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A RAND NOTE

Variability in the Budget Forecasts for Depot-Level Component Repair

Thomas F. Lippiatt

January 1991

RAND

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Prepared for the
Assistant Secretary of Defense
(Production and Logistics)

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PREFACE

This Note reports on a research project conducted for the Office of the Assistant Secretary of Defense (Production and Logistics). Its primary goals were to:

- Identify the nature and causes of variability in the U.S. Air Force's budget estimates for depot-level component repair.
- Review the current depot-level repair requirements estimation and budget execution processes, and recommend future research to identify alternative processes to cope with this variability.

This project was conducted in the Acquisition and Support Policy Program of RAND's National Defense Research Institute, an OSD-sponsored federally funded research and development center. This research complements other work at RAND for the U.S. Army and the U.S. Air Force in the area of uncertainty surrounding forecasts of peacetime and wartime logistics resource requirements.

This Note should interest analysts involved in logistics resource requirements research and personnel in the Office of the Secretary of Defense and the Services involved in determining future logistics resource requirements policy.

SUMMARY

This Note identifies some major sources of variability in the Air Force's budget forecasts for depot-level component repair. These forecasts are estimates of the amount of money the depot system will need to repair components that:

- Cannot be repaired at base-level maintenance facilities.
- The depot repairs as part of an overhaul or repair of a higher assembly or end item, such as an airplane or missile.

These two kinds of components constitute the component repair portion of the Depot Programmed Equipment Maintenance (DPEM) budget.

THE PROBLEM OF VARIABILITY

Forecasts for the DPEM component repair budget for a particular target year are typically made during a number of successive earlier years. However, these forecasts for the target year vary greatly from one year to the next. This variability in forecasts makes the setting of future budget requirements extremely difficult, especially in an environment of fiscal constraint. It also casts serious doubt on the validity of the process used to set budget requirements.

RESEARCH GOALS

This research aims at identifying the nature and causes of this variability and suggesting future research to cope with the Services' inability to make accurate forecasts of depot-level component repair during the requirements process.

To do so, this Note addresses selected components as defined by Air Force System Management Codes (SMCs):

- SMC 328Z components common to the F-15.
- SMC F16Z components common to the F-16.
- SMC 327Z components common to the F-4.
- SMC 9999 components common to many weapon systems.

For each forecast, we computed the effect of changes in three principal parameters (program, unit repair cost, and depot demand rate) on changes in the total dollar requirement between the years forecasts were made (1983, 1984, 1985, and 1986) and a single target year (1987). We also controlled for items that entered and left the inventory between the year the forecast was made and the target year:

- **New items** show a requirement during the target year but are not in the database during one or more of the forecast years. If these items were not controlled for, the analysis would indicate that the repair requirement was underestimated in the forecast year.
- **Discontinued items** show no requirement during the target year but are in the database during one or more of the forecast years. If these items were not controlled for, the analysis would indicate that the repair requirement was overestimated in the forecast year.
- **Program** is typically the projected number of flying hours that a particular component will undergo in the time frame of interest.
- **Unit repair cost** is the projected cost to repair the component.
- **Depot demand rate** is the projected rate at which the depot will repair the component.

PRINCIPAL FINDINGS

Accurate forecasting of individual repair requirements, especially over long time horizons, is an extremely difficult task. Although all forecasts tend to overestimate repair requirements, forecasts made close to the target year tend to become more accurate. All parameters—not just demand rates—affect the accuracy of forecasts. In addition, all parameters undergo variability over time, even when their aggregate effects on the total requirement are small.

This Note finds that current requirements and capability assessments systems do not explicitly consider parameter variabilities and forecasting uncertainties. It suggests that these uncertainties will always be present in some form and that the Services should focus on enhancing management adaptation during budget execution and explicitly account for these adaptations during the requirements process. It also finds that the Services do not use consistent operational goals when developing requirements and executing the budget.

To address these problems, this Note proposes that future research should focus on developing requirements methods and budget execution systems that account for uncertainties and potential management adaptations, support tradeoffs between the repair and procurement of spares, and consistently reflect the operational priorities of the Services.

ACKNOWLEDGMENTS

Thanks to the following RAND colleagues who contributed to this project: Patricia Dey and Fred Finnegan compiled the databases and ran the statistical analyses, Bill Stringer reviewed and analyzed the CSIS data, Jim Hodges helped derive the equations described in App. A, and Jack Abell wrote the description of DRIVE found in App. B. C. Lynn Batten provided invaluable assistance with document editing and production.

In addition, special thanks go to Dr. T. J. O'Malley at the Logistics Management Institute for providing the only reliable source of archived Air Force D041 data and to Major James Daup, USAF/LEX, for allowing Dr. O'Malley and his staff to take the time to help.

GLOSSARY

AFLC	Air Force Logistics Command
ALC	*Air Logistics Center*
C	Unit Repair Cost
CLOUT	Coupling Logistics to Operations to meet Uncertainties and the Threat
CSIS	Central Secondary Item Stratification
D	Depot Demand Rate
DI	Discontinued Item
DPEM	Depot Programmed Equipment Maintenance
DRIVE	Distribution and Repair In Variable Environments
FY	Fiscal Year
JR	Job Routed
LRU	Line Replaceable Unit
MDS	Mission Design Series
MICAP	Mission Incapable, Awaiting Parts
NI	New Item
NJR	Nonjob Routed
NRTS	Not Repairable This Station
NSN	National Stock Number
OIM	Organization and Intermediate Maintenance
P	Program
POM	Program Objective Memorandum
POS	Peacetime Operating Stocks
PPBS	Planning, Programming, and Budgeting System
SMC	System Management Code
SRU	Shop Replaceable Unit
TAC	Tactical Air Command
VTMR	Variance-to-Mean Ratio
WRM	War Readiness Material
WRSK	War Readiness Spares Kit

CONTENTS

FIGURES

I. INTRODUCTION

FORECASTING THE BUDGET FOR DEPOT-LEVEL COMPONENT REPAIRS

This Note identifies some major sources of variability in the Air Force's budget forecasts for depot-level component repair. These forecasts are estimates of the amount of money the depot system, both organic and contractor, will need to repair components that:

- Cannot be repaired at base-level maintenance facilities. This is referred to as the Organization and Intermediate Maintenance (OIM) requirement for repair of items that are identified as Not Repairable This Station (NRTS) by base-level maintenance personnel.
- The depot repairs as part of an overhaul or repair of a higher assembly or end item, such as an airplane or missile. This is referred to as the Nonjob Routed (NJR) requirement.

These two categories of components constitute the component repair portion of the Depot Programmed Equipment Maintenance (DPEM) budget.[1]

To calculate future DPEM component repair budgets, the Air Force cannot merely estimate OIM-NRTS and NJR quantities[2] and then multiply them by estimated repair costs. Estimates of DPEM budgets must account not only for a keep-up requirement but also for a catch-up requirement. By keep-up requirement, we mean the sum of the OIM-NRTS and NJR repair quantities; it is the total of everything that breaks. By the catch-up requirement, we mean an additional repair requirement that is a function of the total number of spare parts needed by the system (forecast stock levels) and the number of parts estimated to be available for repair during the time frame of interest. If the number of parts needed in the future increases and there are depot-level repairable assets on hand (as in the case of a long supply position), then the catch-up requirement is positive and the depot will increase repair quantities (above the keep-up requirement) to fill the

[1]There is a third category of depot repair referred to as Job Routed (JR). Its repair budget is included in the budget for the next higher assembly and therefore is not included directly in DPEM component repair budget estimates.

[2]These quantities must also be reduced by the estimated quantities that bases and depots cannot economically repair. Such items are condemned.

forecasted short supply of spare parts. If, on the other hand, the future parts requirement decreases and there are excess serviceable assets forecasted to be available, the catch-up requirement is negative and the depot can decrease its repair accordingly. In such a case, the depot does not need to repair additional parts since it can use serviceables on hand.

The Central Secondary Item Stratification (CSIS) system produces estimates for both the total repair requirement (keep-up plus catch-up) and the spares procurement requirement. If the catch-up requirement is greater than what can be met by repairing assets on hand, the assets will have to be bought.

THE PROBLEM OF VARIABILITY

Forecasts of the DPEM component repair budget for a particular target year are made during a number of successive earlier years as the Services develop their out-year plans as part of the Program Objective Memorandum (POM) and budgets. These forecasts for the target year typically vary from one year to the next. This variability makes setting budget requirements extremely difficult, especially in an environment of fiscal constraint. It also casts serious doubt on the validity of the process used to set budget requirements and the credibility of the stated requirement.

RESEARCH GOALS

It is not the aim of this research to prove the existence of this variability in forecasts. The Office of the Secretary of Defense and the Air Force have known of it for a long time. Rather, the goals of this research are to identify the nature and potential causes of this variability and suggest future research to cope with the Services' inability to make accurate forecasts of depot-level component repair during the requirements process.

SCOPE OF RESEARCH

The thrust of this research compares the forecasted values of parameters used in computing DPEM depot-level component repair for a particular target year with the actual parameters as measured in the target year. The principal parameters to be examined are demand rates (typically a function of hours flown), the flying program (typically in flying hours), and the depot-level repair costs. In addition, this research estimates the relative contribution of parameter forecast errors to the total budget error.

This research focuses primarily on the OIM-NRTS portion of the keep-up requirement, because actual data on the NJR portion of the requirement are not readily available in the standard Air Force data systems.[3] It also focuses on a single target year (1987) and its four forecast years (1983, 1984, 1985, and 1986).[4]

This research does not address the catch-up requirement in detail, because determining the catch-up requirement involves the whole spares requirements determination process and is beyond the scope of the current project. However, the accuracy of parameters that affect the OIM-NRTS portion of the keep-up requirement also affects the spares requirement. Section III does briefly compare the scrubbed forecast total repair requirement (keep-up plus catch-up) with the actual total repairs to assess how well the overall process works.

This research addresses only selected components as defined by Air Force System Management Codes (SMCs):

- SMC 328Z components common to the F-15.
- SMC F16Z components common to the F-16.
- SMC 327Z components common to the F-4.
- SMC 9999 components common to many weapon systems.[5]

ORGANIZATION OF DOCUMENT AND PRINCIPAL FINDINGS

Section II of this Note looks at the nature and causes of variability in budget forecasts for depot-level component repair. It finds that the accurate forecasting of individual repair requirements, especially over long time horizons, is an extremely difficult task. Although the tendency was to overestimate repair requirements during the period we considered, forecasts made close to the target year tend to become more accurate.[6] All parameters—not just demand rates—affect the accuracy of forecasts. In addition, all parameters undergo variability over time, even when their aggregate effects are small.

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[3]In addition, the relative absence of archived data makes longitudinal studies impossible.

[4]Because of the defense buildup during these years, the results presented here may be indicative only of a buildup period. Research similar to that presented in this Note should be undertaken on a regular basis for other target years.

[5]Common refers to components that are installed only on that type of aircraft but include all series (A, B, etc.). The purpose here was to see if there were differences in the variation in parameters for older and newer weapon systems.

[6]The period studied can be characterized as one with significant increases in defense spending and force buildup. It is not clear that the tendency to overestimate the requirement would be as dramatic during periods of decline or stable spending.

To assess how well the overall requirements process works (not just the keep-up requirement), Sec. III compares the scrubbed forecasted total repair requirement (keep-up plus catch-up) with actual total repairs. It finds, again, that the requirement is consistently overestimated. It also finds that actual repair seems influenced not only by the spares requirement but also by constantly changing asset positions.

Section IV looks at the overall requirements and capability assessment systems[7] and finds that they do not explicitly consider parameter variabilities, forecasting uncertainties, and management adaptations to these uncertainties. It also finds that they do not use consistent operational goals when developing requirements and executing the budget.

Section V proposes that future research should focus on developing requirements methods and budget execution systems that account for forecasting uncertainties and potential management adaptations; support tradeoffs among repair, procurement of spares, transportation, and management systems; and reflect the operational priorities of the Services.

Appendix A describes the equations used to calculate individual cost requirements, total cost requirements, and aggregate effects of individual parameters. Appendix B provides a brief description of RAND's depot-level priority repair and distribution system now under test at the Air Force's Air Logistics Center (ALC) at Ogden, Utah.

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[7]Capability assessment systems are used to estimate the impact of varying budget or resource levels on operational capability.

II. NATURE AND POTENTIAL CAUSES OF VARIABILITY IN FORECASTS

NATURE OF VARIABILITY IN FORECASTS

To investigate the nature of variability in forecasts of depot-level component repair, we examined four forecasts of the OIM-NRTS keep-up requirement for the target year of 1987. These forecasts were made in 1983, 1984, 1985, and 1986.[1] We then compared these forecasts with *actual* OIM-NRTS as recorded in 1987. We do not consider the catch-up requirement in this analysis. (By contrast, Sec. III compares forecasts of the total repair requirement made in 1986 with actual repairs that occurred in 1987; it also examines the net catch-up requirement.)

