

Indirect evidence of the importance of management decisions and additive programs is provided by Figures 2-8 through 2-10, which show depot maintenance funding, aircraft inventory, and flying hours trends from 1979 through 1988. Intuitively, one would expect a far stronger correlation than is actually visible. Figure 2-11 shows the total number of OIM reparables generated at the depot over the period 1982 through 1989. In that figure, we see some downward trend, which may be a contributor to the overestimation problem discussed earlier. However,

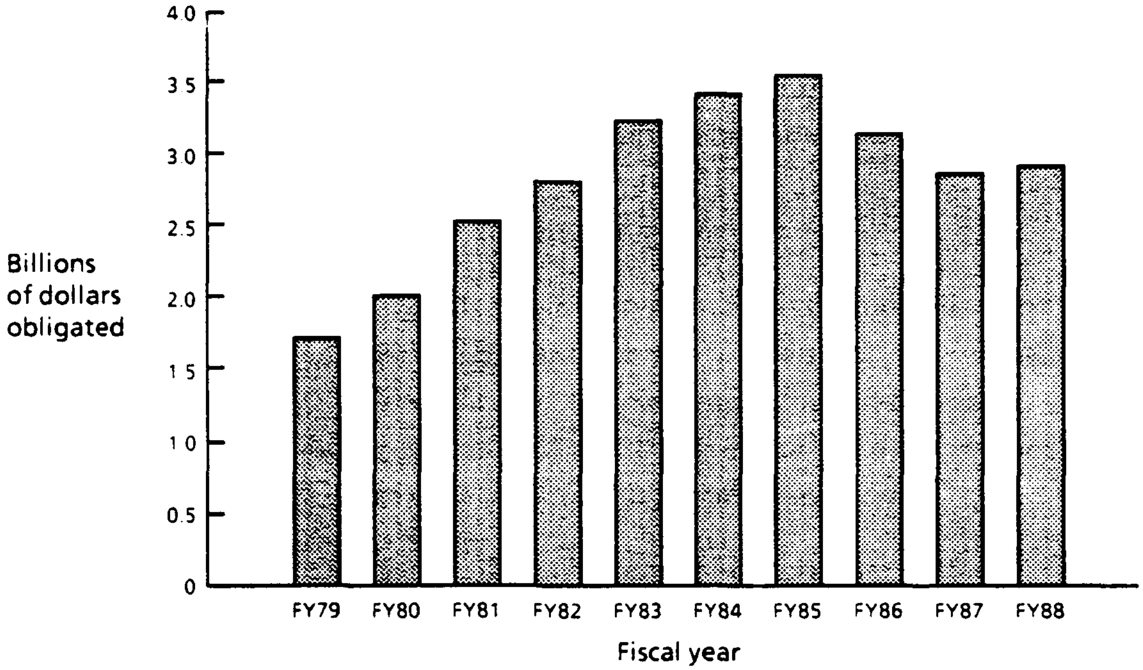


FIG. 2-8. DEPOT MAINTENANCE FUNDING TREND

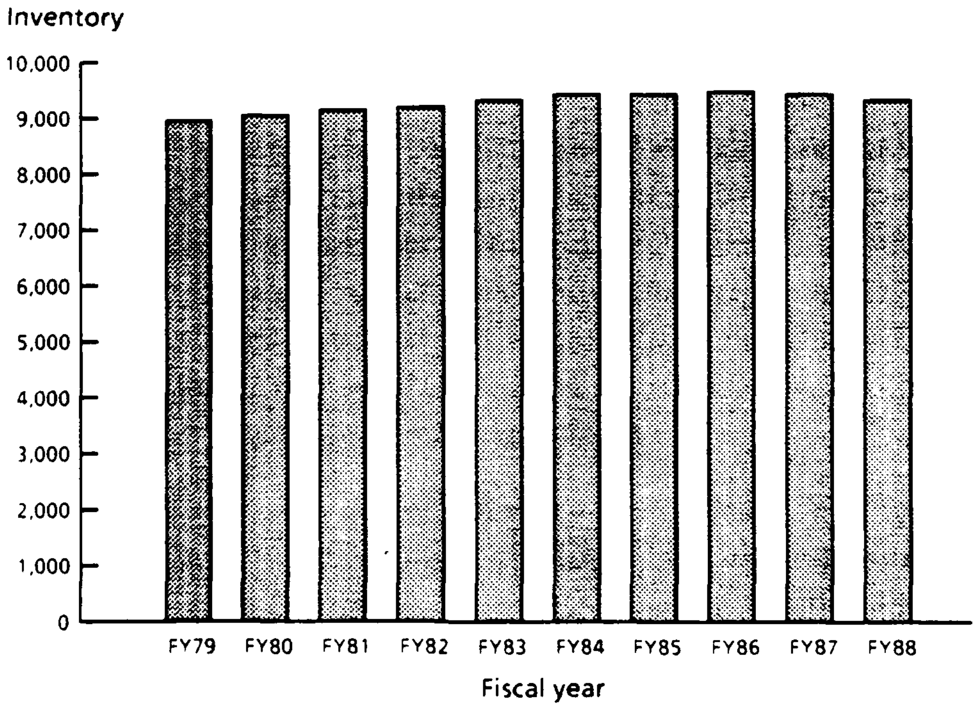


FIG. 2-9. TOTAL AIRCRAFT INVENTORY TREND

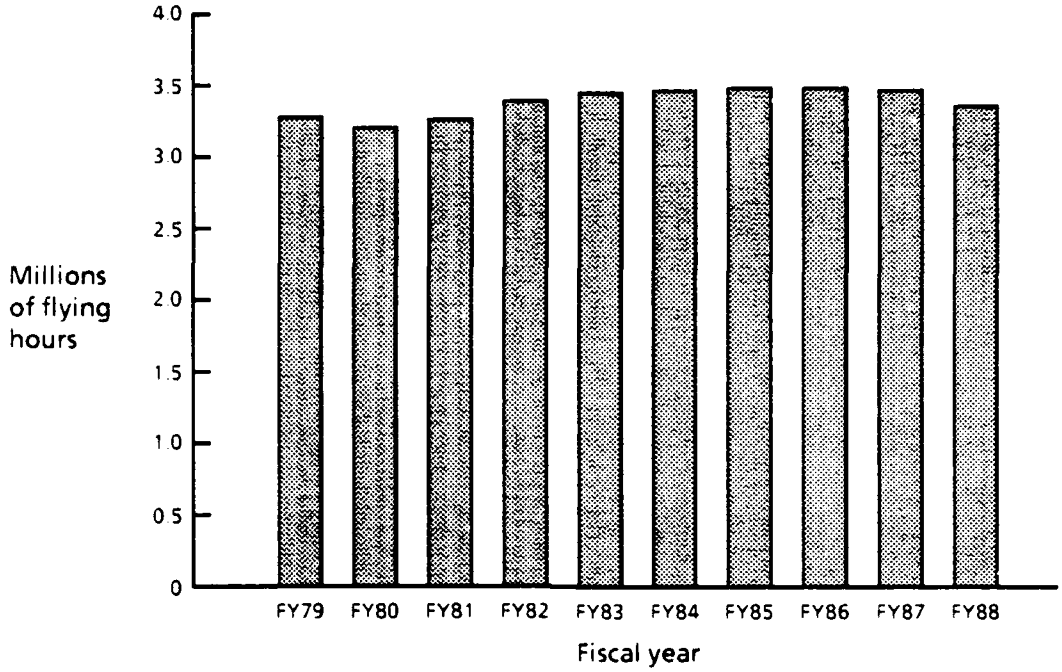


FIG. 2-10. FLYING-HOUR TREND

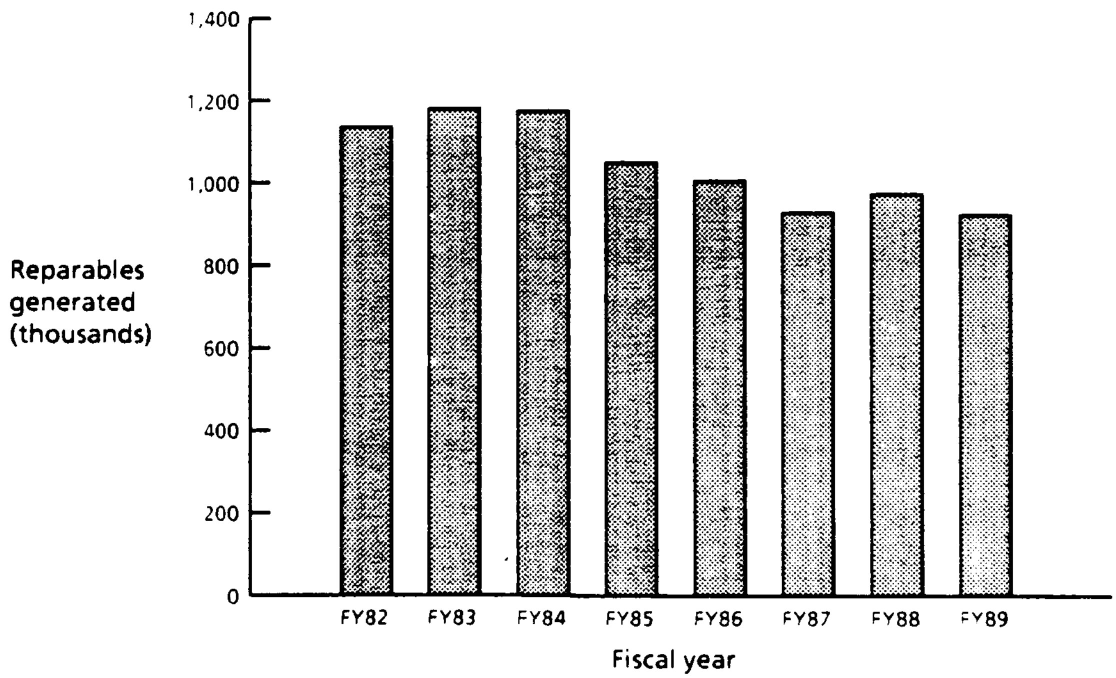


FIG. 2-11. OIM DEPOT REPARABLES GENERATED

(Base NRTS)

there seems little correlation with funding profiles, which suggests that the variations in requirements and funding are due more to additives, management decisions, high-level determination to increase readiness, and the like, than to statistical variability in component demand processes.

Management decisions are an important and necessary part of the requirements process and will remain so in the future. In addition, the large cost of a relatively small number of programs makes them inherently difficult to forecast statistically. No statistical model was likely to forecast the increases in procurement requirements caused by the F-100 core upgrade program, for example. Those approaches to improving the requirements process that fail to address this issue can provide, at best, marginal improvement in the programming and budgeting process.

CHAPTER 3

ESTIMATING THE EFFECT ON AIRCRAFT READINESS AND SUSTAINABILITY

INTRODUCTION

What are the probable effects that large shortfalls in depot maintenance funding have on aircraft readiness and sustainability? The magnitude of the projected shortfalls in FY88 through FY89 made it clear that the Air Force would not be able to rely on a "business as usual" approach. At the unit level, it would need to rely heavily on workarounds such as cannibalization, expedited repair, and the use of war reserve assets. At the ALC level, it would need to rely on identifying and performing the minimal necessary work and strictly re-evaluating the necessity of additive programs.

Preliminary estimates of the effect of using the Procurement/Repair version of the Aircraft Availability Model (AAM)[1] showed too much sensitivity to be credible. That was not surprising. The AAM is a steady state, peacetime operations model, typically used in analysis of peacetime operating stock (POS) requirements. It does not consider war reserve assets to be available for use in peacetime and allows only historically typical cannibalization rates. As a POS requirements model, the AAM calculates requirements for all reparable components, regardless of essentiality, while the Air Force would need to direct the limited FY88 funds available to overhaul only the most essential and critical items. Further complicating the issue was the uncertainty as to how AFLC would allocate shortages across the DEP/REP/MOD major programs and which additive programs would be canceled or deferred.

The method we developed shows the sensitivity of both peacetime readiness and wartime sustainability to changes in depot maintenance funding. We modeled the increased use of war reserve assets to maintain peacetime mission capable (MC) rates in the face of shortages, and we quantified the resulting degradation in wartime sustainability caused by drawdown of war reserve assets.

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[1]T. J. O'Malley, *The Aircraft Availability Model: Conceptual Framework and Mathematics*, LMI Report AF201, June 1983.

A detailed technical description of the analysis is included in its entirety as the Appendix A of this document. We include a short outline here because our findings offer insights into some of the observed effects of the maintenance funding cut and because those findings dramatically illustrate the need for the Air Force to integrate its peacetime and wartime requirements computations.

THE APPROACH

We performed the analysis on the squadron level, using a representative F-16A 24-aircraft squadron and an F-111D 18-aircraft squadron. (Each squadron was analyzed independently.) We limited the analysis to components (national stock numbers) in the squadron War Readiness Spares Kit (WRSK), which excluded nonessential items and used item factors – rates, repair times, procurement and repair costs, transportation times – from the Air Force D041 system for peacetime factors and the D029 WRSK/BLSS (Base Level Self-Sufficiency) and Authorization Computation System for wartime factors. Using the AAM, we derived squadron POS stock levels so that the total squadron assets (POS and WRSK) supported aircraft availability rates which corresponded to observed peacetime measures.[2]

We then simulated several levels of cuts in depot maintenance funding over a 2-year period. To do so, we used the D041 component peacetime factors and the squadron's planned flying-hour program to estimate 2 year's worth of depot returns, item by item, and then calculated the total repair cost of those returns.[3] Then to simulate, say, 80 percent funding, we allowed the use of only 80 percent of that total funding to repair the full 2 year's worth of demands. We used the AAM to prioritize the repairs so that we obtained the maximum possible peacetime availability rates for the constrained repair funds.

We now had a situation in which the squadron's POS asset position was reduced to reflect lack of repair funds. We evaluated the squadron's peacetime aircraft availability and simultaneously calculated the increased usage of assets from the WRSK to make up for POS shortfalls. This allowed us to estimate the level of depletion in the WRSK that results from increased peacetime usage and to evaluate

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[2]Aircraft availability is defined to be the probability that an aircraft is not missing a component (in this case a component which is in the WRSK). It is an estimator of one minus the reported not mission capable–supply (NMCS) rate.

[3]Strictly speaking, this is really only the keep-up requirement.

[using Dyna-METRIC[4] (Dynamic Multi-Echelon Technique for Recoverable Item Control)] the resulting degradation in sustainability if the squadron had to deploy with the depleted WRSK. We used a notional 30-day wartime scenario with an initial 7-day high-activity surge period to estimate sustainability impacts. Figure 3-1 presents a conceptual schematic, and the results of the analysis are shown in Tables 3-1 and 3-2.

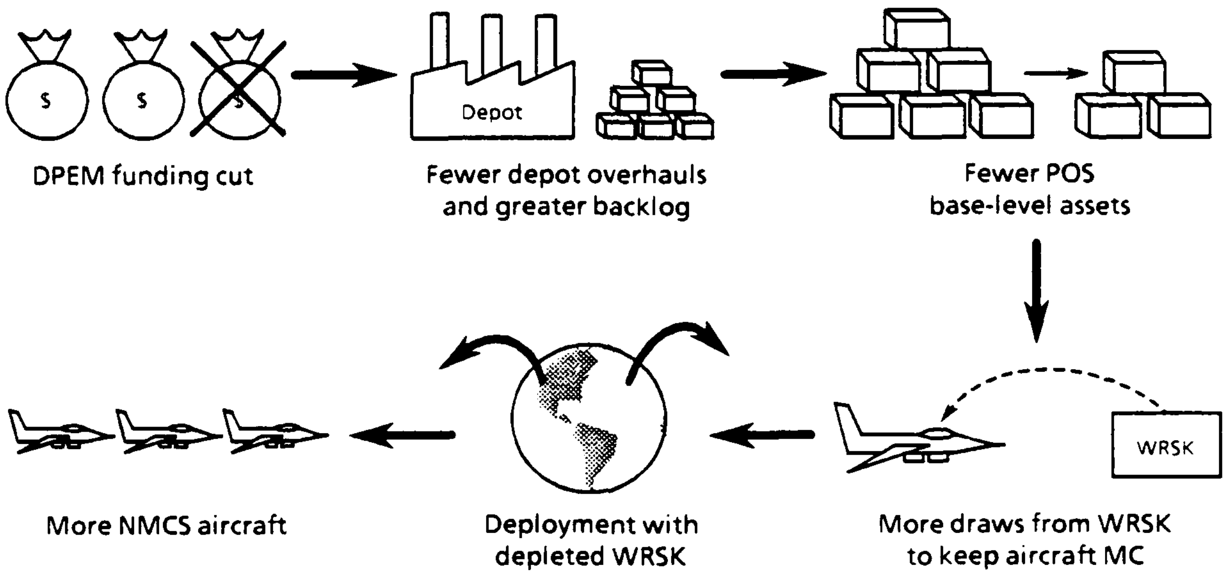


FIG. 3-1. LINKAGE BETWEEN DEPOT PURCHASED EQUIPMENT MAINTENANCE AND SUSTAINABILITY

TABLE 3-1

READINESS AND SUSTAINABILITY IMPACTS COMBAT SUPPORT MANAGEMENT SYSTEM AUTHORIZED KITS

(F-16A results)

Exchangeables' dollar reduction	Peacetime aircraft availability rates	Expected sorties over 30 days	Percent requirement	Sorties lost
None	0.96	1,153	99	-
20%	0.96	1,061	92	92
30%	0.82	1,044	90	109
40%	0.56	968	84	185
Total sortie requirement: 1,156				

[4]Karen Isaacson, et al, *Dyna-METRIC Version 4*, The RAND Corporation, Report R-3389-AF, 1988.

TABLE 3-2

READINESS AND SUSTAINABILITY IMPACTS
COMBAT SUPPORT MANAGEMENT SYSTEM AUTHORIZED KITS

(F-111D results)

Exchangeables' dollar reduction	Peacetime aircraft availability rates	Expected sorties over 30 days	Percent requirement	Sorties lost
None	0.99	1,369	99	-
20%	0.99	862	63	507
30%	0.86	625	45	744
40%	0.14	419	30	950
Total sortie requirement: 1,376				

The issue here is not the precise values in Tables 3-1 and 3-2[5] but the general sensitivity displayed. Even with significant cuts in maintenance funding, peacetime rates could be maintained. The price paid in sustainability in the F-16A case was not large although the F-111D, intrinsically harder to support, does suffer. Since the analysis did not include the effect of other types of workarounds, presumably the effect could be reduced further.

In essence, actual experience in FY88 supported the analysis. As we see in Chapter 4, exchangeables' repair decreased by 25 percent, which would have approximately the same effect as a 2-year 12½ percent cut in our analysis. MC rates remained high throughout the Air Force as we would expect, and the major commands reported concerns over increased drawdowns of WRSK.

We are not making claims of perfect predictions for this approach. Precise mathematical validation would be of little value since so many other factors are involved: deliveries from the "rich" procurement of 1985 and previous years increased the total inventory by over $4 billion, authorized WRSK was downsized in many cases to reflect lessons learned in the CORONET WARRIOR WRSK fly-out exercises, and so on. The analysis, however, indicates the resiliency of the Air Force to depot maintenance cuts as well as the pitfalls involved in looking only at single

[5]In fact, the 40 percent cut does not leave enough peacetime capability to deploy the full squadron and is thus beyond the range of validity.

indicators such as peacetime MC rates to determine the results of funding actions. Most important, it shows the need for an integrated requirements computation. Interaction between peacetime stocks and wartime stocks are important and should be explicitly considered in Air Force procurement and repair computations.

CHAPTER 4

SOME EFFECTS OF THE FY88 DEP/REP/MOD FUNDING CUT

DEP/REP/MOD funding dropped from an all-time high of $3.56 billion in FY85 to $2.92 billion in FY88. That decline amounted to a return to the funding levels of the early 1980s (see Table 4-1). As we see, the use of the term "cut" is something of a misnomer as the FY88 level was actually slightly above that of FY87 and not far below FY86 funding. The crucial point – the cause for concern – was the fact that the projected requirement was so much higher than the funding. As FY88 began, Air Force estimates of DEP/REP/MOD backlogs, defined as the difference between the projected requirement (including carryover from prior years) and DEP/REP/MOD funding, were on the order of $800 million for FY88. Backlogs were projected to total $1.5 billion through FY89.

TABLE 4-1

DEP/REP/MOD OBLIGATIONS

(Millions of dollars)

FY80	FY81	FY82	FY83	FY84	FY85	FY86	FY87	FY88	FY89
2,012	2,530	2,813	3,237	3,433	3,563	3,143	2,875	2,921	3,158

Source: *AFLC Command Information Digest*, 31 December 1989

To gauge the effects of the cut, we examine depot maintenance performance from several perspectives. (Naturally, we cannot claim that the shortfall in depot maintenance funds was the sole cause of all changes we observe.) We first look at maintenance outputs, focusing on production of exchangeables, programmed depot maintenance (PDM), and engines. In the second section, we study the impact on the supply system, using depot fill rates and wholesale backorders. Next, we focus on operational effects, examining MC rates, not mission capable–supply (NMCS) rates, and partially mission capable–supply (PMCS) rates. In the fourth section, we examine some of the means used to cope with the depot repair funding cuts, focusing on asset levels, the use of WRSK assets, and cannibalization Finally, we discuss how the Air Force maintained readiness in FY88 in the face of reduced depot maintenance funding.

MAINTENANCE OUTPUTS

The bulk of DEP/REP/MOD activity is in three areas: production of exchangeables, PDM (airframes and modifications), and engine overhauls. Exchangeables constitute about 55 percent of DEP/REP/MOD expenditures, programmed aircraft maintenance and modifications constitute approximately 25 percent, and engine overhauls are roughly 10 percent. We examine production levels for each category over the past several years.

Table 4-2 displays organic (noncontractor) exchangeables production by fiscal year. While production was fairly stable during FY84 through FY87, a 25 percent drop in production occurred from FY87 through FY88. Total exchangeables' revenue for DMIF (contract and organic) decreased from $2.096 billion in FY87 to $1.879 billion in FY88, suggesting an overall drop in production of just over 10 percent.

TABLE 4-2

ORGANIC EXCHANGEABLES' PRODUCTION

(Thousands)

FY78	FY79	FY80	FY81	FY82	FY83	FY84	FY85	FY86	FY87	FY88	FY89
1,088	1,030	1,195	1,163	1,192	1,202	1,093	1,082	1,116	1,115	837	784

Source: AFLC Command Information Digest, 31 December 1989.

Organic production of PDM and modifications of aircraft declined 19 percent from FY86 to FY87 and an additional 17 percent from FY87 to FY88. Table 4-3 displays organic production of PDM and modifications by fiscal year. In addition to the absolute drop, PDM work packages were downsized in reaction to the cut in funds. For instance, Strategic Air Command (SAC) B-52s were not painted unless the Air Force found specific evidence of corrosion. Contract and interservice PDM decreased from a production of 584 units in FY87 to 419 in FY88.

TABLE 4-3

ORGANIC PROGRAMMED DEPOT MAINTENANCE/MODIFICATION PRODUCTION

(Aircraft)

FY79	FY80	FY81	FY82	FY83	FY84	FY85	FY86	FY87	FY88	FY89
1,235	1,205	1,134	1,123	1,152	1,166	1,322	1,322	1,066	883	989

Source: *AFLC Command Information Digest*, 31 December 1989

Overhauls of engines and engine modules do not exhibit a clear trend over the past several years (see Table 4-4). Roughly 1,500 engine overhauls a year have been performed at Oklahoma City ALC over the past 10 years, with a pronounced peak in FY86. Engine overhauls at San Antonio ALC have dropped from 1,332 in FY83 to 640 in FY88, but that drop reflects the transition from whole engines to engine modules. Engine module overhauls were running at about 4,500 to 5,000 a year from FY84 through FY88. Sources at the depots have said, however, that they are "doing more B jobs"; that is, they are doing the easier overhauls and deferring the more difficult ones.

TABLE 4-4

DEPOT-LEVEL ENGINE PRODUCTION

(Organic and contract/interservice)

ALC	FY79	FY80	FY81	FY82	FY83	FY84	FY85	FY86	FY87[a]	FY88	FY89
Oklahoma City											
Engines	1,591	1,542	1,453	1,549	1,529	1,506	1,500	1,892	1,420	1,480	1,338
San Antonio											
Engines	1,761	1,843	1,835	1,851	1,711	1,317	1,332	973	576	640	747
Modules	1,111	1,293	2,987	3,124	3,843	4,465	4,851	5,124	4,028	5,373	2,574

Source: *AFLC Command Information Digest*, 31 December 1989

[a] Data for FY87 were incomplete.

So we see that depot production of exchangeables, PDM, and modifications did indeed decline during FY88. In overhauls of engines and engine modules, the depots have shifted toward performing the easier overhauls at the expense of more difficult ones.

Our emphasis in this report is on the effect of depot maintenance on aircraft readiness and sustainability, but we must at least mention the internal difficulties depot management experienced as a result of the funding cut. Although management avoided furloughing skilled personnel, the work force did decrease because of early-out programs and the release of temporary, on-call labor. AFLC-directed fencing of funds led to unavoidable mismatches between funded workload and available skills at the depots. While the purpose of depot maintenance funding is to support aircraft rather than make the job of depot managers easy, the need to train and maintain a skilled work force is a real one. The depots appear to have weathered the storm this time but cannot be expected to operate under such great funding instability in the future.