For each forecast, we computed the contribution of changes in three principal parameters (program, unit repair cost, and depot demand rate) to changes in the dollar requirement between the forecast year and the target year. We also controlled for items that entered and left the inventory between the year the forecast was made and the target year:

- **New items**, identified by National Stock Number (NSN), show a requirement during the target year (1987) but are not in the database in the year the forecast was made. They cause an underestimate of the requirement.
- **Discontinued items**, identified by NSN, show no requirement during the target year (1987) but are in the database in the year the forecast was made. They cause an overestimate of the requirement.
- **Program** is typically the projected number of flying hours that a particular component will undergo in the time frame of interest.[2] When multiplied by the depot demand rate (see below), it yields forecast repair quantity. It reflects changes in force structure, peacetime aircraft flying program, and the configuration of the aircraft.
- **Unit repair cost** is the projected cost of repair charged by either the organic depot repair facility or the contractor. It is typically the current cost (during

[1]The forecasted data came from the March computation of the Air Force D041 data system in 1983, 1984, 1985, and 1986. Each quarterly computation forecasted requirements for the next 27 quarters. The target quarters were the 3d and 4th quarters of FY 1986 and the 1st and 2d quarters of FY 1987. The actual data were obtained from the history file in the March 1987 D041.

[2]In some cases, however, program reflects other measures of use. For example, gun component demands are a function of rounds fired rather than flying hours.

the year the forecast is made) of repair weighted between the amount done by contractor and the amount done by organic depot repair.[3]

- **Depot demand rate** is the projected rate at which the depot (or contractor) will need to replace OIM-NRTS components (components that cannot be repaired at the operational location) as a function of the program, i.e., keep-up divided by program.

Appendix A describes the equations used to calculate item repair cost requirements, total repair cost requirements (as a function of the parameters described above), and effects of changes in the individual parameters.

Effect of Individual Parameters on Variability in Forecasts

First, we examined the effect of changes in the individual parameters over time on the total difference between the forecasted dollar requirement and the actual OIM-NRTS dollar requirement as it occurred in the target year.

With a focus on F-15 common equipment (SMC 328Z), Fig. 2.1 compares the 1984 forecast for 1987 with the actual requirement for 1987. The forecast for the 1987 requirement was $122 million, the actual requirement was $88 million, and the difference was $34 million.

The left side of Fig. 2.1 displays individual effects of the different parameters on this $34 million overestimate. New items caused an underestimate of the 1987 requirement by roughly $16 million, and discontinued items had a roughly equal opposite effect. Changes in program for each item produced the greatest portion of the overestimate (about $22 million).[4] Changes in unit repair cost produced virtually no aggregate effect.[5] Finally, changes in depot demand rates produced a moderate effect, causing an overestimate of the 1987 requirement by about $13 milion.[6]

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[3]The analysis uses current-year dollars. To the extent inflation has an effect, it will be captured in the analysis of cost variability. Actual "scrubbed" Program Objective Memorandum (POM) estimates are adjusted by inflation estimates before submittal.

[4]In 1984, estimates of the flying program associated with each F-15 component were higher on average than the program that actually transpired in 1987.

[5]The aggregate effect of differences between the 1984 and 1987 unit repair costs tended to cancel out so that the total effect was small. See Fig. 2.6.

[6]In 1984, estimates indicated that depot demand rates would be higher than they actually turned out to be in 1987.

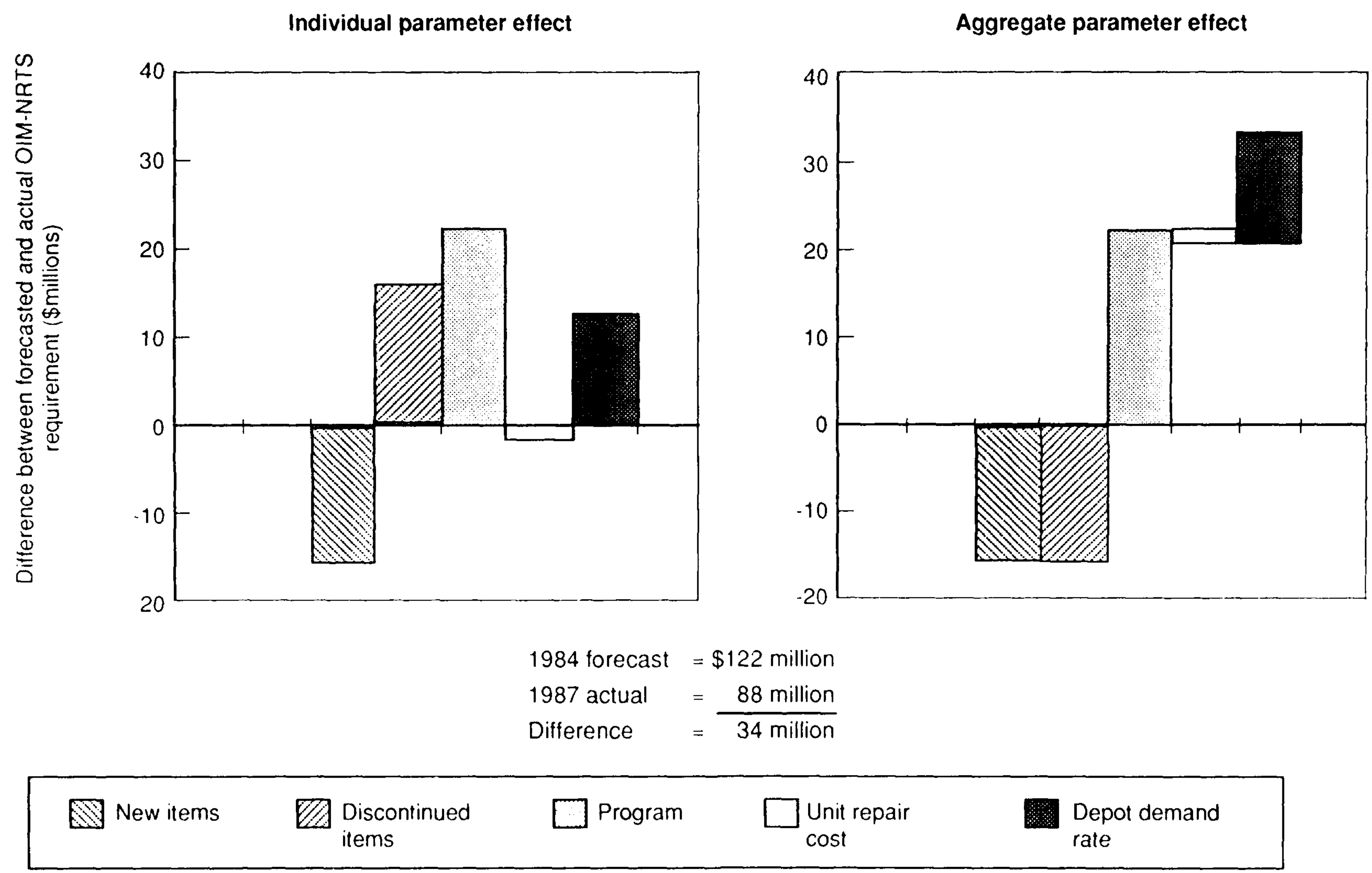

Fig. 2.1—Comparison of 1984 forecast with the 1987 actual requirement: F-15 common items (SMC 328Z)

The right side of Fig. 2.1 aggregates the individual parameter effects just discussed. Its individual bars should be read from left to right. The first bar (new items) begins at zero and brings the overall difference between the forecasted and actual requirement to roughly –$16 million. The second bar (discontinued items) begins at –$16 million and brings the overall difference essentially back to zero. The third bar (program) begins there and brings the overall difference up to $22 million. The fourth bar (unit repair cost) begins at $22 million and brings the overall difference down to $21 million. Finally, the fifth bar (depot demand rate) begins at $21 million and brings the overall difference up to $34 million.

This is the method used in Figs. 2.2 through 2.5, which show the aggregate contribution of changes in the individual parameters when calculating differences between the forecasted and actual requirements.

Figure 2.2 shows individual aggregate parameter effects over all four forecast years for F-15 common equipment (SMC 328Z). Here we see three trends that reappear in subsequent figures:

- As forecasts approach the target year, they more accurately predict the actual requirement as it occurred in the target year.
- Improvements in virtually all individual parameters contribute to this improved accuracy.
- Miscalculations of depot demand rates do not uniformly account for most of the inaccuracy. (In 1984, 1985, and 1986, aggregate program effects were greater than aggregate depot demand rate effects.)

Figure 2.3 shows similar information for F-16 common equipment (SMC F16Z). Here we see a major variation in the 1984 forecast caused largely by discontinued items. Informal discussions with personnel at ALCs have confirmed our belief that this forecast error resulted from problems in the F-16's configuration management file.[7]

Figures 2.4 and 2.5 show similar information for SMC 327Z equipment on the F-4 and SMC 9999 equipment common to a wide spectrum of weapon systems.

[7]Configuration management files are used to maintain the configuration of items installed on an aircraft. As in this case, problems occur if a new subsystem is added before an old one is removed from the file.

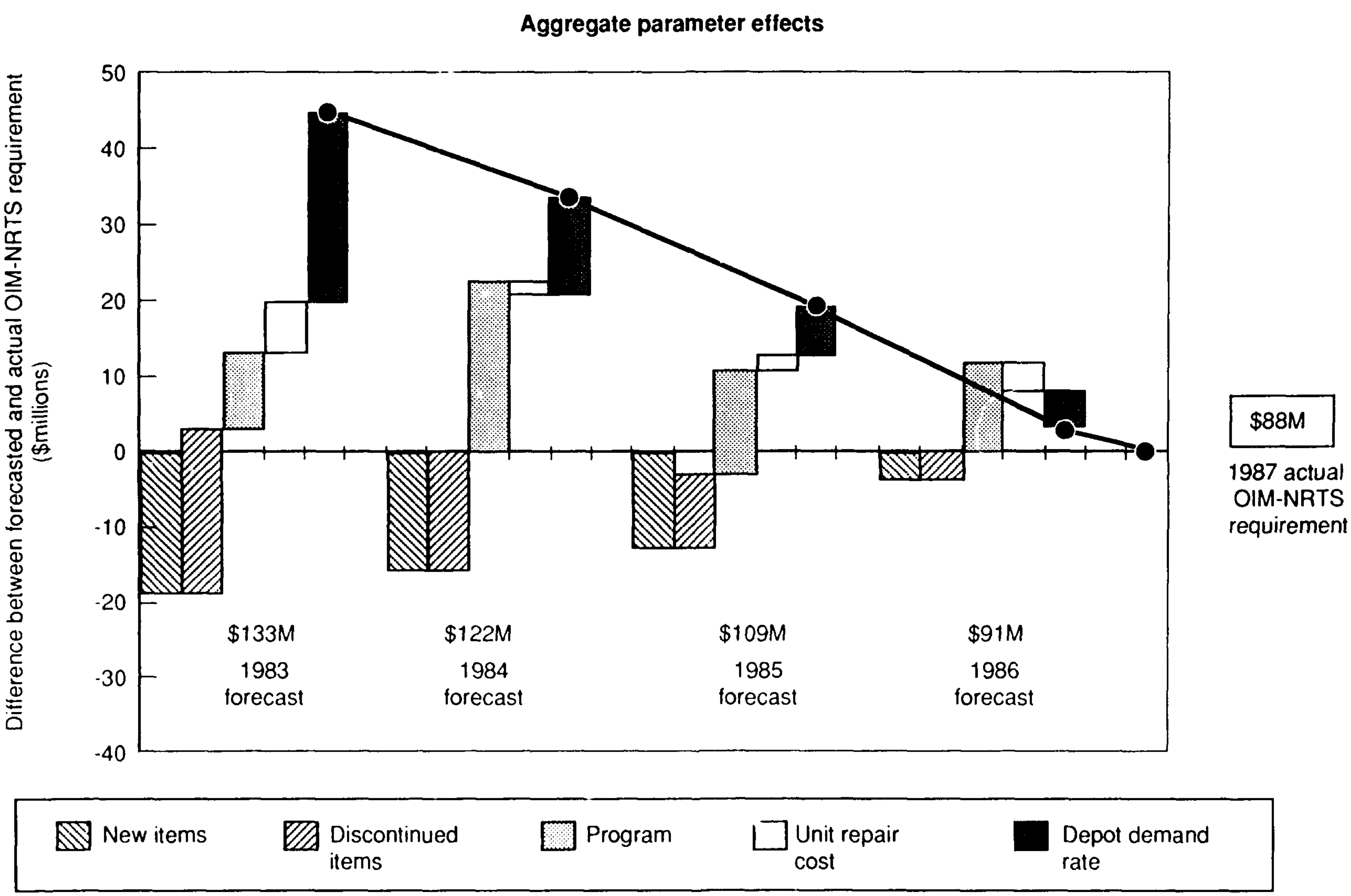

Fig. 2.2—Comparison of forecasts with the actual requirement: F-15 common items (SMC 328Z)