SUPPLY INDICATORS

Supply indicators show increasingly poor performance through FY88 and early FY89. Table 4-5 displays depot fill rates, the percentage of requests for spares that is filled on demand during some time interval. In FY82 through FY84, the introduction of the D028 Central Leveling System[1] generally increased base levels and pushed assets out to the bases and was largely responsible for a decline in depot fill rates from roughly 70 percent to 55 percent. This shifting of assets was not an indication of trouble in the supply system but was in fact a more efficient way to set base and depot levels. Depot fill rates declined in FY88 and continued to do so in FY89, presumably as a result of decreased exchangeables' production. Fill rates for the first 8 months of FY89 ranged from a low of 20 percent to a high of 31 percent. The average for the period was 25.6 percent, roughly half of what it was less than 2 years earlier (see Table 4-5).

Wholesale backorders are outstanding unfilled requests for parts from the depots at a point in time. A decline in backorders between the end of one period and the end of the next indicates that the depot is reducing unfilled requests (at least

[1]Christopher H. Hanks and Robert C. Kline, *Assets vs. Requirements: Why Asset-Based Central Leveling is a Good Idea*. LMI Report AF601R4, August 1987.

TABLE 4-5

DEPOT FILL RATE

(Percent)

FY79	FY80	FY81	FY82	FY83	FY84	FY85	FY86	FY87	FY88	FY89
69.0	70.4	71.0	70.6	63.3	54.7	55.0	49.7	47.9	39.0	24.2

Source: *AFLC Command Information Digest*, 31 December 1989

temporarily). Successive decreases in backorders over several time periods are a better indicator of improved supply system performance. On the other hand, sustained increases in backorders are a sign that the supply system is falling farther behind in filling requests.

Backorders for exchangeables increased by 31 percent from the end of FY87 to the end of FY88, improving somewhat in FY89 (see Table 4-6).

TABLE 4-6

END-OF-YEAR DEPOT BACKORDERS FOR EXCHANGEABLES

(Items in thousands)

FY79	FY80	FY81	FY82	FY83	FY84	FY85	FY86	FY87	FY88	FY89
84.5	95.4	100.8	118.5	155.8	189.3	212.4	275.8	279.7	365.9	348.8

Source: *AFLC Command Information Digest*, 31 December 1989

Declining depot fill rates and increasing wholesale backorders indicate that the supply system has been stressed and reflect the decreased production of serviceable assets from depot maintenance. Both measures, however, focus on a level of the supply system one echelon above the bases. They do not tell us the extent to which aircraft readiness has been hurt. We examine those indicators in the following sections.

OPERATIONAL INDICATORS

Readiness, averaging across all aircraft types, remained at roughly the same level, despite the maintenance funding shortfall. In fact, Air Force-wide MC rates –

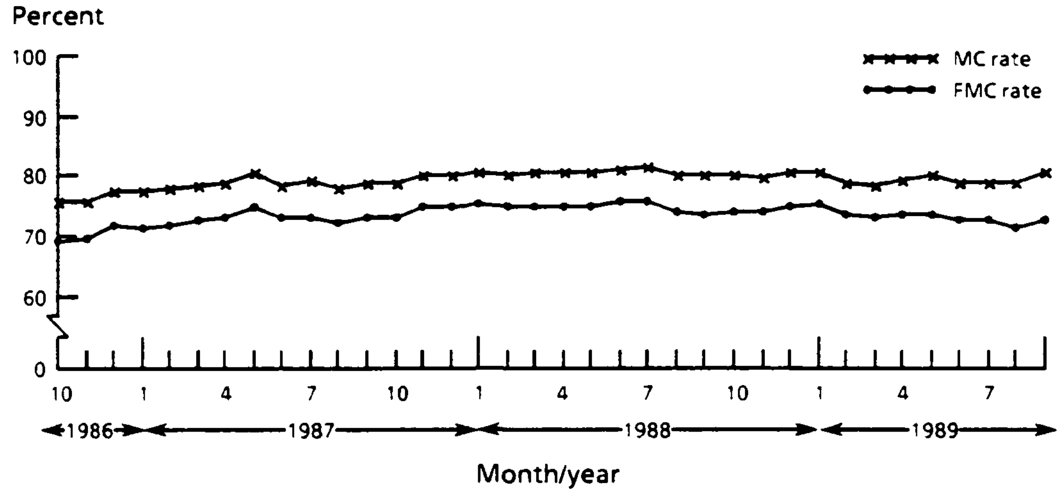
the proportion of aircraft that can fly at least one of their missions – rose from 79 percent to 81 percent between October 1987 and September 1989 (see Figure 4-1). Air Force-wide fully mission capable (FMC) rates – the proportion of aircraft that can fly all of their missions – began and ended the period at 73 percent.

Parts shortages did have a slight negative effect on readiness Air Force-wide (PMCS and NMCS rates were up), but it was canceled out by a decline in not mission capable–maintenance (NMCM) rates, reflecting improved base maintenance. PMCS rates increased from 2.3 percent at the outset of FY88 to 3.4 percent near the end of FY89. Over the same period, NMCS rates increased from 3.5 percent to 4.4 percent and NMCM rates dropped from 14 percent to 11 percent (see Figure 4-2).

The readiness of individual weapon systems varied. Although Air Force-wide FMC rates stayed up in FY88 through FY89, the high rate does not reflect steady levels of readiness for all aircraft types. Between October 1987 and September 1989, FMC rates declined from 77 percent to 58 percent for the B-52 aircraft, declined from 52 percent to 46 percent for C-5 aircraft, and declined from 86 percent to 81 percent for F-16 aircraft. For the F-15, the FMC rate declined from a high of 77 percent in early FY88 (following an increase in FY87) to 73 percent at the end of FY89 (see Figures 4-3 and 4-4).

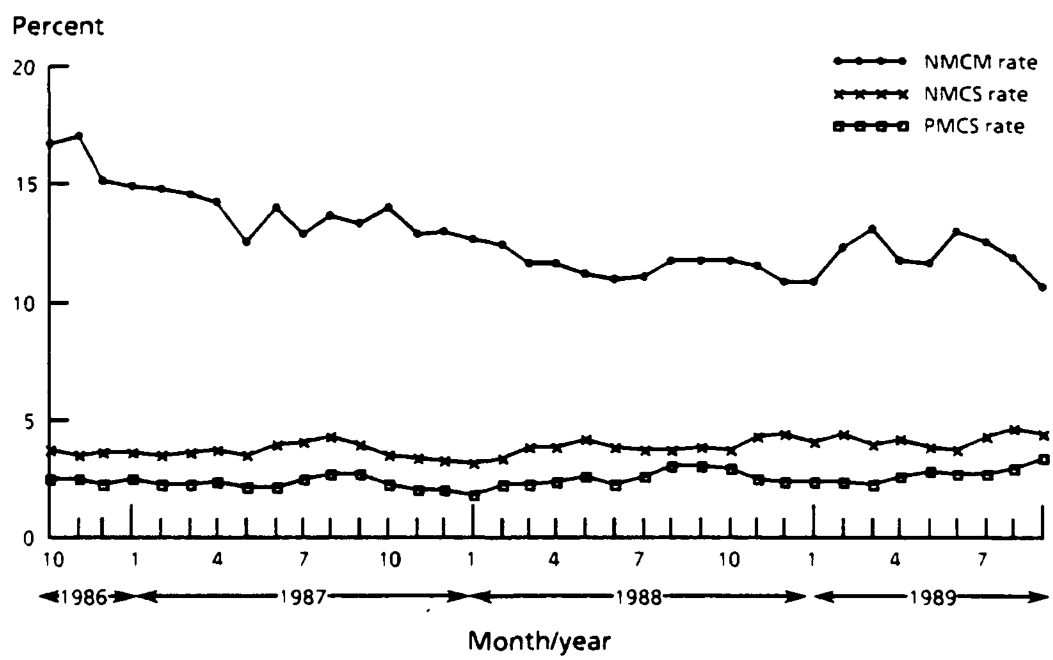
Thus, some aircraft were less ready for some of their missions at the end of FY89 than they were at the start of FY88 and supply problems were partly responsible. PMCS rates increased for all aircraft except the F-16, which exhibited no clear trend (see Figures 4-5 through 4-8). The fact that Air Force-wide FMC rates stayed up means that FMC rates increased for some aircraft types. As one would expect, parts shortages have affected some types of aircraft more than others.

Although DEP/REP/MOD funding for FY88 was short of the stated requirement, the supply and repair system was flexible enough to minimize any decline in readiness. In fact, if we limit consideration to MC and NMCS rates, the typical month-to-month variations mask any trend that declined depot production might have caused.



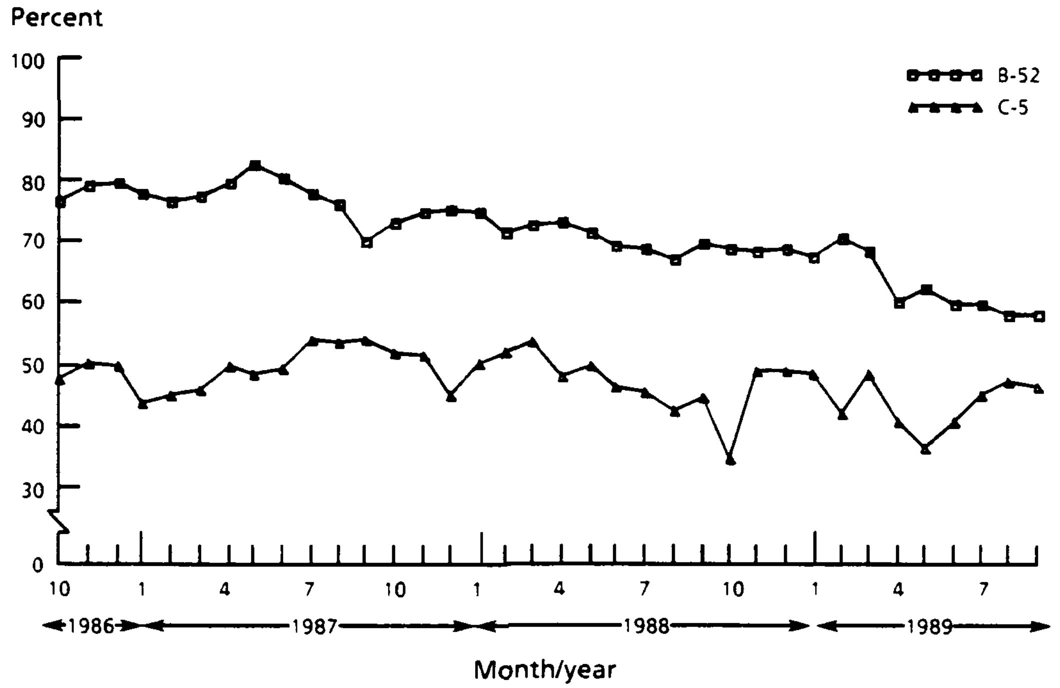
Source: Weapon System Management Information System (WSMIS), July – November 1989.
Note: Includes A-10, B-52, C-5, C-130, C-135, C-141, E-3, E-4, F-4, F-15, F-16, F-111, T-37, and T-38 aircraft.

FIG. 4-1. MISSION CAPABLE RATES



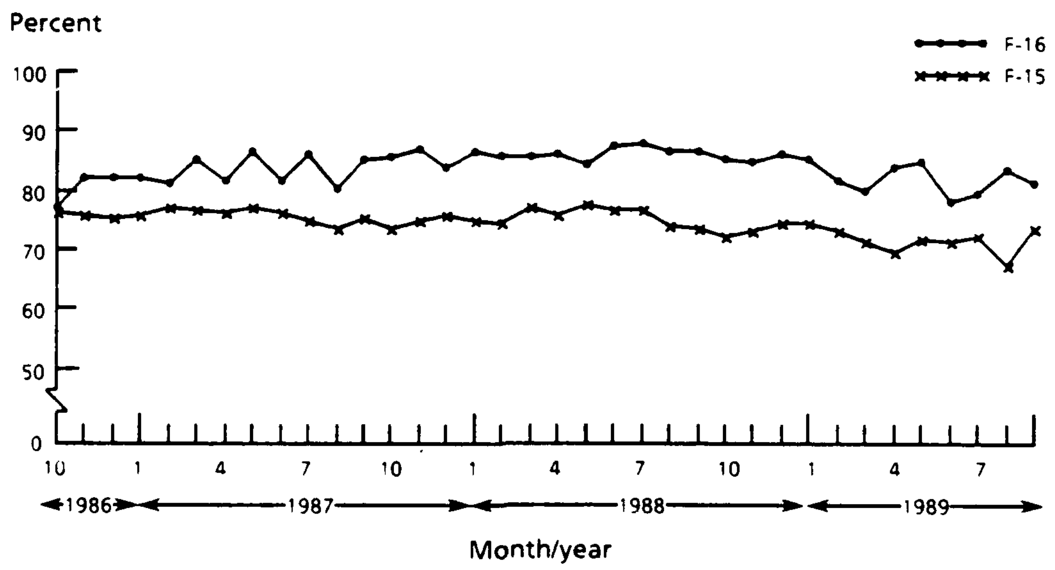
Source: Weapon System Management Information System (WSMIS), July – November 1989.
Note: Includes A-10, B-52, C-5, C-130, C-135, C-141, E-3, E-4, F-4, F-15, F-16, F-111, T-37, and T-38 aircraft

FIG. 4-2. NOT MISSION CAPABLE AND PARTIALLY MISSION CAPABLE RATES



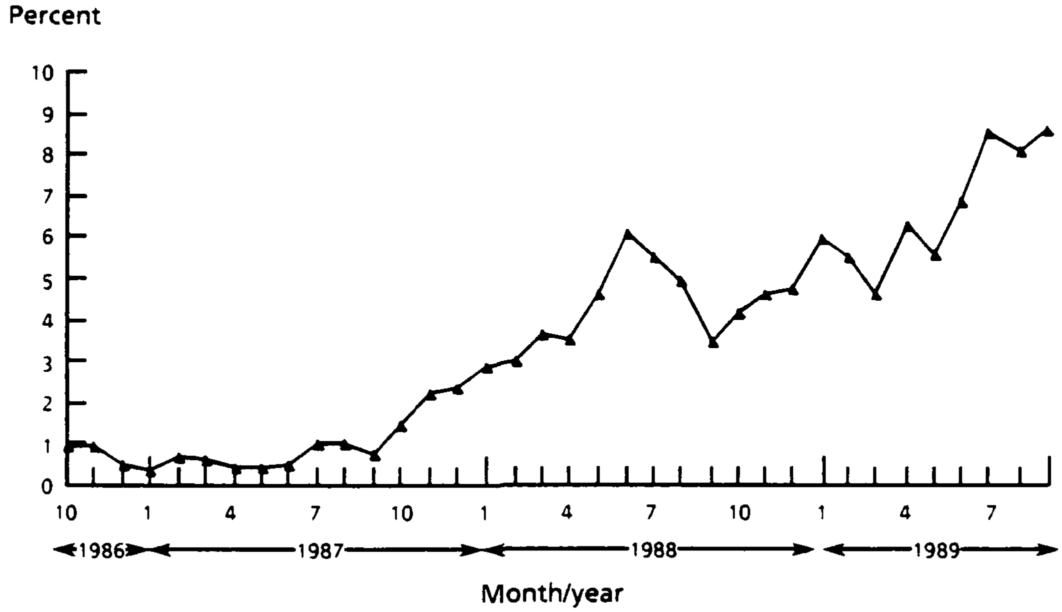
Source: Weapon System Management Information System (WSMIS), July – November 1989

FIG. 4-3. FULLY MISSION CAPABLE RATES: B-52 AND C-5



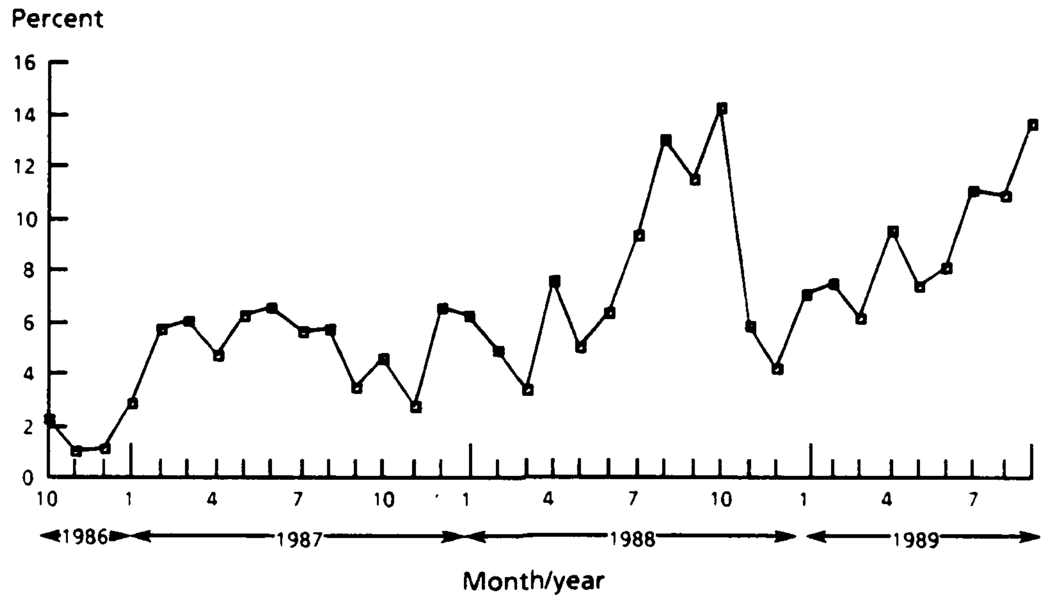
Source: Weapon System Management Information System (WSMIS), July – November 1989

FIG. 4-4. FULLY MISSION CAPABLE RATES: F-16 AND F-15



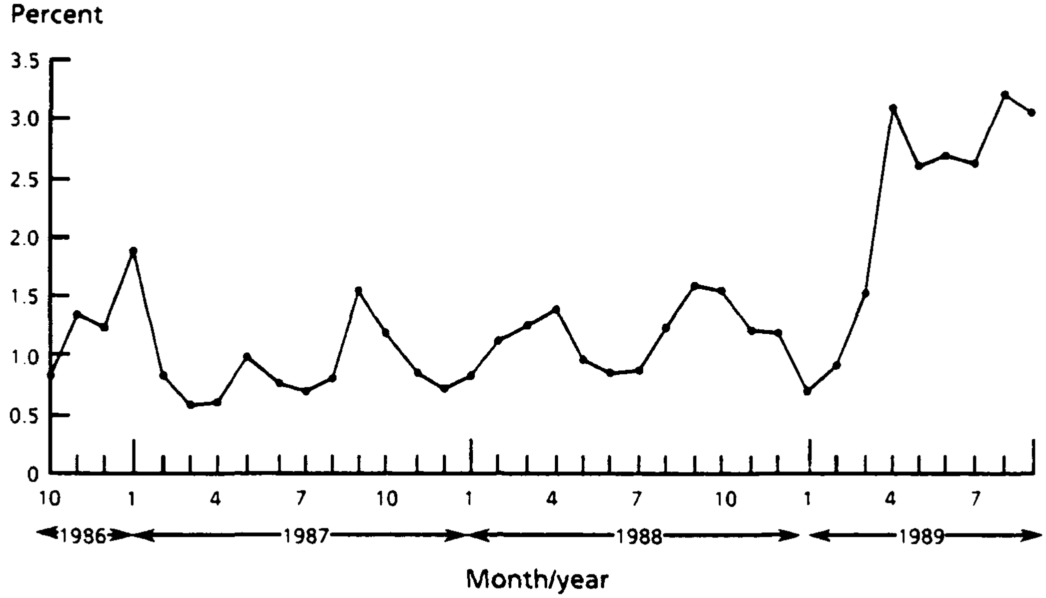
Source: Weapon System Management Information System (WSMIS), July – November 1989.

FIG. 4-5. PARTIALLY MISSION CAPABLE RATES: B-52



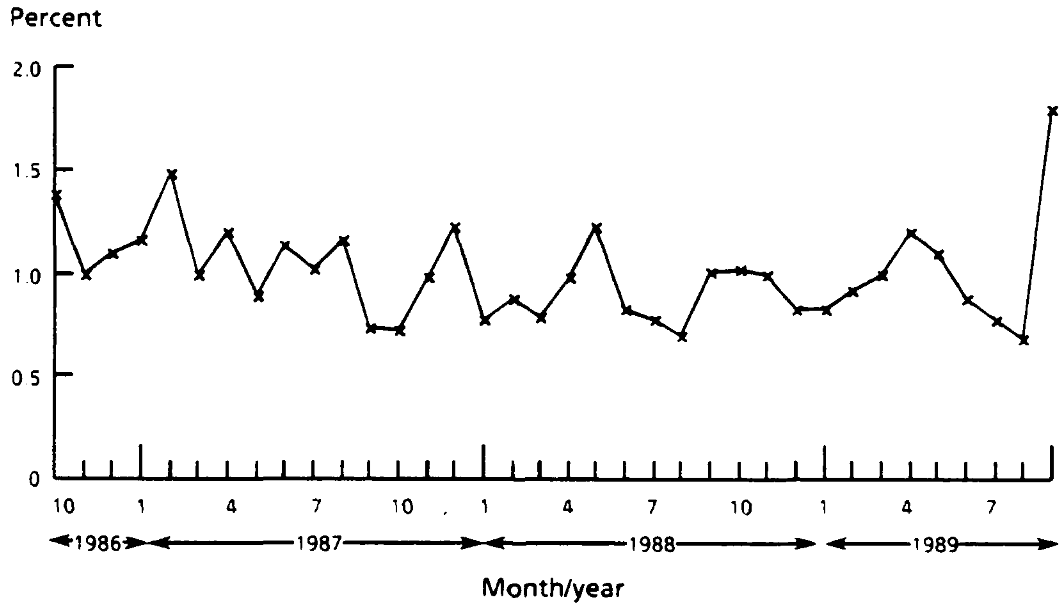
Source: Weapon System Management Information System (WSMIS), July – November 1989.

FIG. 4-6. PARTIALLY MISSION CAPABLE RATES: C-5



Source: Weapon System Management Information System (WSMIS), July – November 1989

FIG. 4-7. PARTIALLY MISSION CAPABLE RATES: F-15



Source: Weapon System Management Information System (WSMIS), July – November 1989

FIG. 4-8. PARTIALLY MISSION CAPABLE RATES: F-16

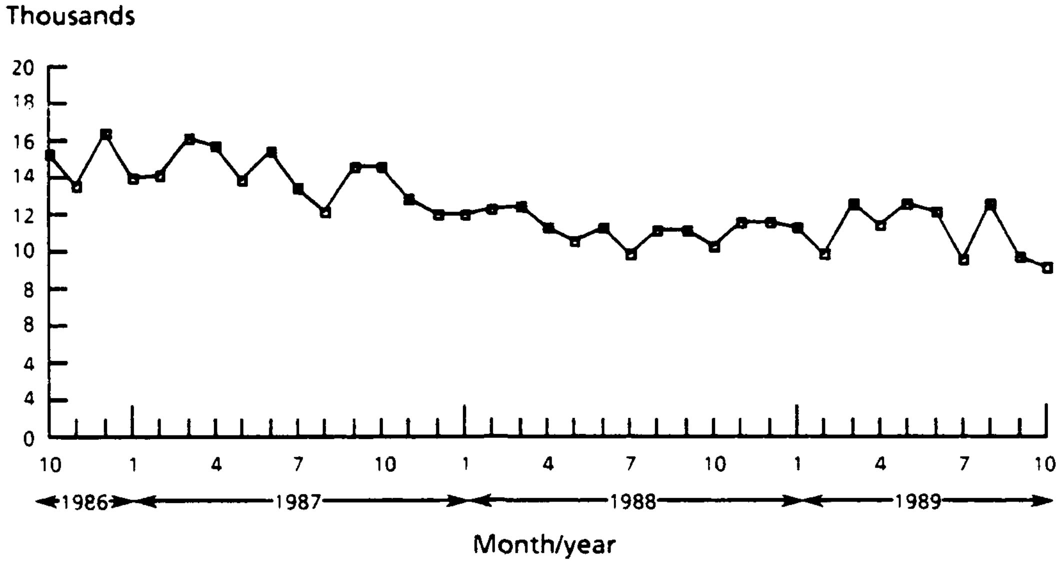
HOW READINESS WAS MAINTAINED

Why did the level of readiness stay up? One major reason was ample spares procurement funding through FY85. While the depots repaired only 75 percent as much in FY88 as in FY87, the total reparable spares inventory increased from $29.7 billion to $34.0 billion during FY88. As shortages of depot repair funds drained serviceable spares from inventories, assets arriving from prior procurement filled the gap. Of course, not all of these previously procured items were precisely the ones needed in FY88 and FY89. Base maintenance also utilized "workarounds" and sources of parts other than POS to maintain readiness. Other sources most frequently used were the WRSK, cannibalization, and lateral resupply.

If POS lacks a part needed to fix an NMCS or PMCS aircraft, base maintenance may use a part from the WRSK instead. Accordingly, our analysis outlined in the previous chapter predicted that one effect of the DEP/REP/MOD funding cut would likely be increased War Reserve Materiel (WRM) withdrawals.