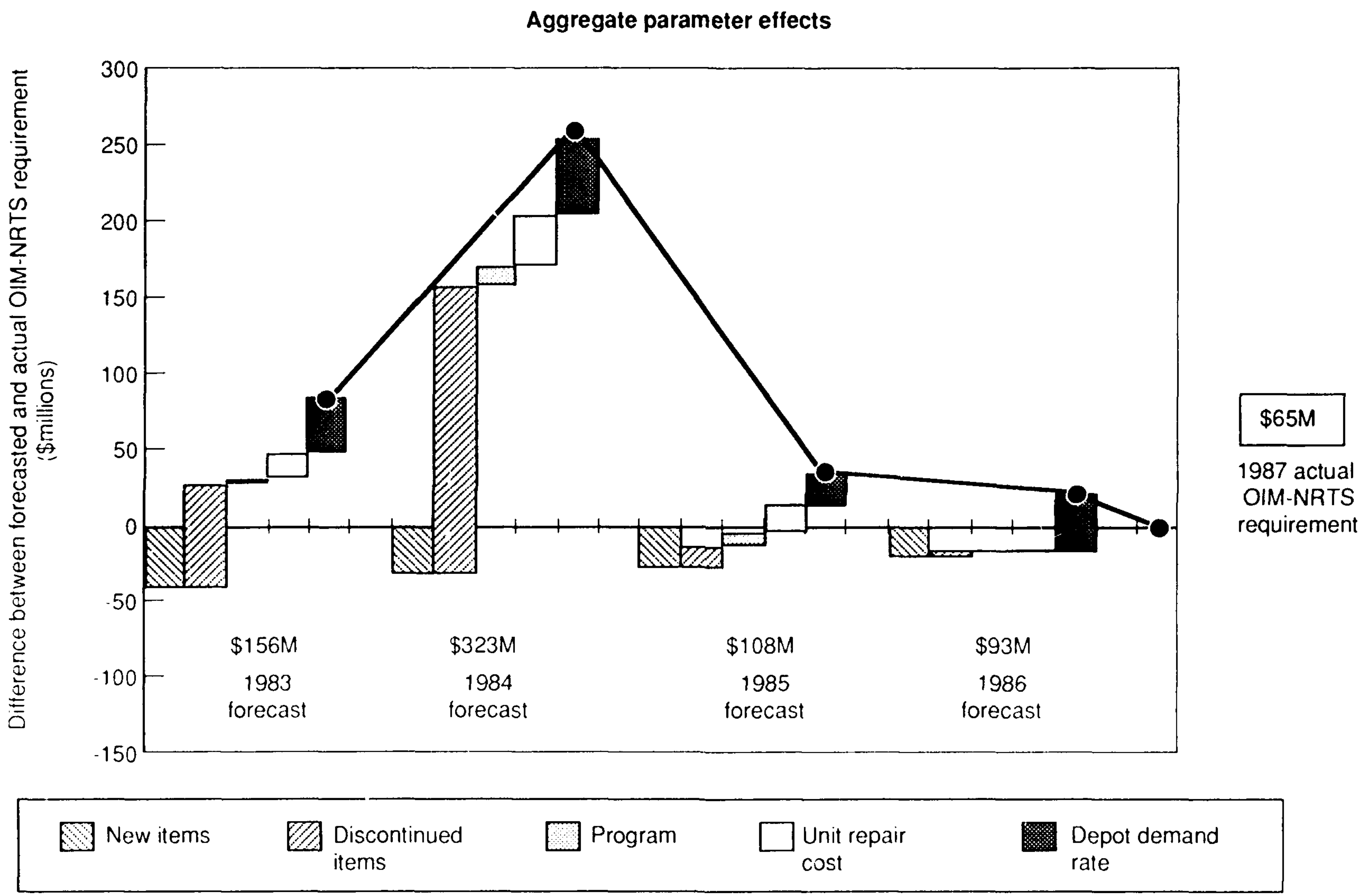

Fig. 2.3—Comparison of forecasts with the actual requirement: F-16 common items (SMC F16Z)

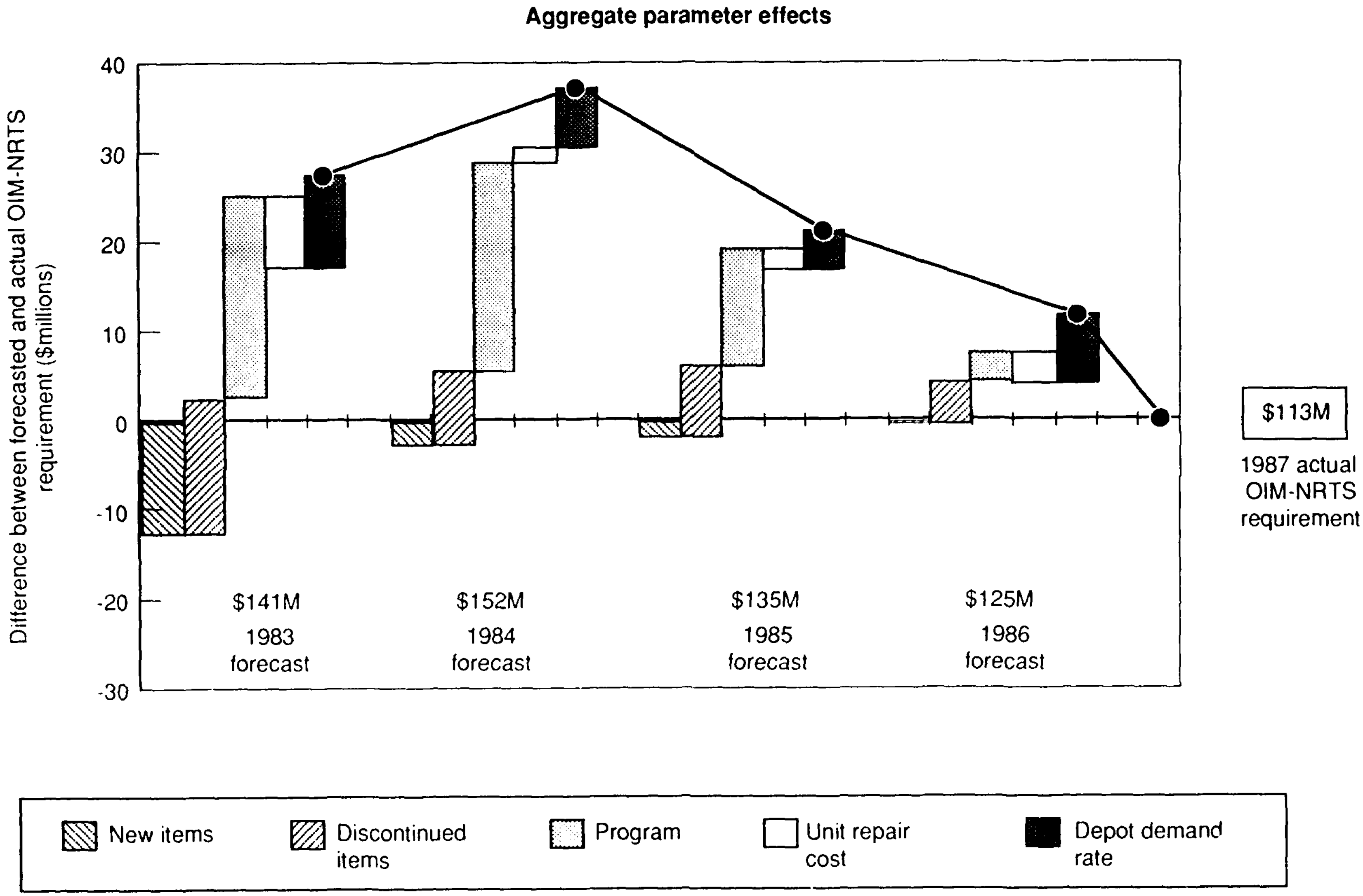

Fig. 2.4—Comparison of forecasts with the actual requirement: F-4 common items (SMC 327Z)

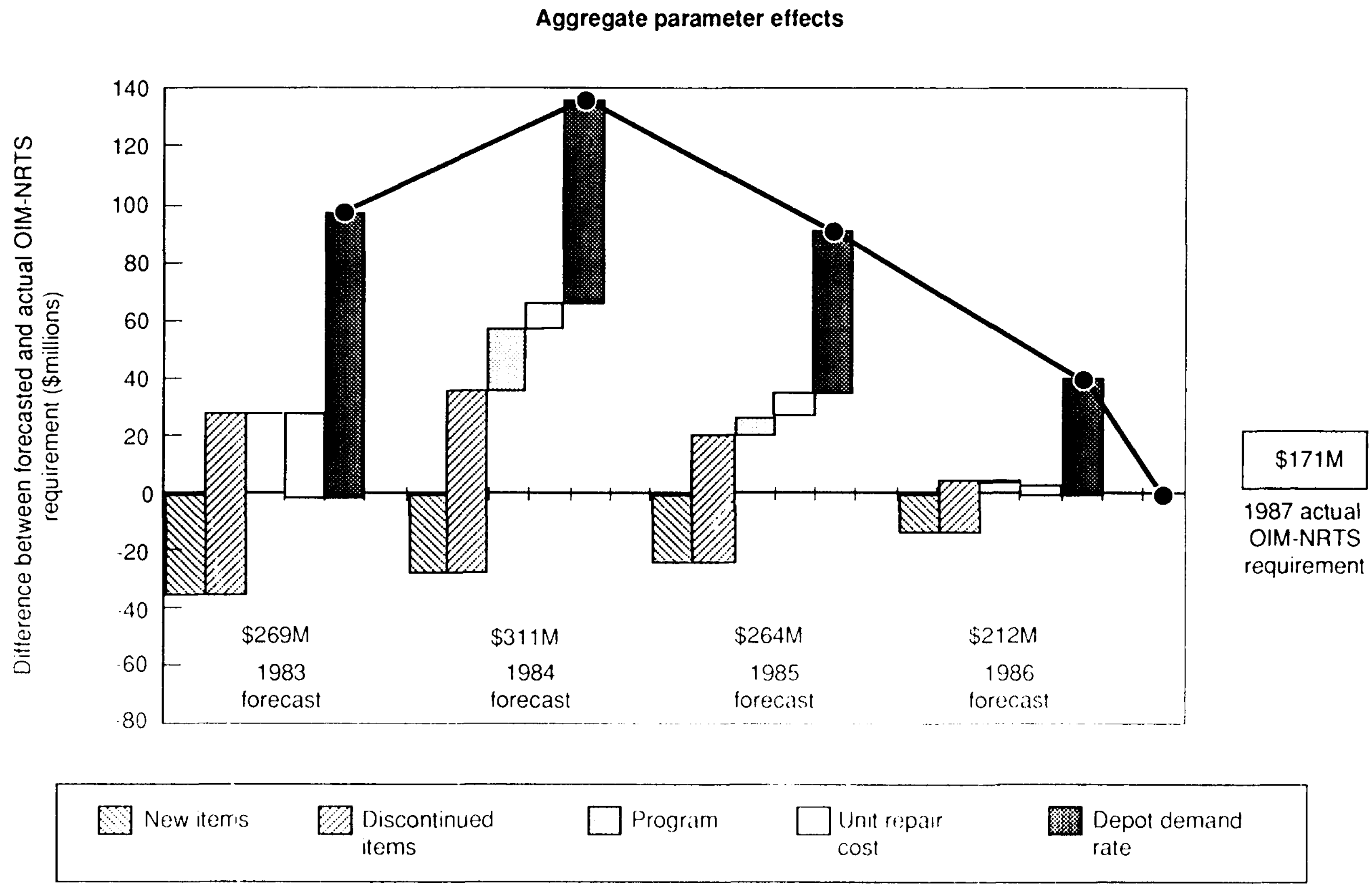

Fig. 2.5—Comparison of forecasts with the actual requirement: items common to wide spectrum of weapon systems (SMC 9999)

Variability of Individual Parameters

In addition to examining the aggregate effects of parameter variability on the total keep-up requirement, we also examined the variability of the individual parameters themselves (program, unit repair cost, and depot demand rate) across forecast years and the target year. Bars on the left sides of Figs. 2.6 through 2.9 show the percentage of items (by NSN) that experienced changes of varying magnitudes (measured as percentage change) between the forecast year and the target year. As a point of reference, the right sides of these figures repeat the relevant information from Figs. 2.2 through 2.5 concerning the aggregate effects of parameters causing differences between the particular forecast and the actual OIM-NRTS keep-up repair dollar requirement. Only one forecast year is shown for each SMC code, but the other years, although not shown, yielded similar results. The figures are in the same order (by SMC) as Figs. 2.2 through 2.5.

Figure 2.6, for example, shows the parameter variability in F-15 common items (SMC 328Z) between the 1984 forecast year and the 1987 target year:

- **Program** — Between the forecast year and the target year, approximately 60 percent of these items experienced a decrease between 1 and 25 percent, while approximately 25 percent had increases up to 25 percent. This is consistent with the data to the right of Fig. 2.6, which show that the largest aggregate parameter effect resulted from overestimates of the 1987 program made in 1984. Indeed, some items had changes up to 100 percent in either direction.
- **Unit repair cost** — Although changes in unit repair costs varied greatly, these changes in both directions tended to cancel each other out in the aggregate.
- **Depot demand rates** — Like program estimates, depot demand rates varied considerably in both directions. More items decreased than increased, thus contributing to the overestimate in the aggregate repair requirement.

Figure 2.7 uses similar data for F-16 common items (SMC F16Z) to compare 1985 forecasts with 1987 actual requirements. The results are similar to those for the F-15 except that all three parameters had considerable variability and significant aggregate effects on misestimating the total requirement.

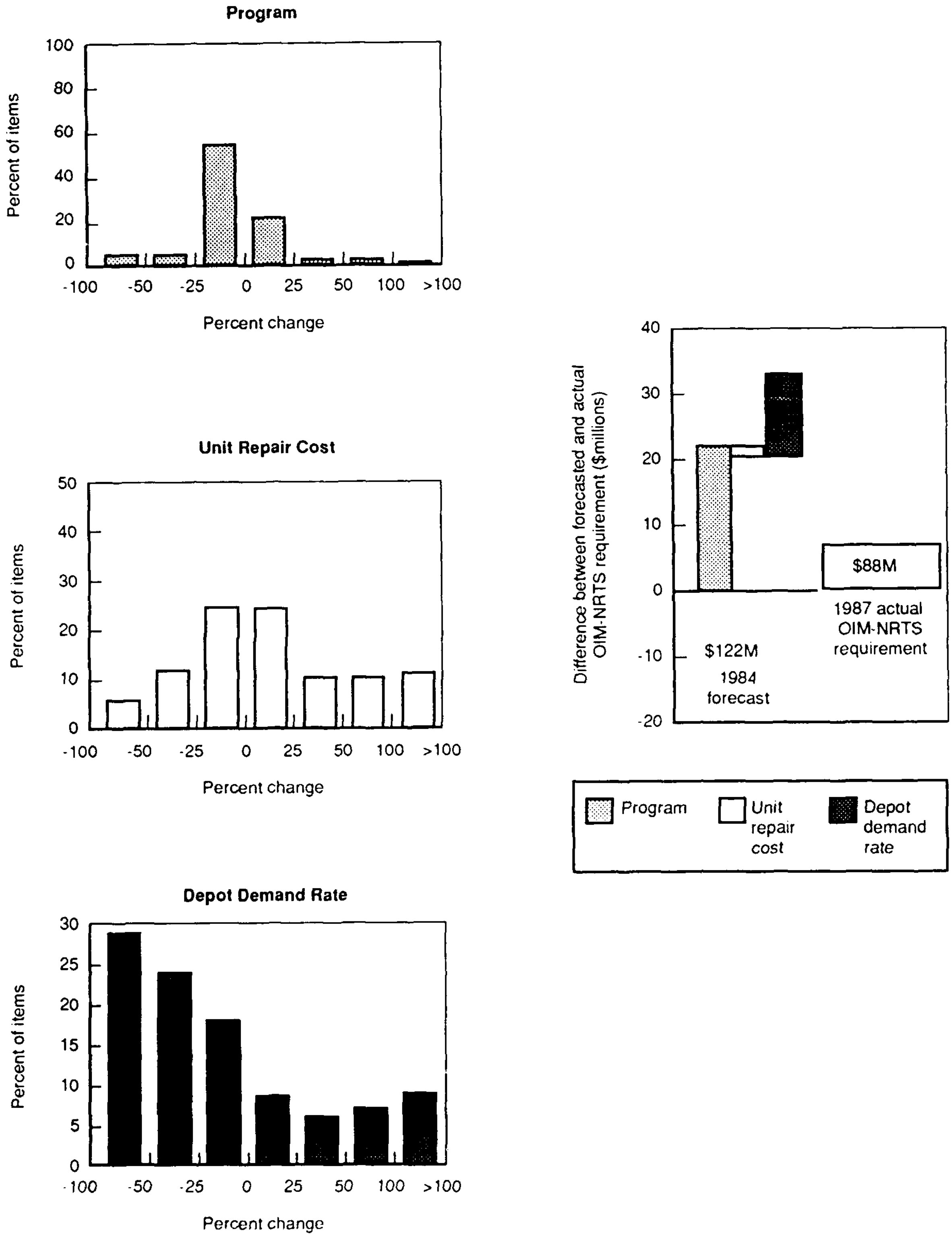

Fig. 2.6—Parameter variability in F-15 common items (SMC 328Z): forecast year 1984

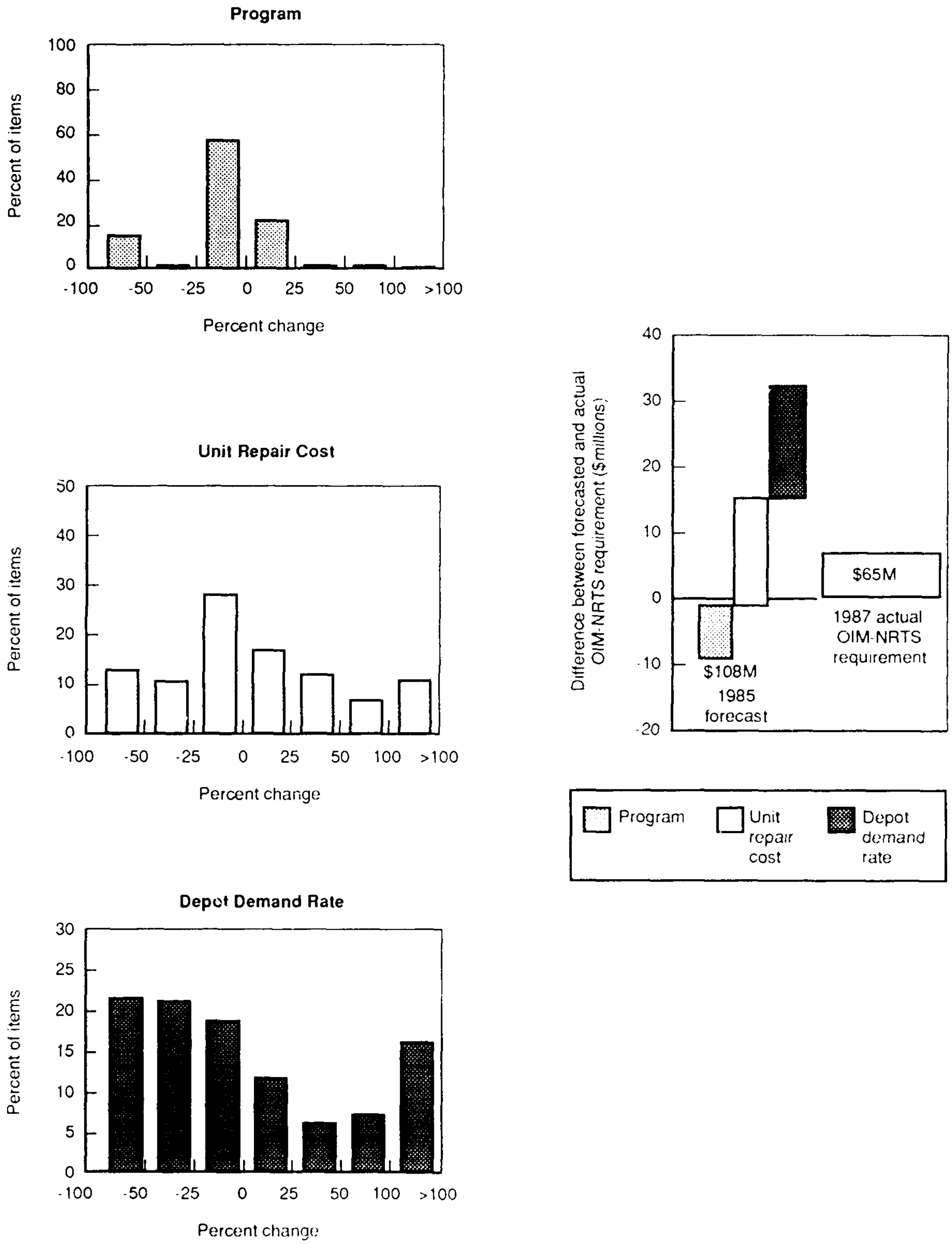

Fig. 2.7—Parameter variability in F-16 common items (SMC F16Z): forecast year 1985

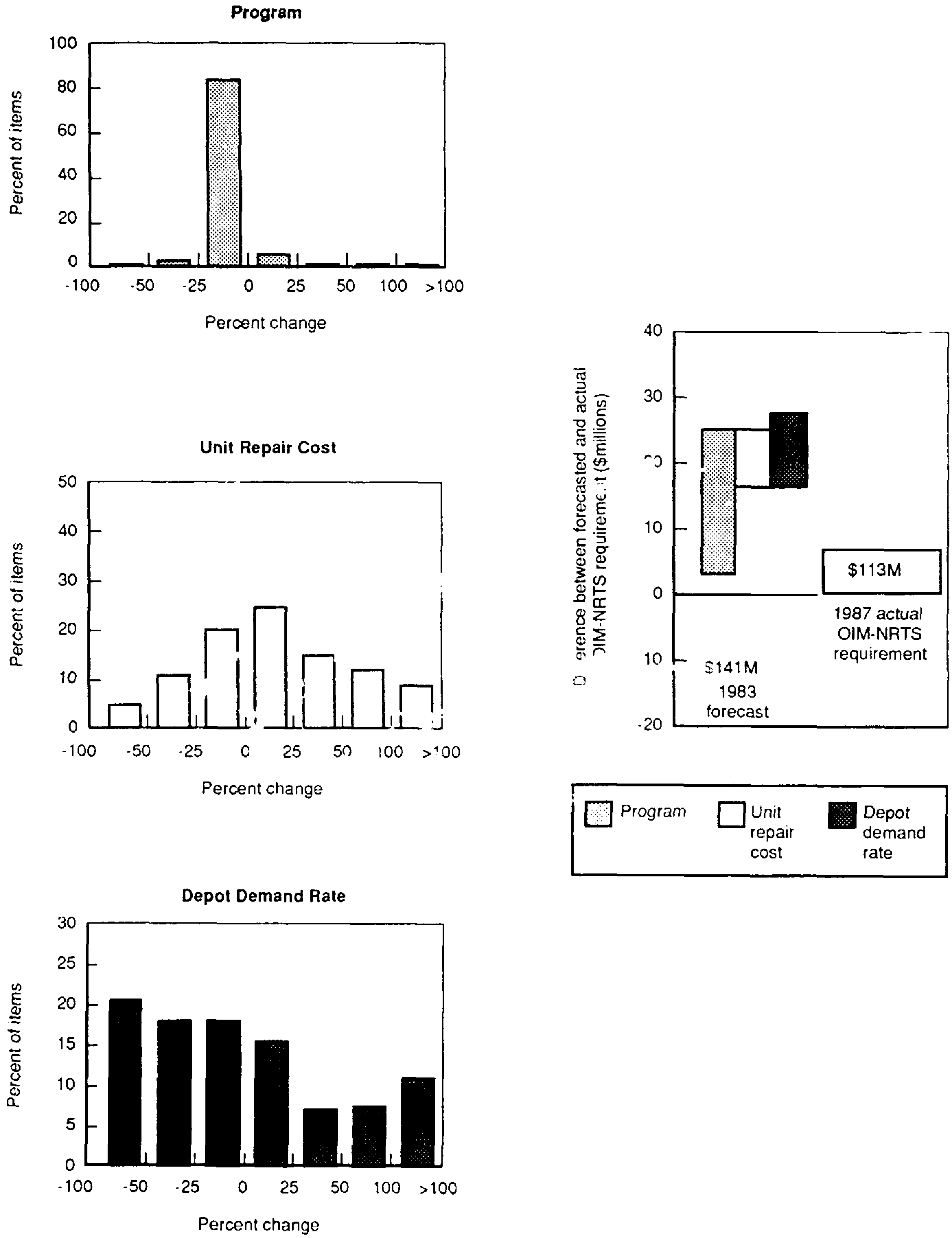

Fig. 2.8—Parameter variability in F-4 common items (SMC 327Z): forecast year 1983