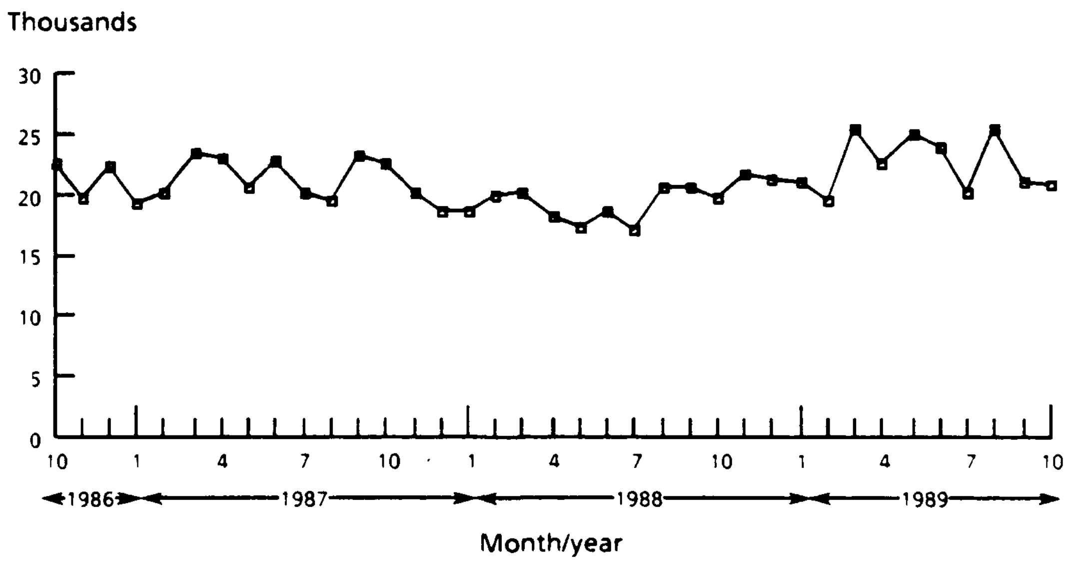
In fact, the number of WRM withdrawals to resolve MICAP incidents (requisitions on supply for conditions that affect *mi*ssion *cap*ability) declined from 14,564 in October 1987 to 9,118 in October 1989, a drop of 37 percent (see Figures 4-9 and 4-10). The decline in WRM withdrawals makes sense, however, once one realizes that the kits were already short or out of some items, as evidenced by the steady increase in cannibalization. Tactical Air Command (TAC) sources have confirmed that their increasing reliance on cannibalization was due to insufficient POS and WRSK supplies of some items. TAC also informed us that in some cases assets were in such short supply that replacements meant to replenish WRSK never got back into the kit because by the time the asset was received on base, another MICAP aircraft needed it. Rather than replacing the item in the WRSK and then drawing it, the asset was applied directly to the aircraft MICAP. The serviceables were needed so urgently that they were never cycled back to be counted again as a WRSK withdrawal. Nonetheless, the effective level of WRSK assets was drawn down.

Cannibalizations (to preclude MICAP incidents as well as to resolve existing incidents) increased by 68 percent between October 1987 and October 1989, rising from 3,156 to 5,309 (see Figure 4-11). Cannibalizations to resolve existing MICAP incidents have more than doubled, rising from 1,796 in October 1987 to 3,879 in October 1989.



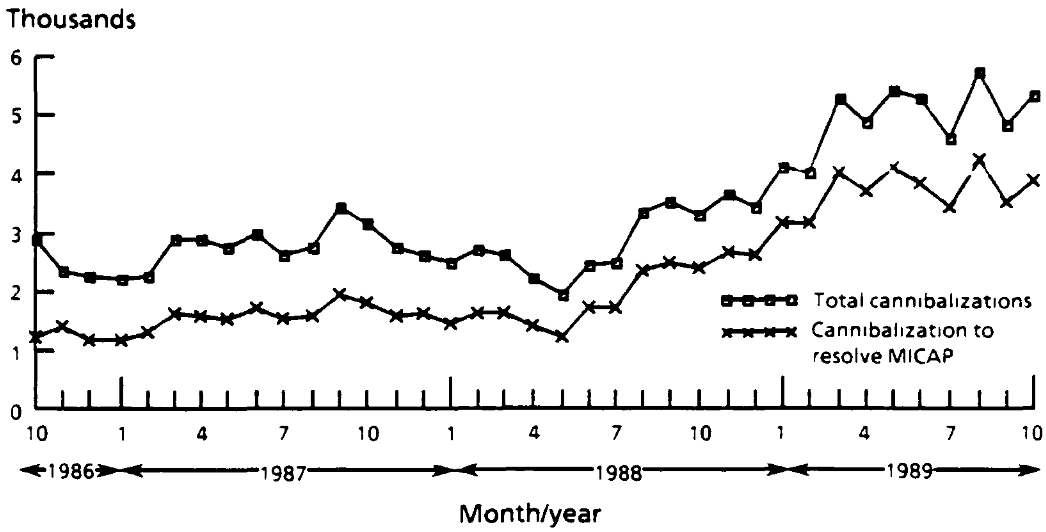
Source: Weapon System Management Information System (WSMIS), July – November 1989

FIG. 4-9. NUMBER OF MICAP INCIDENTS RESOLVED WITH WRM ASSETS



Source: Weapon System Management Information System (WSMIS), July – November 1989

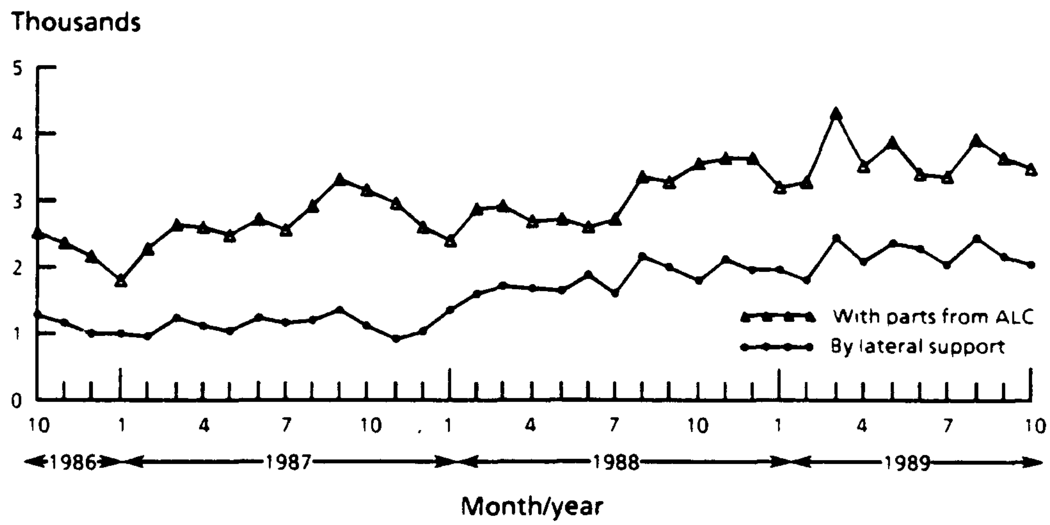
FIG. 4-10. TOTAL NUMBER OF MICAP INCIDENTS RESOLVED



Source: Weapon System Management Information System (WSMIS), July – November 1989.

FIG. 4-11. CANNIBALIZATIONS

Cannibalization was not the only workaround that made up for the shortfall in POS and WRSK stocks of certain items. MICAP incidents resolved by lateral resupply rose from 1,132 to 2,039 over the same period, reflecting increased efforts to better allocate scarce supplies at the base level (see Figure 4-12).



Source: Weapon System Management Information System (WSMIS), July – November 1989

FIG. 4-12. NUMBER OF MICAP INCIDENTS RESOLVED

CHAPTER 5

CONCLUSIONS

Despite grave forecasts of large maintenance backlogs and resulting declines in readiness in FY88, actual experiences were quite different. Aircraft readiness declined slightly, and the backlog at the conclusion of FY88, double-checked and verified by the ALCs, was closer to $200 million than the forecasted $818 million. It is tempting, but incorrect, to conclude from these observations that the requirement was overstated and that depot maintenance has little effect on aircraft readiness and sustainability.

As we showed in Chapter 2, estimates of component returns to the depot were overstated. The fact that only 970,000 components failed and were returned to the depot in FY88 rather than the 1,160,000 that had been projected a year earlier certainly contributed to the drop in the backlog estimate. Much of the drop, however, was due to specific, conscious efforts by the Air Force in reaction to the fiscal situation. Some aircraft modification programs were moved to the major commands and performed with base-level resources. Base-level maintenance judgment as to whether to repair on site or at a depot tilted toward base level. PDM packages were downsized, and overhaul life limits on selected engine components were extended. The F-4C phaseout was accelerated, eliminating those related maintenance requirements. Programs were deferred or canceled. The backlog did not shrink by itself; the Air Force made it shrink by re-evaluating the necessity and desirability of the maintenance actions and programs originally planned.

Base-level maintenance and workarounds took up the slack left by reduced depot production to essentially maintain readiness. They continue to do so today.

These events, and earlier Air Force experiences with changing forecasts for both spares procurement and repair requirements, have serious implications for how the Air Force should develop and justify those requirements. The requirement can and should be based on aircraft readiness and sustainability as measured by tools like the Aircraft Availability Model (AAM) and Distribution and Repair in a Variable Environment (DRIVE). The Air Force, in fact, is committed to this course and it is a correct one. We must recognize, however, that a substantial part of the requirement will be composed of additive programs and special, nonrecurring requirements. The statistical models in use and under development today do not account for the effect of such additives; determining their validity and priority unavoidably requires management judgments.

While we cannot mechanize the *decision* process involved in validating additive requirements, it is certainly desirable to automate the collection of current decisions to aid in managing and resetting priorities as circumstances change and the requirement and available funding evolve. Judgments on programmatic requirements, content of overhaul work packages, and so on, are valuable management levers, but we have no formal structure for exploring those avenues.

The issue of whether these models can be used, i.e., incorporated in the CSIS framework, for long-term budget forecasts is another matter entirely. Air Force experience with the D041 Variable Safety Level model (the predecessor to the AAM) to forecast procurement and repair budget requirements through the 1980s shows that the process is subject to great instability.[1]

The AAM and DRIVE models are not solutions to the problem. Although they determine better mixes of spares for procurement and repair, they are based on item demand rates that are intrinsically difficult to forecast over the long term and do not account for volatility in the additive portion of the requirement. Using the AAM or DRIVE model *this* year to estimate what they will say *next* year does not work.

We believe that the attempt to forecast budget requirements by aggregating bottom-up item requirements is unworkable. Further, the seeming precision of the current bottom-up CSIS process invites micromanagement by Congress.

The proper role of such statistical inventory models as the AAM and DRIVE or the integrated approach outlined in Chapter 3 in budget forecasting is to provide insight, not answers. They can provide information on trends in the supply and maintenance system and provide valuable insights into the possible effects of changes in funding levels or system operations. The CSIS furnishes valuable information for projected budget years; we just should be wary of confusing it with the truth. Improvements in long-term demand forecasting (e.g., removing the bias in

[1]Christopher H Hanks, *Can the Air Force Solve Its Spares Forecasting Problem?*, LMI Report AF501R3, September 1986.

estimates of returns to the depot) are valuable to improve insights. In fact, a policy of continuous process improvement should be adopted, but we should not expect it to ever reach perfection.

Granting that bottom-up item-specific budget requirements estimates will always be subject to instability, it follows that the Air Force needs to develop more-stable aggregate methods to estimate budget requirements and the Air Force needs to develop management structures and processes to manage to targeted levels. Use of the AAM allows the Air Force to adjust its execution of the demand-based portion of the requirement to meet available funding levels; DRIVE will provide the same capability for depot repair. The Air Force still needs similar mechanisms to manage and establish priorities for the additive portion. Many of the necessary management structures were identified in the CORONA REQUIRE report; logistics systems now under development, particularly the Requirements Data Bank (RDB) and WSMIS, were guided to some extent by the conclusions of CORONA REQUIRE. In particular, the RDB will provide Air Force managers with near-real-time information on how the budget is being executed and enable them to make mid-course changes much more easily and more confidently than before. (The results of the mid-year D041 computation providing such information today will not available until the last quarter of the fiscal year.) This timely picture of the constantly changing requirement can be extremely valuable to AFLC and ALC managers; it can also be extremely confusing and cause more erosion of credibility if it is incorporated too literally into the budgeting process.

Stock funding depot-level reparables, now under way, will reduce the budget leadtime and remove spares procurement requirements from the scrutiny of an appropriated account. However, funds will need to be appropriated to the O&M account to buy spares from the stock fund, and stock fund obligational authority will be subject to comptroller review and approval. The problem of budget forecasting may change but it will not vanish.