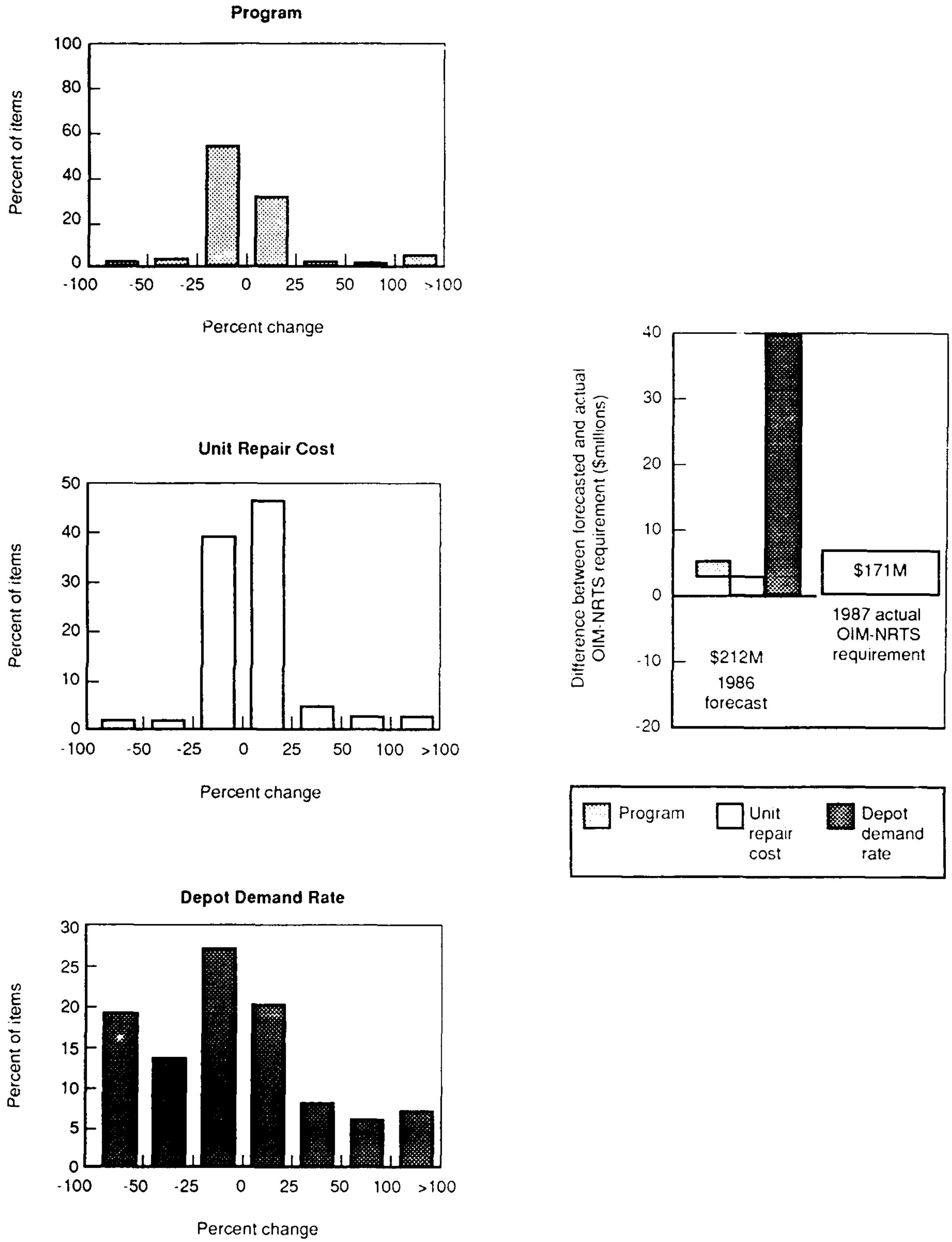

Fig. 2.9—Parameter variability in items common to wide spectrum of weapon systems (SMC 9999): forecast year 1986

Figures 2.8 and 2.9, respectively, show similar results when using F-4 common items (SMC 327Z) to compare 1983 forecasts with 1987 actual requirements and when using items common to a wide spectrum of weapons (SMC 9999) to compare 1986 forecasts with 1987 actual requirements.

From these data, we conclude that there is wide variability in both directions—overestimates and underestimates—between forecast and target years for all parameters. As we have shown, in some cases this variability may have a significant effect on the estimate of the total dollar requirement and in other cases it may have no effect at all.

POTENTIAL CAUSES OF VARIABILITY IN FORECASTS

There are a number of potential causes for the observed variability in the parameters used to forecast depot-level repair dollar requirements. Unfortunately, we lack adequate data to pinpoint the exact causes of variability between forecasted and actual parameter data. In this subsection, however, we describe some potential causes of variability in each of the parameters, or problems in forecasting: future weapon system configuration (new and discontinued items), program, unit repair cost, and demand rates. This discussion aims at shedding some light on the difficulty of forecasting requirements. (Section IV will then provide some insights concerning potential improvements to the system, and Sec. V will propose research to address these improvements.)

Weapon System Configuration

Keeping track of the future configuration of a weapon system by NSN is a difficult task, and as we have seen in Figs. 2.2 through 2.5, new and discontinued items (as we have defined them) can have a significant impact on the forecasted depot dollar requirement, especially in those cases when the forecast is over a long time horizon. Aircraft in the inventory are constantly being improved through modification (mod) programs.[8] The timing of these mods is forecasted and tracked by system specialists at AFLC, but actual installation is subject to outside influences, such as budgets for the mod kits or the availability of resources to install them. As a result, a mod might be scheduled for a particular year but not actually installed until a later year. Or a mod might be accelerated so that there was no allowance forecasted for depot-level repair. Also, databases are slow to be updated. A mod might be installed, but the item on the aircraft

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[8] This was especially true during the period examined in this study.

that was replaced by the mod may be left in the database and a depot repair requirement calculated for it.

Program

The program parameter is usually the flying program "assigned" to a particular component. It reflects estimates concerning future:

- Force structure (the number of this type of aircraft that will fly in a particular year).
- Peacetime flying program (the number of hours this type of aircraft will fly in a particular year).
- Aircraft configuration (the number of this type of aircraft that will have this component installed).

The Air Staff provides future *force structure* and *peacetime flying* program data to the D041 system each quarter. Because they are constantly being revised with each POM and budget cycle, these estimates may not materialize as originally forecasted. Although the D041 system receives quarterly updates, they always occur "after the fact." Estimates sent forward by AFLC as part of a POM or budget exercise thus do not reflect subsequent changes to future force structure and peacetime flying program. As a result, forecasts of programs as realized in the D041 database are always behind. Moreover, as flying program allocations change between the year the forecast is made and the target year, errors in the forecasted repair quantities will occur.

The program also reflects *aircraft configuration*. Since not all aircraft of the same mission design series (MDS) have identical components, the program assigned to a particular component reflects estimates of the percentage of airplanes that will have it installed.[9] As discussed earlier, this may change over time as modification programs occur at different rates from those originally planned or as force structure growth occurs at different rates. We examined the changes in peacetime flying program and force structure by MDS over time and found that they did not explain all the variability shown in the program parameter. Although we don't know if configuration management

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[9] As a consequence, aircraft configuration also influences new items and discontinued items.

problems explain all of the remaining variability, it is likely that they contribute significantly.

Unit Repair Cost

Unit repair costs can change for a variety of reasons between the year the forecast is made and the target year, resulting in inaccuracies in the forecast. Unit repair costs reflect primarily manpower costs (which dominate in most cases) and the costs of parts used in executing repairs. Those costs may change over time. For example, contractor repair prices may increase or government workers may get a raise. Parts costs may also increase or decrease.

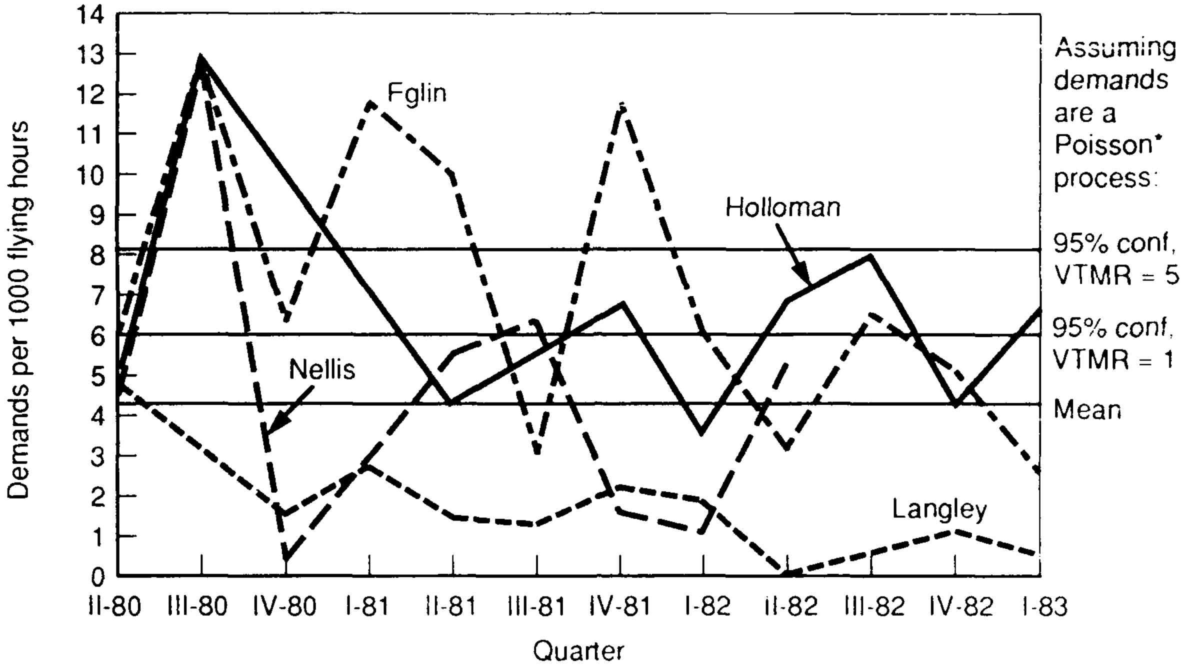
In addition, the work package itself may change. Severe problems with a component may produce additional manpower costs; improvements in it, on the other hand, may lead to reductions in the regular work package. Ongoing programs within AFLC constantly review work packages in an attempt to reduce their content and thus the manpower required to execute them. Data presented here (Figs. 2.2–2.5) show a number of cases when the aggregate unit repair costs have been coming down over time.

Depot Demand Rates

The Air Force faces a number of difficulties in trying to estimate demand rates, any one of which can potentially affect estimates of depot repair costs. They include intrinsic variability in the demand process; methods of "averaging" demands over time to estimate demand rates; changes in the scope of repair at base level, which affect the NRTS rate; and finally the perceived quality of the demand and NRTS data and the process of manually reviewing or "scrubbing" the data kept in the standard data systems.

Over the last few years, RAND's Uncertainty Project has identified variability within many segments of the Air Force's logistics operations.[10] Figure 2.10 shows the variability in demand rates for the F100 engine's unified fuel control at four operating locations over 12 quarters. The figure appears quite "busy," but this is indicative of the high variability in the demand rates actually experienced. This variability, measured in terms of the variance-to-mean ratio (VTMR), is great both over time and over

[10]For example, see Gordon B. Crawford, *Variability in the Demands for Aircraft Spare Parts: Its Magnitude and Implications*, The RAND Corporation, R-3318-AF, June 1987; I. K. Cohen et al., *Coupling Logistics to Operations to Meet Uncertainties and the Threat: An Overview of CLOUT*, The RAND Corporation, forthcoming.



*Note: Classic inventory theory frequently assumes that the number of demands arriving in a given time interval follows a Poisson probability distribution and, when modeled as such, is known as a Poisson process

Fig. 2.10—Unified fuel control demands per 1000 flying hours (average VTMR = 3.9)

geographical ·a‹· ›n; the VTMR of 3.9 in this case is considerably higher than a VTMR of 1, which is usually assumed for such demand processes. Whether at base or depot level, whether in planning or execution processes, this variability confounds attempts to accurately predict and prepare for future peacetime and—more importantly—wartime needs.

In the Air Force's D041 depot data system, an eight-quarter moving average is used to estimate current and future demand rates. Data in Figs. 2.6 through 2.9 and the historical variability in Fig. 2.10 suggest that this moving average may be too slow to respond to observed rapid changes in depot demand rates.

In addition, changes in depot demand rates may result from variability in the NRTS rates. One cause of such variability may be change in the scope of repair at base level. Between the forecast year and the target year, some intermediate-level repairs may shift from depots to bases. Or items that were repaired at bases now may be totally repaired at depots. Such would be the case if an item were part of a modification program and all items removed from the aircraft were sent to the depot for modification and repair. Again, such changes would affect the accuracy of forecasts.

Another source of problems may be the "scrub" (or item managers' and equipment specialists' review) of the D041 data on depot demand rates. This scrub aims at adjusting current and forecast parameter values to account for future changes not reflected in the historical data. Item managers and equipment specialists may tend to be conservative in these estimates, especially when they affect future requirements. For example, if they see a downward trend that is not captured in the moving average, they may be slow to manually adjust the rate for fear it may turn around and result in shortages.

Another data problem may occur in the reporting of actual NRTS actions through the standard data systems. Discussions with item managers have indicated discrepancies between the NRTS quantities reported in the data systems and the quantities that show up at ALCs for repair. In some cases these discrepancies may be reflected during a data scrub, which was discussed earlier.

In an attempt to solve these and other problems with standard data systems, the Air Force has undertaken an effort called the Dirty Data Project. Some initial briefings on the project's status have indicated possibly significant underreporting of data on NRTS and depot demands, because some transactions may not be getting to AFLC and into the D041 system. There is no published final report on how severe the problem is or what the project recommended, but we understand that some corrections are underway. Such underreporting does not, however, coincide with our observations that, on balance, future depot demand rates are overestimated.

The data presented here and the results of RAND's Uncertainty Project suggest that peacetime depot demand rates are very difficult to forecast and that we are not likely to understand or eliminate all the sources of variability. Changes in parameters other than depot demand rates are generally caused by factors external to the data and the process used to compute requirements. For example, program and unit repair cost are essentially functions of management decisions, and these decisions may change over time based on new information, changes in policy, or budget constraints.

III. COMPARISON OF TOTAL FORECASTED REPAIR COSTS TO ACTUAL REPAIR COSTS

In Sec. II, we examined the variability over time of individual parameters used in estimating the repair requirement and their aggregate effect on the accuracy of the OIM-NTRS dollar requirement, i.e., the keep-up requirement (less the NJR portion). In this section, to understand the effects of the catch-up requirement computation, we compare the actual total repair expenditures (keep-up plus catch-up)[1] from the 1987 D041 database with the forecasted total expenditures from the 1986 database and the Central Secondary Item Stratification (CSIS).

The CSIS database includes the *total* keep-up (OIM-NRTS+NJR) and catch-up (changes in supply levels) requirement. This is the scrubbed budget requirement that AFLC sends to the Air Staff. Unfortunately, there are no actual repair data in the D041 system for nonjob routed (NJR) repairs. As a consequence, we have excluded them from all comparisons in this section.[2]

Figures 3.1 through 3.4 show comparisons for the four SMCs we examined in Sec. II:

- SMC 328Z components common to the F-15.
- SMC F16Z components common to the F-16.
- SMC 327Z components common to the F-4.
- SMC 9999 components common to many weapon systems.

In each figure, the left bars of the "1986 Forecast for 1987" and the "1987 Actual" are the *keep-up* forecast and the actual *keep-up* quantity (OIM-NRTS shipped to depot for repair) derived from the same data used in Figs 2.1 through 2.4.[3]

The right bar of the "1986 Forecast for 1987" is the *total* forecast (keep-up plus catch-up minus NJR requirement) derived from the CSIS database. The right bar of the "1987 Actual" is the actual *total* repair (keep-up plus catch-up minus NJR repairs) that

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[1]Recall that the catch-up requirement can be negative if the system is in a long supply position of serviceable assets, thus reducing the need to repair all OIM-NRTS items.

[2]The estimated 1987 NJR dollar requirements for the SMCs of interest are SMC 328Z = \$9M, SMC F16Z = \$4M, SMC 327Z = \$26M, and SMC 9999 = \$33M.

[3]As we saw in Sec. II, in all cases the 1987 actual *quantity* was less than the 1986 forecasted quantity.

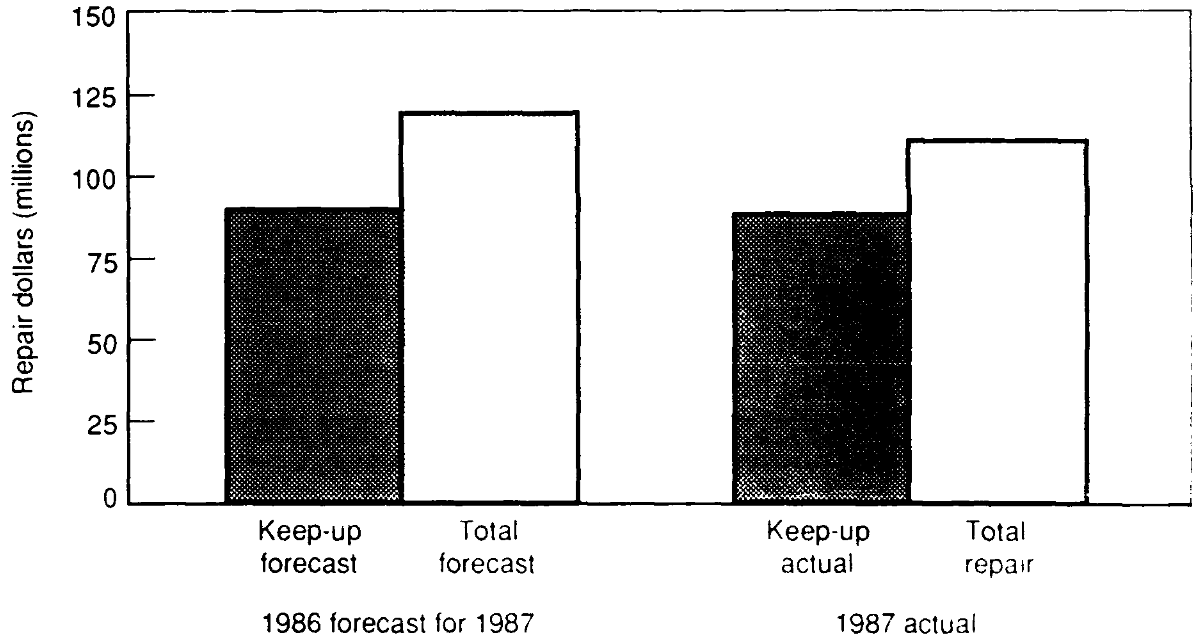

Fig. 3.1—Comparison of 1986 forecast total with 1987 actual repair total: F-15 common items (SMC 328Z)

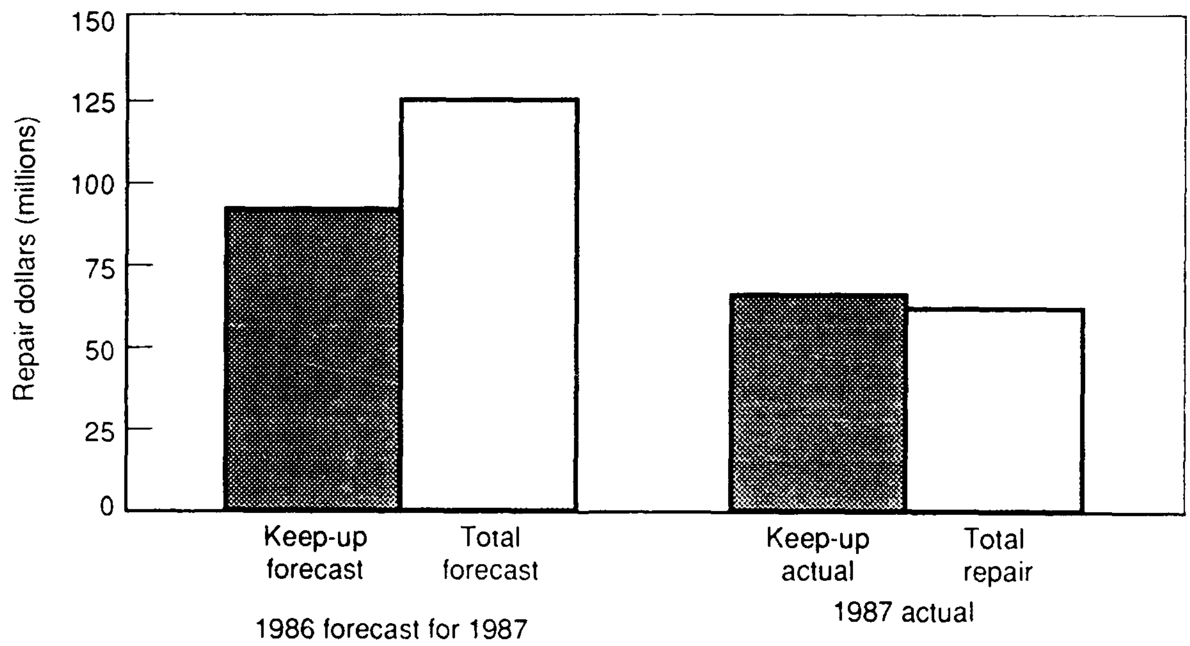

Fig. 3.2—Comparison of 1986 forecast total with 1987 actual repair total: F-16 common items (SMC F16Z)

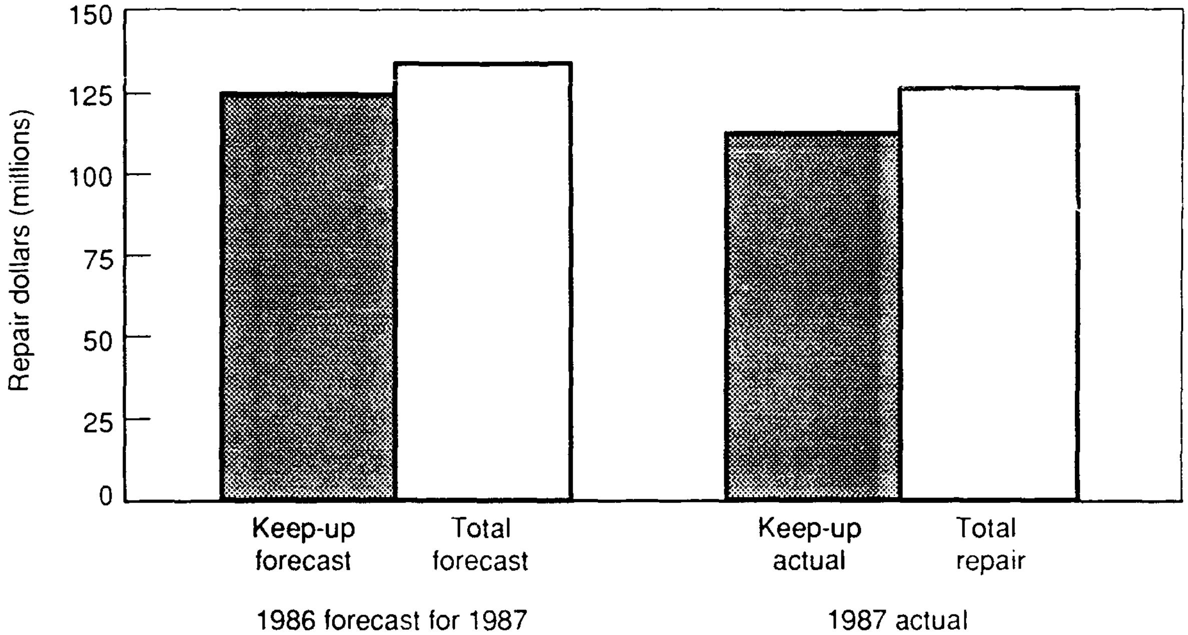

Fig. 3.3—Comparison of 1986 forecast total with 1987 actual repair total: F-4 common items (SMC 327Z)

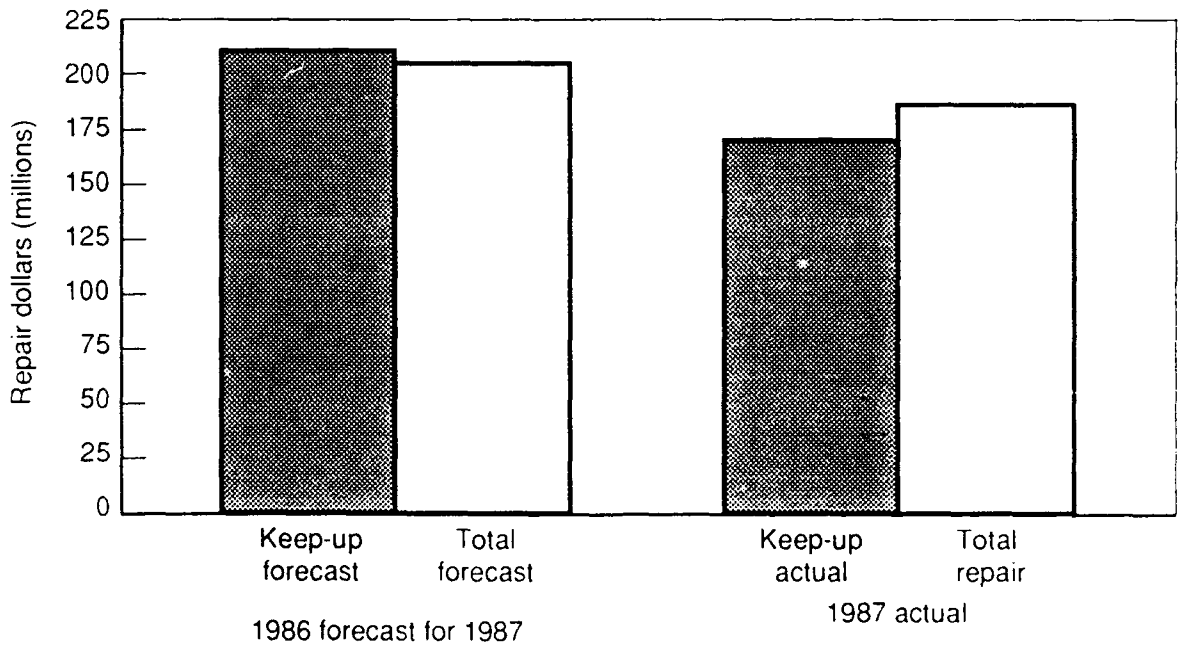

Fig. 3.4—Comparison of 1986 forecast total with 1987 actual repair total: common items (SMC 9999)

occurred in 1987. The difference between the keep-up and the total is the catch-up quantity.

The 1987 catch-up requirement as estimated in 1986 (i.e., the total requirement minus the keep-up requirement) by itself is positive for all SMCs except SMC 9999 common items. For the F-15, it is \$30M; for the F-16, it is \$33M; and for the F-4, it is \$10M. In the case of SMC 9999, the estimated catch-up requirement was negative; i.e., it was estimated that there would be, in the aggregate, a long supply position of serviceables and therefore the total keep-up requirement would not have to be repaired.

As described earlier, the catch-up requirement is a function of forecasted spares levels and the availability of spares to meet those estimated levels. In turn, these forecasted spares levels are a function of depot demand rates and program as is the repair requirement. If these parameters are overestimated, then the future spares levels will be inflated and, to the extent that repairables are forecasted to be available beyond the keep-up quantity, the repair requirement will be increased accordingly to meet the increased spares requirement. Insofar as this occurs, the repair requirement "chases" the spares requirement, and if the forecasted spare levels are inflated, the result in the long run will be an excess supply position.