We recommend that the Air Force revisit the CORONA REQUIRE study. Many years have passed since its completion; while the basic guidance of the study is still valid, the environment has changed and so have management personnel. The Air Force needs to ensure that it has not lost sight of the CORONA REQUIRE recommendations and needs to expand the application of the study to depot maintenance as well as procurement. The study should address the new procedures necessitated by stock funding and the new capabilities provided by the ongoing modernization of Air Force logistics system.

The agenda for "CORONA REQUIRE II" would focus on the development of a requirements *process* that recognizes the innate variability and judgmental quality of the requirement and provides the necessary levers for effective management control. Some of these management tools are already in place or are being developed. The task then is to integrate them into the process and ensure that management procedures are in place to take advantage of them.

The core of the process should be an integrated item requirement computation, which calculates wartime and peacetime repair and procurement requirements to meet specified readiness and sustainability goals. It should include an aggregate long-term forecasting model for POM and budget funding requirements. Conceivably, a budget-forecasting model might operate on the item-specific forecast with an overall adjustment to allow for churn. However, churn must be better understood before such a model can be developed. Is churn relatively constant over time? Does churn change predictably over a weapon system's life cycle? How much of churn is controllable and how much of it is purely statistical nonstationarity? The most important thing to note about the forecasting model is that *it need not, in deed can not*, forecast precisely what the requirement will be several years in the future. It is only the first step in a forecasting *and* management process; it need only estimate close enough to the "true" requirement that the Air Force can manage to that estimate.

Whatever the accuracy of the forecasting model, the Air Force needs feedback as time passes and item estimates become definitized. To guide execution, the Air Force is implementing DRIVE to establish priorities for inductions and to track expenditures, and a performance measurement system to identify bottlenecks, inadequate supply support, or other impediments to productivity. The process also needs to consider additive requirements in the prioritization scheme and coordination with the evolving financial controls for the DLR stock fund.

An effective decision support system is the key to bridging the gap between programming, budgeting, and execution. Such a system should be sensitive enough to respond to significant change but not so sensitive that it will be overwhelmed by random noise in the estimates. Just as models such as DRIVE or the AAM can establish priorities for individual item buys or repairs, the decision support system must be able to help Air Force managers set priorities for additive and programmatic requirements and examine the effects of alternative funding levels, force strength, and flying-hour programs.

The current "process" has no memory; it has no formal mechanisms to provide stability in the evolving estimates of a particular year's requirement. Serious attention must be paid to finding workable and credible budgeting methods that are more aggregate in nature, with CSIS output being a factor rather than the final result. The Air Force must ensure that the logistics systems now being developed will provide the management tools to prioritize and control requirements to provide stability in programming and budgeting without jeopardizing the support of the forces.

APPENDIX A

THE EFFECT ON AIRCRAFT READINESS AND SUSTAINABILITY OF DEPOT MAINTENANCE FUNDING[1]

SUMMARY

In the fall of 1987, the Air Force was faced with large cuts in Depot Purchased Equipment Maintenance (DPEM) appropriations, which support depot overhaul of airframes and engines, component repair, and other maintenance activities. Recent Program Objective Memorandum (POM) estimates of DPEM requirements have been overstated compared to actual obligations, and that overstating diminishes confidence in the requirements estimation process. Contributing to this crisis of confidence is the observation that previous cuts in DPEM funding have had no discernible effect on peacetime readiness as measured by mission capable (MC) rates. Consequently, the Air Force wishes to quantify the effects of the cuts in DPEM appropriations on peacetime readiness and on wartime sustainability. In this report, we provide preliminary information on that issue.

In the event of a shortage of serviceable spare parts, the maintenance and repair personnel of an Air Force squadron have the option of withdrawing the needed parts from its War Readiness Spares Kit (WRSK). When a part is withdrawn from the WRSK, it is used to support peacetime operations and the WRSK is not fully capable of serving its intended purpose – at least until a like part in serviceable condition is returned to it. In this case, peacetime MC rates do not decrease, but wartime sustainability does because of the withdrawal of the asset.

When DPEM appropriations are cut below the level required to maintain serviceable spares to assure desired MC rates, we expect to see more frequent withdrawals from WRSKs. The use of WRSK assets during peacetime effectively increases the peacetime operating stock (POS) asset position. In the short term, the increasing use of WRSK assets offsets the lack of money to repair enough parts to maintain peacetime MC rates, but does so at the cost of wartime sustainability. We

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[1]This appendix is taken in its entirety from Richard C. Scalzo, *The Effect on Aircraft Readiness and Sustainability of Depot Maintenance Funding*, LMI Report AF801TR1, October 1988.

found that while cuts in DPEM funding of between 15 percent to 20 percent may not result in a discernible change in peacetime MC rates, they may create severe problems during wartime.

BACKGROUND

An important factor influencing the cuts in DPEM funding appropriations is shown in Table A-1, a listing of Direct Air Force (DAF) funding and DAF obligations. DAF funding is that portion of DPEM that is used to support the day-to-day operations of the Air Force. The fact that the POM estimates, which are projected early in the program and budget cycle, have recently greatly exceeded the actual dollars obligated has raised questions about the requirements process underlying the budget estimates. The POM overestimates combined with the observation that cutting DPEM funding levels has caused no noticeable decrease in MC rates in the past, clearly indicates that the effects of such cuts on readiness *and* sustainability must be assessed.

TABLE A-1

DAF REQUIREMENTS AND DAF OBLIGATIONS

PPBS[a] instrument	As of FY85 ($ millions)		As of FY86 ($ millions)	
POM	3,917	(5/83)	4,216	(5/84)
BES[b]	4,149	(9/83)	4,091	(9/84)
President's Budget	3,915	(1/84)	3,789	(1/85)
Actual obligation	3,395	(11/85)	3,177	(11/86)

[a] Planning, Programming, and Budgeting System

[b] Budget Estimate Submissions

The Air Force has had difficulty in using quantitative tools to link dollar requirements for DPEM exchangeables (the largest part of DPEM and the most sensitive to changes in funding) to measures of readiness and sustainability for, inter alia, the following reasons:

- No item-by-item model has been developed to account for the complicated interaction between DPEM appropriations and the cost of depot operations.

- Long-range projections of factors used in requirements computation, especially failure rates and DPEM backlog, are difficult to calculate.
- Existing models do not incorporate many of the subtleties of repair policy, especially when changes in repair priorities occur.

Considerable time elapses between the computation of requirements and the budget execution; this time lag combined with attempts to stabilize depot charges to customers means that DPEM obligations tend to underfund the true costs of depot operations. The connection between DPEM appropriations and the manner in which these funds are disbursed is not addressed in existing models. In addition, inflation projections made several years into the future have corresponded very poorly with actual inflation rates, and a model has no way of incorporating such misjudgments.

Time lags are not the only problem in determining DPEM requirements several years into the future. In addition, DPEM requirements are inherently unstable, primarily because of the difficulty in accurately projecting failure rates for 180,000 items over a 5-year period. Our experience has shown that overestimation of failure rates for as few as 50 high-cost items can cause a significant overstatement of the dollar value of provisioning requirements, as well as that of future repair requirements. If, on the other hand, an unanticipated increase in failure rate of an item occurs, the number of repairs experienced surges and the actual repairs needed for that component are larger than the predicted requirement.

Finally, existing models do not adequately account for the resiliency of the Air Force logistics system. As funding for spare parts, maintenance, and repair become tighter, the system reacts by increasing workarounds, such as base- and depot-level cannibalization, lateral supply, working hours for base-levei personnel, and the use of WRSK assets in peacetime.

This resiliency of Air Force logistics also contributes to the credibility crisis in the requirements process. It contributes to the controversy over the requirements process because people have seen DPEM funded at less than stated requirements with no corresponding decrease in the observed MC rates. The real questions, however, devolve to these

- How much of the DPEM dollar requirement is really needed?
- What level of workarounds is tolerable (especially WRSK withdrawals), for peacetime readiness and wartime sustainability?

This report describes a promising method for answering those questions.

APPROACH

When funding for spare parts for maintenance and repair becomes tight, the Air Force logistics system reacts. Since previous analyses performed with the LMI Aircraft Availability Model (AAM) have focused only on POS assets and peacetime readiness, they tended to overestimate the effects of reductions in DPEM funding by not considering the resiliency of the Air Force logistics system. Although we cannot address this resiliency comprehensively, we can consider the interplay between POS and war reserve stocks. In this analysis, we develop methods to quantify the effects of increased use of War Reserve Materiel (WRM) on peacetime readiness and wartime sustainability.

When maintenance and repair funding is reduced, the effect is felt sooner than that of a similar cut in procurement funding primarily because procurement lead-times are much longer than repair times. As the effects of the cuts are felt, a depot will be unable to repair all of the unserviceable assets returned to it from the bases, a larger fraction of POS assets will remain in an unserviceable condition and accumulate at the depots, and base POS serviceable asset levels will decrease. Thus, there will be an increased likelihood that components will fail and no serviceable POS spares will be available. The most appealing short-term solution to that problem is to use a spare from the squadron's WRSK. That solution has the immediate benefit of keeping the squadron MC rate up without incurring the problems associated with cannibalization. Using squadron WRSK assets has the apparent effect of enlarging the base's serviceable asset position. However, since the depot cannot now return enough POS assets for use, this results in a net increase in the average use of squadron WRSK assets. In case the increase in unserviceable POS assets does not exceed available WRSK assets, peacetime aircraft availability will not change. If, however, the increase in unserviceable POS assets exceeds available WRSK assets, peacetime aircraft availability will decrease. Thus, as far as peacetime operations are concerned, cuts in DPEM funding have no immediately discernible effect. In the event of war, however, squadrons will deploy with WRSKs that have been depleted to support peacetime operations and a squadron will be less able to meet its required wartime sortie schedule.

Our analysis considered a squadron of 24 F-16A aircraft and a squadron of 18 F-111D aircraft. We analyzed only items in the WRSK (by National Stock Numbers) and used logistics factors – failure rates, repair times, unit costs – from the Air Force reparable component requirement system, D041 (Recoverable Consumption Item Requirements System). We calculated an initial POS asset position using a version of the AAM. That asset position was chosen so that when the squadron's WRSK assets were added to it, the squadron availability rate approximated the observed MC rates for the aircraft type. Since in peacetime, even when DPEM is fully funded, both POS and WRSK assets are used to support flying activity, this calibrates our squadron availability to experienced spares support levels. When only part of the repair requirement is funded, fewer base-level POS serviceables are available, and since WRSK assets are used to maintain MC rates at desired levels, the level of serviceable assets in WRSK will decline.

We considered then the effects of DPEM cuts of 20 percent, 30 percent, and 40 percent over a 2-year period. We used an item-by-item estimate of depot reparables generated (i.e., failures requiring depot repair) over the 2-year period as a surrogate for the squadron's portion of the DPEM requirement.[2] Given 100 percent DPEM funding, the depot would overhaul all of these reparables and the POS asset position would remain unchanged. With, say, 80 percent depot overhaul funding, we repaired the candidate carcasses optimally in order of improvement in (peacetime) aircraft availability per dollar of repair cost until the funding was exhausted. Those unrepaired carcasses then represented a decrease in POS assets. The total pool of assets (POS and WRSK) gives an estimate of the asset position that will be experienced during peacetime when DPEM funding is limited.

At this point, the question remaining unanswered is how many serviceable assets can be expected to remain in the squadron's WRSK? Since we expect fewer WRSK assets to be in serviceable condition, we calculated the average number of WRSK assets in use to support peacetime operations for each reparable spare in the kit for each funding level under consideration. This allowed us to compute the expected number of serviceable spares for each reparable item in the kit.

[2]The DPEM requirement is computed on an aggregate, worldwide basis rather than squadron by squadron. For any given item, previously uninducted assets, nonrecurring requirements, and other special requirements can affect the overall requirement. We have adopted the one-for-one replacement requirement as a reasonably accurate simplification.

After computing the expected asset position of the WRSK after cuts in funding, we were in a position to evaluate the wartime sustainability of the kit using the Dynamic Multi-Echelon Technique for Recoverable Item Control (Dyna-METRIC) model. The sustainability associated with the various states of the squadron's WRSK was measured by computing the cumulative expected sortie generation over a nominal 30-day scenario. The cumulative sortie generation capability associated with each state of the kit could then be compared with the planned sortie schedule.

Since we did not know how the funding cuts would be distributed across the various DPEM funding categories, and since our analysis applies only to the exchangeables portion of the DPEM appropriations, we considered three possible funding levels for the exchangeables portion of DPEM. As noted previously, the levels chosen were 60 percent, 70 percent, and 80 percent, respectively, of the full requirement.

A more detailed description of the method can be found in the "Methodology" section.

RESULTS

We examined the impacts of DPEM funding cuts for a squadron of 24 F-16A aircraft and a squadron of 18 F-111D aircraft. We used the Combat Support Management System (CSMS) kits in order to obtain a "snapshot" of onhand serviceable WRSK assets for each squadron, i.e., the starting assets (before any drawdown) reflect the onhand inventory levels of the CSMS.