With the exception of the F-16 (when the OIM-NRTS or keep-up quantity exceeded the quantity repaired), the total repair dollars spent in 1987 exceeded the keep-up repair dollars required in 1987; i.e., the catch-up requirement was positive. Since repair is usually executed based on data that are six to nine months old, some repair was probably executed against an inflated estimate of the total requirement. That is, there was an inflated keep-up requirement *and* an inflated catch-up requirement because of the inflated estimate of the spares requirement. A positive net catch-up repair quantity is not necessarily bad; it can be legitimate if based on current data.

Three points can be made here: (1) during this period the total repair requirement was overestimated as was the keep-up requirement, (2) the spares requirement is affected by the same parameters as the repair requirement and can compound forecasted errors in the depot repair requirement, and (3) executing repairs using old data under conditions when the total requirement (keep-up plus catch-up) is declining will result in a long supply position.

IV. OBSERVATIONS ON CURRENT RESOURCE REQUIREMENTS AND CAPABILITY ASSESSMENT METHODS

In previous sections we examined in some detail how the variability in the parameters used in the requirements process affected the Services' ability to forecast depot repair dollar requirements. We suggested that forecasting uncertainties are likely to present problems to the requirement determination process even if perfect timely data were available. In this section we step back and take a more general view of the problems in logistics resource requirements determination and allocation. We will focus on three issues: (1) the extent to which such variability is explictly considered in the determination of spares and repair requirements; (2) the consideration of variability in capability assessments systems, systems that relate resource levels (or expenditures) to operational capability of the force; and (3) the Services' ability to adapt to the uncertainties in the forecast in varying degrees through management adaptations during budget execution.

Reviews of the Air Force's spare parts and depot repair requirements systems and of their readiness and sustainability assessment systems show that they typically do not compensate for the forecasting uncertainties described in this Note. However, the Air Force adapts to forecast uncertainties as well as "budget shortfalls," usually in "real time," through a variety of management mechanisms to minimize the effects of resource shortages. This is not to say that these adaptation mechanisms are perfect or can totally absorb these uncertainties. But, because the requirements systems and assessment systems do not explicitly account for the uncertainties or such adaptations, decisionmakers do not have a realistic view of the outcomes of their resource allocation decisions. As a result, users of these systems are frequently misled as to the operational implications of different budget levels or resource quantities. For example, a capability assessment model might predict a significant decline in force readiness given a certain budget level for spare parts, but through management adaptations such as priority repair and priority transportation, the predicted decline might be lessened significantly. Decisionmakers should be in a position to know when such adaptations could affect the outcomes of their resource decisions.

Typically the budget requirements systems and the budget execution mechanisms use different goals and data. That is, there is a disconnection between the system used to determine how much money is needed and the system that determines how the money is spent. As a result, the outcome of a particular budget may be quite different from that forecasted. The Services need an integrated system, from POM development to actual execution of the budget. This system should reflect consistent operational goals for resource requirements determination and for the allocation and reallocation of resources. Such an integrated system should use the most current data available to minimize the effects of forecasting error.

Capability assessment systems need to be developed to (1) evaluate the "robustness" of dollar budgets[1] (and the effects of budget changes) in terms of these operational goals, (2) consider a wide range of forecasting uncertainties and management adaptations, and (3) support tradeoff analyses among spares, repair, transportation, and enhanced management adaptations.

ACCOUNTING FOR FORECASTING UNCERTAINTIES

A number of studies have addressed the problems of forecasting peacetime and wartime demands for spare parts and of representing these uncertain demands in requirements and capability assessment models.[2] These studies stress the high variance around estimated peacetime mean demand rates for a significant number of items (see Fig. 2.10). In addition, these studies show that these variances, as well as the means, are not stable over time. The Coronet Warrior exercise conducted by the Tactical Air Command reinforced these conclusions by showing that some parts far exceeded expected demands while others were much lower.[3] Moreover, forecasting wartime demands is even more difficult. In some scenarios, the use of aircraft and the tempo of flying could vary dramatically from the planned scenario, and the damage to critical resources could be quite high depending on the course of the war and actions taken by the enemy (e.g., attacks on U.S. theater bases). As we will discuss in the following

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[1]By "robustness" we mean, for example, how the budget will fare in meeting desired operational goals in the face of a variety of uncertainties in the demand for the resources that the budget is targeted to provide.

[2]See Gordon Crawford, *Variability in Demands for Aircraft Spare Parts: Its Magnitudes and Implications*, The RAND Corporation, R-3318-AF, 1988; I. K. Cohen and M. Rich, *Recent Progress in Assessing the Readiness and Sustainability of Combat Forces*, The RAND Corporation, R-3475-AF, 1987; Z. Landsdowne and R. Pyles, *Analysis of Naval Aviation Demand Predictability*, The RAND Corporation, forthcoming; M. Rich et al., *Improving U.S. Air Force Readiness and Sustainability*, The RAND Corporation, R-3113/1, 1984; C. Sherbrooke, *Evaluation of Demand Prediction Techniques*, AF601R1, Logistics Management Institute, 1987.

[3]Captain D. Pipp, USAF, "Coronet Warrior," *Air Force Journal of Logistics*, Summer 1988.

paragraphs, these forecasting uncertainties are considered to a limited extent only in a few of the resource requirements and capability assessment models currently in use.

The only attempt to include forecasting uncertainty in the formal logistics requirements process is in the computation of the requirement for peacetime operating stocks (POS). The current POS requirement includes an estimate of the peacetime variance in demand rate (at an increased spares procurement cost), but Cohen and Rich have shown that these variances are not stable over time. Using them for these purposes may lead to an imbalanced mix of spares when procurement is finally completed in two to three years. More importantly, as will be suggested below, the use of variances may be unnecessary because base- and depot-level priority repair and other management adaptations may be able to "absorb" much of the peacetime variability with no adverse effect on readiness.

Computations of war readiness material (WRM) requirements[4] do not include the peacetime and wartime forecasting uncertainties discussed above. As RAND's Uncertainty Project has shown, the ability of a War Readiness Spares Kit (WRSK) to support a unit in meeting its stated wartime aircraft availability goal is put in serious doubt if it is assumed, as current plans do, that the unit will operate in isolation of other units and have to depend only on those spares they bring with them for a given period. The great uncertainty in wartime demand, when explictly considered, showed that shortages would eventuate and the computed WRSK levels would not support the unit at the desired readiness level. On the other hand, if the logistics system could provide mutual support such that many units could share resources through lateral resupply actions, i.e., units did not have to operate in isolation, WRM levels, as currently computed, may be adequate. This is an example of how management adaptations can absorb much of the uncertainty and why both the uncertainty and the adaptations should be explicity considered in computing requirements and performing capability assessments.

Methods used to establish peacetime and wartime depot repair requirements include even less allowance for forecasting uncertainty. The requirement is based on expected peacetime demands (estimated means) for depot-level repair, with no consideration given to the variability of those demands around those expected values. As shown in Sec. II, budget forecasts for depot-level component repair are potentially affected by uncertainties in the flying program, the cost of repair resources (labor, repair

[4] D029 and Dyna METRIC are currently used.

parts, etc.), the extent of required repair (repair package), the base repair rate, the condemnation rate, the rate at which individual items become obsolete, and the modification programs, none of which is explicitly considered in the requirements methodologies. The methodologies assume that future parameter values are known exactly and that there is no variance around those estimates. As a result, little flexibility is built into the management systems and the likelihood of a misallocation of resources is increased.

As typically used by AFLC and the Air Staff, capability assessment tools like WSMIS (Dyna-METRIC)[5] and the Aircraft Availability Model[6] share the same problems as requirements methods. They do not explicitly include forecasting uncertainties as currently used, although these models have the capability to do so in some kinds of uncertainties. As a result, in many cases, wartime capability estimates may be overly optimistic.

ACCOUNTING FOR MANAGEMENT ADAPTATIONS

Current requirements and capability assessment tools[7] do not reflect many of the adaptive management mechanisms and actions that can overcome some of the forecasting uncertainties discussed in the preceding paragraphs. There are a number of such mechanisms currently in use, and several enhancements suggested by RAND's Uncertainty Project have been included in the new Air Force Logistics Concept of Operations.

At base level, many adaptive mechanisms are currently in use: flightline cannibalization, priority intermediate-level maintenance, cross-cannibalization of line replaceable units (LRUs) to minimize the effect of repair part shortages, and "borrowing" from the WRSK to meet peacetime operating needs. Typically, only flightline cannibalization is included in spares requirements and capability assessment methodologies. Although each of these mechanisms enhances peacetime aircraft availability, robbing from the WRSK degrades wartime sustainability.

To overcome MICAP (Mission Incapable, Awaiting Parts) conditions, some major commands use informal mechanisms to achieve lateral resupply. RAND's Uncertainty

[5]K. Issacson et al., *Dyna-METRIC Version 4: Modeling Worldwide Logistics Support of Aircraft Components*, The RAND Corporation, R-3389-AF, May 1988.

[6]R. Arnberg, *The Aircraft Availability Model User's Manual*, Logistics Management Institute, 1986.

[7]RAND's latest version of Dyna-METRIC, version 6, does incorportate many of the adaptations discussed here but has yet to be adopted for use within the Air Force.

Project suggested a more formal and aggressive lateral resupply effort to preclude MICAPs. It showed that lateral repair has significant payoffs, especially when units deploy without intermediate maintenance or when maintenance is lost due to airbase attack. Again, such adaptive reallocation of resources is not included in requirements estimation or capability assessments.

Finally, depot-level adaptations currently include priority repair, distribution, and transportation for MICAP conditions. These priority management actions are not included in the current requirements or assessment processes.

RAND's Uncertainty Project has demonstrated that the logistics support system can use a variety of management adaptations to absorb much of this uncertainty, at least in the near term. Grouped under the general heading of CLOUT (Coupling Logistics to Operations to meet Uncertainties and the Threat), these management adaptations include:

- More responsive allocation of theater resources.
- Enhanced lateral repair and resupply (mutual support).
- Coupling the depot system to the combat force in the early days of a conflict.

The DRIVE (Distribution and Repair In Variable Environments) model developed by RAND is key to making depots more responsive.[8] Given the constraints on repair capacity, this model uses the near "real time" status of resources and operational goals (in terms of aircraft availability targets) to schedule the repair and distribution of critical assets. Many of CLOUT's management adaptations have been included in the new USAF Logistics Concept of Operations now in final development.

Adaptive mechanisms can help deal with unanticipated demands, but by their very nature, they tend to obscure the effects of forecasting uncertainties and fiscal shortfalls. Along with forecasting uncertainties, this may contribute to some of the requirement credibility problems that the Air Force and the other Services face. For example, a Service may forecast a severe degradation in readiness as a result of a budget cut, but because of the internal adaptation mechanisms, that forecast degradation may not occur at all or may not show up for some extended period. Additionally, some adaptations, such as robbing the WRSK, may enhance peacetime aircraft availability but obscure the effect on wartime sustainability. These adaptive mechanisms may deal effectively with

[8]See App. B for a more complete description of DRIVE.

uncertainties and shortfalls in the near term, but in the long run they may not be able to compensate for continued budget shortfalls.

THE NEED FOR INTEGRATING MECHANISMS

Methods for estimating dollar requirements for POM and budget exercises should reflect the actual dollar allocation and execution mechanisms used within the Services. If the requirements systems do not, disconnections will develop when evaluating the adequacy of the dollar requirement. That is, the outcomes desired during the requirements determination process may not occur because the allocation and execution mechanisms use different criteria and adapt in ways not reflected in the requirements process. *Unfortunately, the current allocation and execution mechanisms* also have many of the same drawbacks as the requirement systems. In most cases they do not reflect forecasting uncertainties, management adaptations, or a consistent set of wartime operational goals. This has the potential of resulting in a misallocation of resources.

Given these problems, a consistent set of operational goals is needed throughout the system, from POM through execution, including various forms of adaptive management. These goals should reflect wartime readiness and sustainability priorities for each weapon system. They should be considered in each stage of the process (see Fig. 4.1): in determining the dollar requirements during the POM and budget drills, developing the AFLC annual plan, developing the individual Air Logistics Centers' allocation plans, and executing the spares procurement actions and prioritizing the depot-level repair during execution. In addition, each stage of the process should use the most recent system state and parametric data available to deal with the forecasting uncertainties. Although the outcomes originally desired during the POM and budget process may not actually be achieved because of forecasting uncertainties, the system will come closer to achieving those goals if the allocation and reallocation decisions are based on those desired outcomes and the most current data are used.

The mechanisms to accomplish this integration and to deal with the other problems discussed in this section are not currently available. The following section attempts to lay out a research agenda that could yield a system to deal with these problems.