The impacts of DPEM funding cuts upon sustainability are shown in Figures A-1 and A-2. The F-16A kit seems to be in far better shape to provide the sustainability required than that of the F-111D. In both cases, the authorized kits are able to support the planned sortie generation for both nominal scenarios, as can be seen by examining Figures A-3 and A-4, but again the F-111D kit seems to be more sensitive to cuts in DPEM funding. This is not surprising when we note that the F-111D is a larger and more complex aircraft and is harder to maintain than the F-16A. Consequently, one reason that the F-111D onhand kit is less able to provide sustainability is that it is drawn on more heavily than an F-16A kit during peacetime. The F-111D kit also seems more sensitive to cuts in DPEM funding.

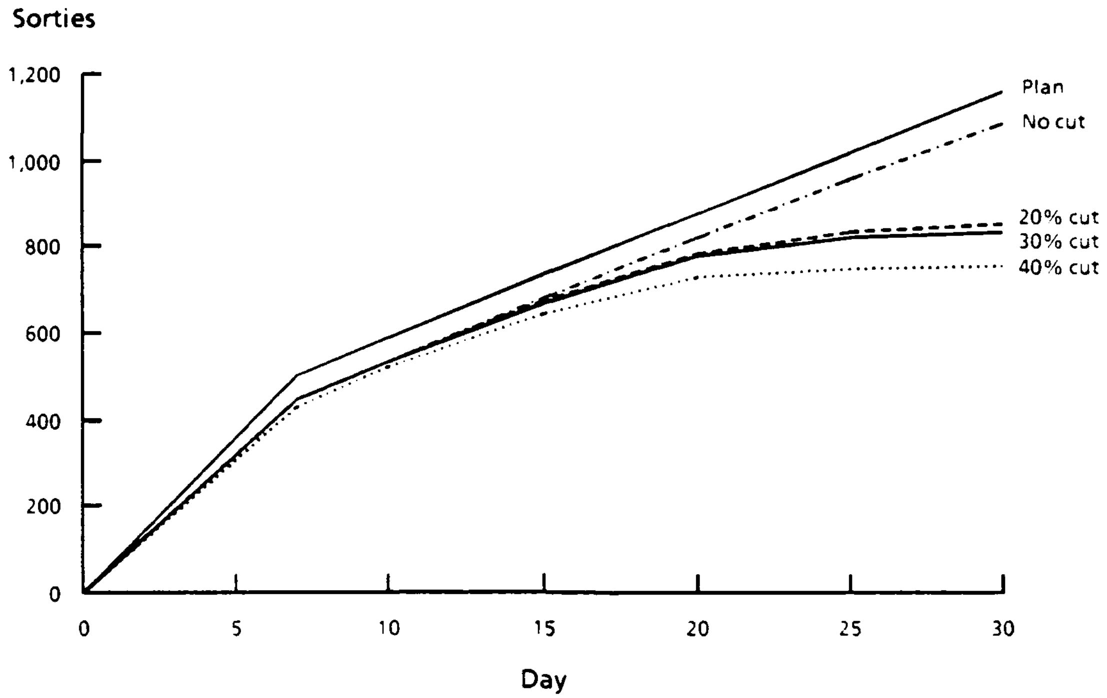

FIG. A-1. CUMULATIVE SORTIE GENERATION: F-16A ONHAND KIT

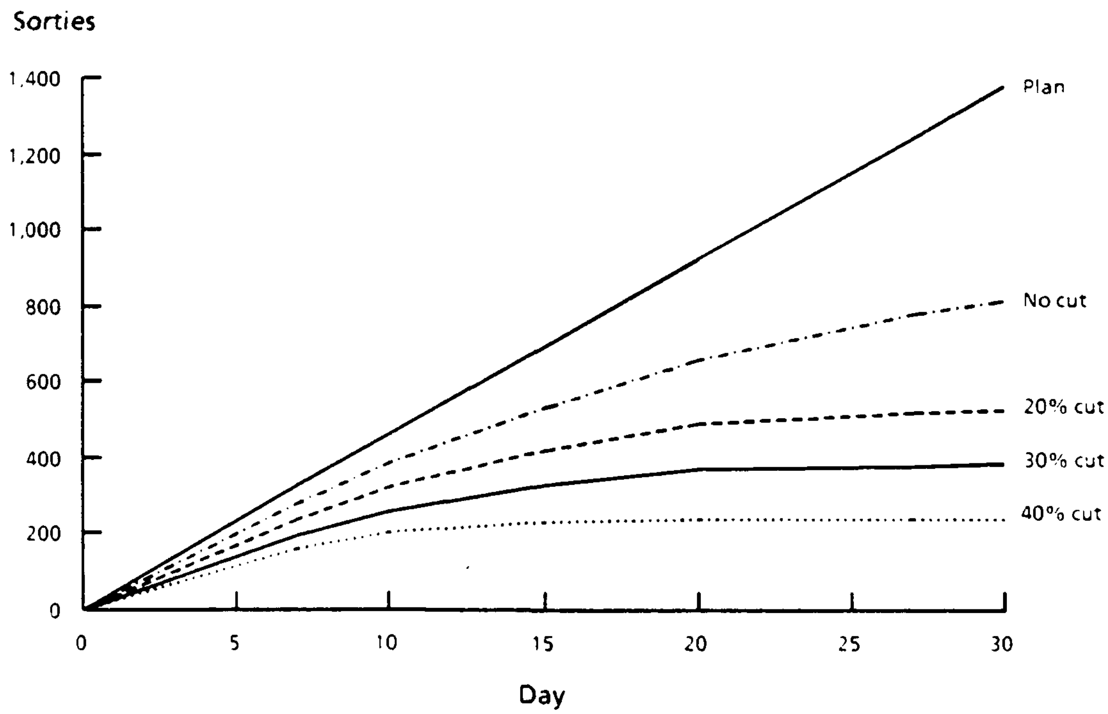

FIG. A-2. CUMULATIVE SORTIE GENERATION: F-111D ONHAND KIT

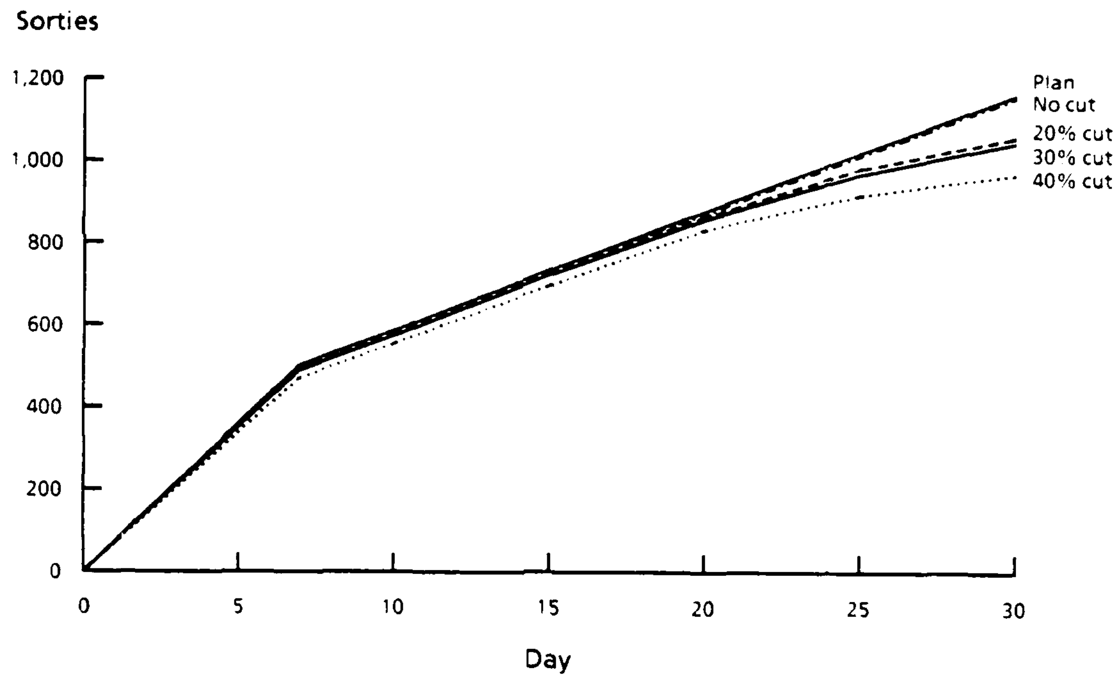

FIG. A-3. CUMULATIVE SORTIE GENERATION: F-16A AUTHORIZED KIT

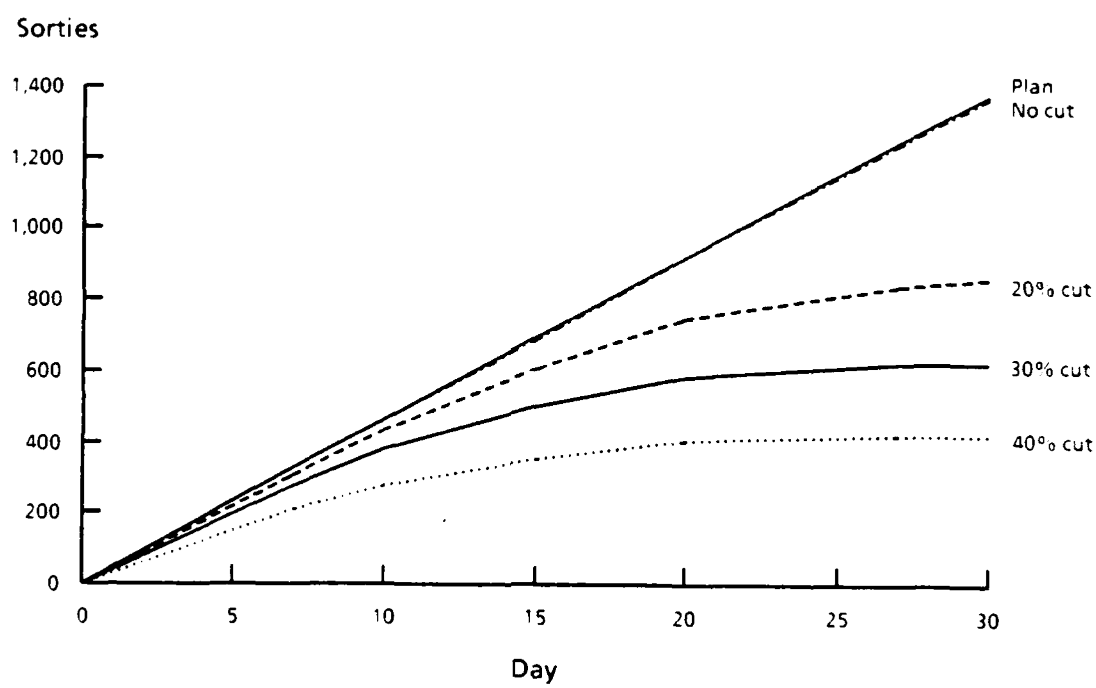

FIG. A-4. CUMULATIVE SORTIE GENERATION: F-111D AUTHORIZED KIT

In order to understand this phenomenon, consider the differences in the scenarios under which sustainability was evaluated (see Table 2). The planned sortie rates for the F-16A are much greater during the first 7 days of the scenario, while the sortie rates for the F-111D remain fairly constant over the duration of the scenario. The F-16A kit is essentially a remove and replace (RR) kit; little or no repair of parts is anticipated, and the effect of kit depletion are not felt until replacement parts have run out later in the scenario. On the other hand, the kit for the F-111D is essentially a remove, repair, and replace (RRR) kit, relying on repair through the scenario to return failed parts to service. The lack of enough spares to cover those unserviceables in base repair will be felt almost immediately, especially early in the scenario when flying activity surges. Just how poor the current state of the F-111D kit is compared to the F-16A kit can also be seen from Table A-3.

TABLE A-2

REQUIRED SORTIE SCHEDULE

F-16A			F-111D		
Days	Sorties per aircraft	Total sorties per day	Days	Sorties per aircraft	Total sorties per day
1 – 7	3.00	72	1 – 7	2.60	48
8 – 19	1.20	29	8 – 27	2.54	47
20 – 30	1.16	28	28 – 30	2.48	46

TABLE A-3

VALUE OF DEPLETED WRSKs

WRSK assets	F-16A ($ millions)	F-111D ($ millions)
No cut		
Authorized WRSK	22.0	113.5
CSMS onhand	18.3	58.7
20% DPEM cut	11.8	38.5
30% DPEM cut	10.9	31.4
40% DPEM cut	9.7	15.8

A summary of the effects of the selected DPEM cuts on both peacetime aircraft availability and wartime sustainability is shown in Tables A-4 through A-7. The F-16A kit seems more robust even when used to support peacetime operations. An examination of Table A-8 shows that the dollar value of the POS required to support the F-16A is a much greater fraction of the cost of the authorized WRSK than for the F-111D. Moreover, the dollar value of the POS for the F-16A is also a much larger fraction of the onhand WRSK than for the F-111D. Thus, the F-16A kit seems to be more complete and less susceptible to peacetime withdrawals than the F-111D kit.