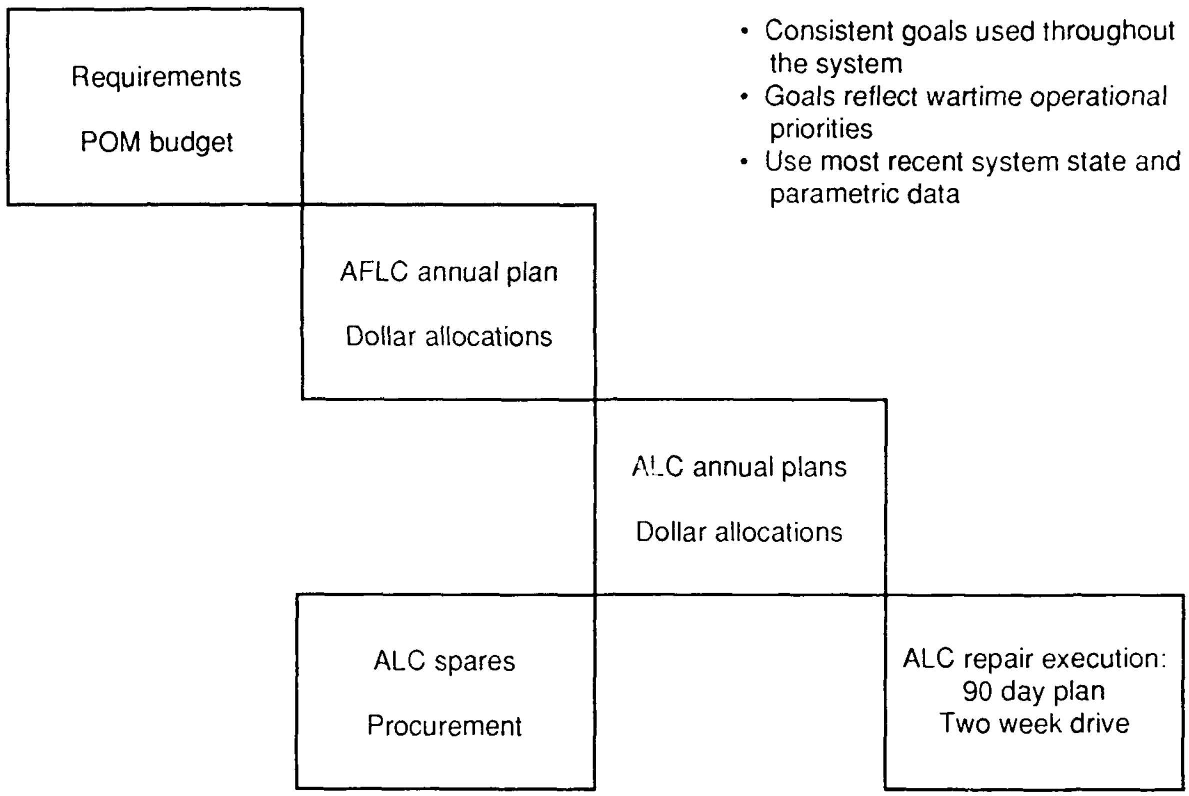

Fig. 4.1—Proposed integrated planning, budgeting, and execution

V. FUTURE RESEARCH IN REQUIREMENTS ESTIMATION

Future research should focus on developing requirements methods for spares and depot-level repair that explicitly:

- Consider forecasting uncertainties and potential management adaptations.
- Support tradeoffs between the repair and procurement of spares.
- Reflect the operational priorities of the Services.
- Respond to changes in critical parameters during the POM and budget processes.

FORECASTING UNCERTAINTIES AND POTENTIAL MANAGEMENT ADAPTATIONS

Future research should examine ways in which requirements computations for future years can compensate for forecasting uncertainties and a full range of management adaptations. As this Note has shown, the demand for depot-level repair for individual items is not stable over time. The variation in demand and NRTS rates directly affects the keep-up and catch-up requirements through their effect on the spares computation. Unfortunately, computations that pretend to explicitly consider future means demands and the uncertainty around those means but *do not* account for current management adaptations yield unacceptably large cost projections. On the other hand, many current management adaptations can hedge against future changes in demand and cost. But to consider all such possible adaptations in a requirements computation may squeeze too much "slack" out of the system, leaving little room to meet operational goals in the face of uncertainties that could not be forecasted. As a consequence, we believe that research should:

- Arrive at a reasonable set of assumptions about future uncertainties and likely adaptations for computing the future dollar requirement.
- Provide enhanced capability assessment models to test the "robustness" of the dollar requirement against a much wider range of future uncertainties and potential adaptations.

TRADEOFFS BETWEEN THE REPAIR AND PROCUREMENT OF SPARES

Future research must also consider the interaction between spares and repair. As Sec. III showed, the same parameters influence both the spares requirement and the depot repair requirement. Since the spares requirement is set two to three years in advance, forecasting errors can produce even worse effects on it than on the repair requirement, which can be estimated using more current data.[1] The point here is that it may be easier to modify the repair program based on the most current data than it is the quantity of spares to be bought because of contractual arrangements and the long procurement lead times. An overestimate of the spares requirement produces future long supply.

Future research should examine hedging strategies that avoid the overbuying of spares. Such strategies might include modifying current contractual arrangements to allow for more flexibility or holding back on a procurement for a given period to see if the requirement holds; temporary shortfalls could be met through management adaptations, such as priority depot- and base-level repair and transportation, suggested in the preceding section. Similar adaptations are used when the future spares requirement is underestimated and the system must wait a portion or all of the long procurement lead time to catch up.

Depot-level repair is currently the least expensive source of spare parts.[2] Therefore, proposed changes in the DPEM exchangeable budget must be considered in light of the spares requirement. That is, cuts in the spares budget should be considered before cuts in the repair budget. Current requirements models do consider depot repair and spares together but assume that both are fully funded. Hence, future requirement methods must facilitate the exploration of tradeoffs between depot component repair and the procurement of spares in the face of potential budget reductions. Such methods should give full consideration to the operational goals of the Service and the allocation of the cuts across the individual components.

OPERATIONAL PRIORITIES OF THE SERVICES

Research is needed to develop and evaluate methods for describing operational priorities and incorporating them into the requirements (and execution) process.

Methods for estimating depot-level component repair requirements should reflect the dollar allocations and execution mechanisms actually in use within the Service. Research should consider the relationship between requirements methods on the one hand

[1] See the discussion of DRIVE in App. B.

[2] On average, a part repaired by the depot costs one-tenth of its procurement cost.

and allocation and execution mechanisms on the other. We believe the mathematical approach used in DRIVE may help develop resource requirements models. It may also help develop models for allocating available dollars during the budget execution year. Such models would use data on the current state of available resources and operational goals.

This allocation concept is yet to be proved, however, and the feasibility of using DRIVE-like algorithms for requirements should be a major issue in future requirements research efforts. If DRIVE proves to be workable for requirements computation and dollar allocation at all management levels (AFLC, ALC, item manager), it could serve as an important integrating mechanism by providing a consistent dollar allocation method and criteria from the Planning, Programming, and Budgeting System (PPBS) process all the way through actual execution of the budget and distribution of repaired assets.

CHANGES IN CRITICAL PARAMETERS DURING THE POM AND BUDGET PROCESS

One source of forecasting uncertainty identified in Sec. II was changes to parameters that were made after the forecast requirement had been set. For example, the *Air Staff often makes changes to the future force structure* after AFLC computes the CSIS and submits the results. Future requirement systems should provide the capability to respond quickly, easily, and accurately to changes in critical parameters during the POM and budget processes.

To deal with uncertainties in parameters, some researchers have suggested the use of more aggregate models to develop the depot-level component repair requirement estimates needed during POM development. It is difficult, however, to understand how long-range estimates can use more aggregate models given forecasting uncertainties, the wide range of potential management adaptations, the need to tie budget decisions to operational priorities by weapon system, and the need to make tradeoffs among spares, repair, and possibly transportation. This is a difficult area deserving of more research.

Finally, capability assessment models could be used to evaluate alternative requirements methodologies. This could also provide a means for evaluating the capability assessment models themselves, as well as demonstrating their use.

Appendix A
EQUATIONS USED IN CALCULATIONS

This appendix describes the equations used to calculate cost requirements, total cost requirements, and aggregate effects of individual parameters.

To calculate the forecasted and actual *individual* OIM-NRTS keep-up repair cost requirement for any given item (R_i), we first used data from the Air Force D041 Data Collection System to compute the depot demand rate for each of the items (D_i). We then multiplied that rate by the program (P_i) and unit repair cost (C_i) for that item:

$$R_i = D_i P_i C_i .$$

To calculate the forecasted and actual *total* OIM-NRTS keep-up repair cost requirement for any given category of items, (R_t), we summed the item repair costs over all items within the SMC:

$$R_t = \Sigma R_i = \Sigma D_i P_i C_i .$$

To calculate the *aggregate effects of individual parameters* on differences between forecasted and actual repair costs, we first developed the following equation to express total change in repair cost requirements (ΔR_t) between the forecast year $\left(\Sigma \overline{D}_i \overline{P}_i \overline{C}_i\right)$ and the target year $\left(\Sigma D_i P_i C_i\right)$:[1]

$$\Delta R_t = \Sigma \overline{D}_i \overline{P}_i \overline{C}_i - \Sigma D_i P_i C_i .$$

Taking a form of Taylor expansion of this equation and including the effects of new items (NI) and discontinued items (DI), we arrived at the aggregate contribution of each parameter to the total difference between requirements in the forecast and target years:

[1] We used this equation for items with data in both the forecast and target year.

$$\begin{array}{lll}
\Delta R_t = \Sigma\, w(P_i, C_i, \overline{P}_i, \overline{C}_i) & (\overline{D}_i - D_i) & \text{Demand effect} \\
\quad + \Sigma\, w(D_i, C_i, \overline{D}_i, \overline{C}_i) & (\overline{P}_i - P_i) & \text{Program effect} \\
\quad + \Sigma\, w(D_i, P_i, \overline{D}_i, \overline{P}_i) & (\overline{C}_i - C_i) & \text{Cost effect} \\
\quad - \Sigma\, NI_i\, D_i\, P_i\, C_i & & \text{New item effect} \\
\quad + \Sigma\, DI_i\, \overline{D}_i\, \overline{P}_i\, \overline{C}_i & & \text{Discontinued item effect}
\end{array}$$

This equation uses a weighting function (w) from the expansion:

$$w(a, b, \bar{a}, \bar{b}) = \frac{2\,\bar{a}\bar{b} + \bar{a}b + a\bar{b} + 2ab}{6}.$$

Appendix B

AN OVERVIEW OF DISTRIBUTION AND REPAIR IN VARIABLE ENVIRONMENTS (DRIVE)[1]

DRIVE is a decision support system that prioritizes component repair actions and allocates the serviceable assets produced to locations in a way that maximizes the probability of achieving a set of aircraft (or other weapon system) availability goals specified by model/design and location. DRIVE assumes that there exists a source of global, user-specified data that reflect peacetime and wartime aircraft availability goals, short-term peacetime operating tempos, planned wartime operating tempos, force beddown, order-and-ship times from the depot to the bases, planning horizon length (explained in the discussion that follows), repair shop capacities, and wartime tasking. These data are combined in a database with data from several standard AFLC data systems that provide a variety of item-related data elements describing item characteristics (e.g., demand rates, NRTS rates, applications, quantities per application, and application percentages), current asset position (a current snapshot of all serviceable and repairable assets in the total system worldwide), primary source of repair, key repair resources, etc.

DRIVE produces essentially two kinds of outputs. One is a sequenced list of repair actions for use by maintenance schedulers, shop chiefs, and others concerned with the maintenance production schedule. The other is a sequenced list of recommended allocations of the serviceable assets emerging from repair for use by the item manager. The first list is sorted by repair resource within primary repair shop; the second, by stock number within item manager.

DRIVE represents a different view of the goals of depot repair than that of the current system. It prioritizes both repair and distribution, always repairing next the asset that is most relevant to the current needs of the combat force, and allocating it to the location where it will do the most good in achieving the specified aircraft availability goals. DRIVE uses very recent data that reflect the worldwide asset position. These data are literally only a few days old when DRIVE is run. Moreover, DRIVE forecasts NRTS actions and sequences repairs over very short time horizons, thus minimizing its vulnerability to uncertainty in repair demands. It focuses on the achievement of aircraft

[1]Appendix B was written by Jack Abell.

availability goals while accounting explicitly for the indenture relationships among weapon system components. It is a model that guides execution. In contrast to such models as the Aircraft Availability Model that allocate stock levels, DRIVE actually allocates serviceable assets.

The logic underlying DRIVE is intended to couple the depot more closely to the combat force through the use of near-real-time asset position data and a dramatically shorter planning horizon than that of the current system. It sequences repair and distribution actions in an attempt to make the most of constrained repair capacity. It accounts explicitly for demand uncertainty, force beddown, and parts indenture relationships. Moreover, it schedules the repair of SRUs one production period in advance to support LRU repair workload, thus effectively implementing a "just-in-time" repair parts inventory system. This concept is intended to reduce the shop flow times of many LRUs while significantly enhancing the efficiency of the LRU repair activity.

A prototype of the DRIVE algorithm is currently being demonstrated in several shops of the Ogden Air Logistics Center. It is currently limited to F-16-peculiar aircraft avionics components repaired in the Avionics Integrated Shop and their SRUs that are repaired in the SRU Repair and Microwave shops.