TABLE A-4

READINESS AND SUSTAINABILITY IMPACTS: CSMS ONHAND KITS

(F-16A results)

Exchangeables dollars	Peacetime aircraft availability rates	Expected sorties over 30 days	Percent requirement	Sorties lost
No cut	0.93	1,086	94	-
20% cut	0.93	850	74	236
30% cut	0.78	834	72	252
40% cut	0.47	756	65	330
Total sortie requirement: 1,160				

TABLE A-5

READINESS AND SUSTAINABILITY IMPACTS: CSMS ONHAND KITS

(F-111D results)

Exchangeables dollars	Peacetime aircraft availability rates	Expected sorties over 30 days	Percent requirement	Sorties lost
No cut	0.91	810	59	-
20% cut[a]	0.83	523	38	287
30% cut	0.24	382	28	428
40% cut	0.00	240	17	570
Total sortie requirement: 1,375				

[a] A 14 percent cut in DPEM exchangeables was the maximum cut that allowed maintenance of 91 percent peacetime rate

TABLE A-6

READINESS AND SUSTAINABILITY IMPACTS: CSMS AUTHORIZED KITS

(F-16A results)

Exchangeables dollars	Peacetime aircraft availability rates	Expected sorties over 30 days	Percent requirement	Sorties lost
No cut	0.96	1,153	99	–
20% cut	0.96	1,061	92	92
30% cut	0.82	1,044	90	109
40% cut	0.56	968	84	185
Total sortie requirement: 1,156				

TABLE A-7

READINESS AND SUSTAINABILITY IMPACTS: CSMS AUTHORIZED KITS

(F-111D results)

Exchangeables dollars	Peacetime aircraft availability rates	Expected sorties over 30 days	Percent requirement	Sorties lost
No cut	0.99	1,369	99	-
20% cut	0.99	862	63	507
30% cut	0.86	625	45	744
40% cut	0.14	419	30	950
Total sortie requirement: 1,376				

TABLE A-8

VALUE OF ASSETS

Assets	F-16A ($ millions)	F-111D ($ millions)
Authorized WRSK	22.0	113.5
WRSK onhand	18.3	58.7
POS assets	9.7	88.5

CONCLUSIONS

Each onhand kit is a "snapshot" of the WRSK assets of a given squadron on a given day and so may not be representative of the expected (or time average) content of the kits. Clearly a sample of two CSMS onhand WRSKs is not large enough to allow us to draw any firm conclusions. However, we believe that the results almost surely bound the problem, with the F-111D providing a worst case. Moreover, we have demonstrated a mechanism whose effects puzzle many observers. Namely, why is it that when DPEM funding is cut, MC rates do not drop discernibly. Part of the answer to that question is that MC rates are being maintained by the peacetime use of WRM, and the cost to wartime sustainability goes largely unnoticed. The resulting diminished capability during wartime is, nonetheless, a real cost.

FUTURE DIRECTIONS

The method developed for this study can also be applied to Air Force-wide computations. The advantage of adapting this method Air Force-wide is that it offers a broader view of the implications of DPEM cuts during peacetime. By using WRSK data from the D029 WRSK/BLSS[3] and Authorization Computation System, we also may be able to examine the effects of DPEM cuts during wartime on a broader scale than was possible on a squadron-by-squadron basis. But more important, the results of this report point to the need to integrate the POS and WRM requirements computation. Given the difficulty of that task, however, it must remain a long-term goal. We believe that some of the techniques developed to solve sustainability requirements problems will eventually prove useful in the development of an integrated requirements computation. We also believe that the further development and refinement of the method presented in this report will serve as an interim method for assessing the impact of changes in DPEM exchangeables funding.

[3]BLSS = Base Level Self-Sufficiency.

METHODOLOGY

The method used to estimate the effects of DPEM funding levels on the readiness and sustainability of aircraft involves the iterative use of a version of the AAM. The method will be described as an algorithm.

- *Phase I* – Estimate the starting POS asset position through the following steps:

  1. Use the AAM to optimally procure spares to a given target for squadron availability, $A_n(\mathbf{s})$. Denote this asset position by $\mathbf{s} = (s_1, \dots, s_n)$, where n is the number of parts under consideration, and s_i is the spares level for component i.

  2. Add the WRSK assets to initial peacetime asset position and evaluate the availability, $A_n(\mathbf{s}+\mathbf{w})$, where $\mathbf{w} = (w_1, \dots, w_n)$ is the WRSK asset position.

  3. Stop if $A_n(\mathbf{s}+\mathbf{w})$ is close enough to 1 – NMCS (not mission capable supply) for the aircraft type that makes up the squadron's planes; otherwise, go to Step 1 and adjust the targeted A_n and have the model compute a new **s** and repeat Steps 2 and 3.

- *Phase II* – Estimate the asset position of the squadron WRSK after 2 years of cuts in repair funds through the following steps:

  1. Delete 2 years of depot returns (used to approximate repair requirements), $\mathbf{r} = (r_1, \dots, r_n)$, from $\mathbf{s}+\mathbf{w}$ to get an initial asset position for repair: $\mathbf{s}+\mathbf{w}-\mathbf{r}$. Let R denote the dollar value of these repairs.

  2. Use the model to optimally "repair" parts, beginning from $\mathbf{s}+\mathbf{w}-\mathbf{r}$, until a given fraction of R is spent, say, f•R. Denote this new asset position as $\mathbf{t} = \mathbf{s}+\mathbf{w}-\mathbf{r}+\mathbf{R}(\text{f•R})$, where $\mathbf{R}(\text{f•R})$ is the "repair" list from the model.

  3. Since the model does not distinguish between POS and WRSK assets, compute the expected distribution of parts among POS and WRSK by calculating the expected drain from the WRSK for each item. To do this, we assume that for each Item i, $t_i = w_i + s_i'$. That is, we assume that the kit at any time is full but that the peacetime assets have been decremented by $\mathbf{R}(\text{f•R}) - \mathbf{r} \le 0$, and we compute the average number of parts missing when the POS is $s_i' = \max[\mathbf{o}, \mathbf{t}-\mathbf{w}]$. Denote the depleted WRSK asset position by $\mathbf{w}'$. The average number of missing WRSK parts of Type i is given by:

  $$\mathrm{EBO}(s_i') - \mathrm{EBO}(t_i),$$

  where $\mathrm{EBO}(s_i)$ denotes the expected backorders given asset level s_i.

- *Phase III* – Evaluate the sustainability of the WRSK when the asset position, **s**, is given by **w**′ from Step 3 of Phase II.

The following important assumptions are inherent in this approach:

- WRSK assets will be used freely to support peacetime availability.
- The only extra stock that supports peacetime availability is contained in the squadron's WRSK.
- Stock levels, once determined, remain constant over the period in question, i.e., no stock condemned.
- The initial asset position is determined by the model, which means it is an optimal procurement policy and all of the sensitivities associated with optimal policies.
- Funding for procurement of spares does not change.
- The flying-hour program does not change over the periods of the computation.
- Only stock in the WRSK is considered in the calculation of A_{Π}.

The following three assumptions are inherent in the version of the Demonstration Aircraft Availability Model (DAAM) used in the analysis.

- At most, two levels of indenture exist.
- No common components.
- QPA (Quantity Per Application) ≡ 1.

This process differs from a standard run of the procurement-repair version of the AAM in the following manner.

The AAM is a procurement-repair model, which means that it solves the procurement-repair problem:

Problem I

$$\max A_{\Pi}(\mathbf{s}_0, \mathbf{w}_0, \mathbf{r}, \mathbf{s})$$

$$\text{s.t.} \quad \sum_{i=n}^{n_p} c_i s_i \le C,$$

$$\sum_{i=1}^{n_r} c_i^* r_i \le R,$$

$$r_i \le R_i.$$

The method outlined above involves the solution of a pair of problems, where:

- s_0 is an initial POS asset position.
- w_0 is an initial WRM asset position.
- **r** is the vector of assets repaired.
- **s** is the vector of assets procured.
- c_i is the procurement cost of a spare of Type i.
- c_i^* is the repair cost of a spare of Type i.
- C is a dollar constraint on POS procurement.
- R is a dollar constraint on repair.
- R_i is the maximum number of repairs that can be made for Item i.
- n_p is the number of national stock numbers (NSNs) procured.
- n_r is the number of NSNs repaired.

The procurement-repair version of the AAM solves this problem by means of marginal analysis, which means that parts are procured or repaired, starting from an initial asset position, s_0, up to an asset position, $s_0 + r + s$. Since any given part, i, is cheaper to repair than to buy, the model repairs up to R_i before making any buys (unless the dollar constraint, R, is breached). When the model is run with the WRM option on, WRM onhand assets and onorder assets are added to the initial asset position for the computation.

Problem II

$$\min \sum_{i=1}^{n_p} c_i s_i$$

$$\text{s.t.} \quad A_{II}(s_0, s) \ge A,$$

and

$$\max A_{\pi}(\mathbf{r}_0, \mathbf{s}_0, \mathbf{w}_0, \mathbf{r})$$

$$\text{s.t.} \quad \sum_{i=1}^{n_r} c_i^* r_i \leq R,$$

where $\mathbf{s}_0$, $\mathbf{w}_0$, $\mathbf{s}$, $\mathbf{r}$, c_i^*, and R have the same meaning as in Problem I. For Problem II, A is a target availability for procurement. Note that Problem II consists of a pair of optimization problems. The first is only solved in order to obtain an initial asset position for the second and is an optimization of a purely procurement process. The second is an optimization of a purely repair process. Both optimizations associated with Problem II are accomplished by means of marginal analysis.

Earlier in our investigation of DPEM funding, we found that Problem I leads to results that were exquisitely sensitive to DPEM funding levels. The method used solves Problem II, and results proved to be less sensitive to DPEM funding levels. In fact, the peacetime results were not sensitive at all to small cuts in DPEM funding levels.

Two reasons that possibly account for this difference in sensitivity immediately come to mind. The first is that Problem I yields an optimal solution to the procurement-repair problem, while Problem II yields a suboptimal solution to the problem. Optimal solutions for the procurement-repair problem are more sensitive to changes in funding than suboptimal solutions. The second reason is that, when Problem I is solved, some NSNs are not associated with the WRM buffer in peacetime for such parts. The question remains as to which effect is dominant.

APPENDIX B

GLOSSARY

AAM	=	Aircraft Availability Model
ACD	=	asset cutoff date
AFLC	=	Air Force Logistics Command
ALC	=	Air Logistics Center
BLSS	=	Base Level Self-Sufficiency
CSIS	=	Central Secondary Item Stratification
CSMS	=	Combat Support Management System
D028	=	Central Leveling System
D029	=	WRSK/BLSS and Authorization Computation System
D041	=	Recoverable Consumption Item Requirements System
DAAM	=	Demonstration Aircraft Availability Model
DAF	=	Direct Air Force
DEP/REP/MOD	=	depot repairs and modifications
DLM	=	depot-level maintenance
DLR	=	depot-level reparable
DMIF	=	Depot Maintenance Industrial Fund
DoD	=	Department of Defense
DPEM	=	Depot Purchased Equipment Maintenance
DRIVE	=	Distribution and Repair in a Variable Environment
Dyna-METRIC	=	Dynamic Multi-Echelon Technique for Recoverable Item Control
EBO	=	expected backorder

FMC	=	fully mission capable
HQ	=	Headquarters
LMI	=	Logistics Management Institute
LMS	=	Logistics Modernization System
MC	=	mission capable
MICAP	=	mission capability
MM	=	Materiel Management
NMC	=	not mission capable
NMCM	=	not mission capable–maintenance
NMCS	=	not mission capable–supply
NRTS	=	not reparable this station
NSN	=	national stock number
O&M	=	Operation and Maintenance
OIM	=	organizational and intermediate maintenance
OMB	=	Office of Management and Budget
OSD	=	Office of the Secretary of Defense
PB	=	President's Budget
PDM	=	programmed depot maintenance
PMCS	=	partially mission capable–supply
POM	=	Program Objective Memorandum
POS	=	peacetime operating stock
PPBS	=	Planning, Programming, and Budgeting System
QPA	=	quantity per application
RDB	=	Requirements Data Bank
RR	=	remove and replace
RRR	=	remove, repair, and replace
SAC	=	Strategic Air Command

TAC	=	Tactical Air Command
USAF	=	United States Air Force
WRM	=	War Reserve Materiel
WRSK	=	War Readiness Spares Kit
WSMIS	=	Weapon System Management Information System